Parsimonious Vole

A Systemic Functional Parser for English

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This dissertation is submitted for the degree of
Doctor of Philosophy

April 2020

thank you

for Adriana

Tamara, Ion and Cristi Costetchi

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements.

Eugeniu Costetchi
April 2020

Acknowledgements

This thesis owes much to the many people who have guided me, supported me, and inspired me throughout its preparation and writing. Here, I attempt to list some of these colleagues, family, and friends, but I cannot hope to thank everyone by name. Thus, upfront, to each and every one I offer my heartfelt thanks.

First and foremost I shall forever be grateful to my academic supervisor, John Bateman, for his guidance, deep insight, patience and a lot of diligent proofreading work when the time finally came. Without him I would never have become a computational linguist and this thesis would not have happened. I am also very much indebted to my advisor, Eric Ras, for his kind encouragements, guidance and support right from the beginning, starting with PhD proposal writing. Without Eric this thesis could not have started in the first place.

I believe knowledge is created between people and I would like to thank all those who have shared this experience with me. To everyone who has shared a chat over coffee, a talk around the table or a talk at a conference or seminar, thank you. In particular I would like to thank my colleague and friend Muriel Foulonneau, who invited me to join LIST research centre and was always engaging in stimulating discussions. Thanks to Anke Schulz who was the first person I met in real need of an SFL parser because she was performing, at that time, tedious manual corpus annotation. That corpus annotation later became part of the Parsimonious Vole evaluation. Thank you to Ela Oren for the work we have done together on corpus annotation, which is also used in the parser evaluation; for inviting me on a short scientific mission to Tel Aviv University; and from whom I have learned about Obsessive Compulsive Disorder. My deep gratitude goes to my colleague Daniel Couto Vale who always welcomed me in Bremen, and enthusiastically shared his knowledge on Systemic Functional Linguistics.

There are many friends that have shared this experience with me and I can't thank each of them enough. To any I have inadvertently left out please don't think you are forgotten. A big thank you goes to my friend Mikolaj Podlaszewski with whom I shared many of thought-provoking philosophical discussions, sometimes fierce debates and who provided me with lots of constructive criticism. My friend, Andrei Mihalceanu,

who unfortunately passed away, has my sincere gratitude for enthusiastic philosophical discussions on language, mind, determinism and entropy. Thanks to Christoph Stahl for his friendship and encouragement to continue writing this thesis.

Even more so than friends, family are there in person and spirit when you need them most, and that is why they deserve the greatest gratitude of all. A huge thank you to my parents Tamara and Ion for their unconditional love, encouragement and support. I want to thank my younger brother Cristi. I haven't always been the best big brother for him, but he has always been there for me. But most of all, I thank Adriana, my beloved wife, who sometimes pushed hard and other times gently encouraged me in the last phase of this thesis, and then patiently waited for the manuscript to mature. This thesis is for her.

Finally, I gratefully acknowledge the support of Luxembourg National Research Fund through an AFR PhD grant which made this work possible in the first place. I also want to thank all those who gave me feedback on drafts along the way. However, mistakes, be them of the conceptual or typographic variety, remain mine and mine alone.

Abstract

Building a natural language parser can be seen as a task of creating an artificial text reader that understands the meaning expressed in some text. This thesis aims at a reliable modular method for parsing unrestricted English text into feature-rich constituency structure using Systemic Functional Grammars (SFG). SFGs are chosen because of their versatility to account for the complexity and phenomenological diversity of human language.

The descriptive power of a Systemic Functional Grammar (SFG) lies in its separation of descriptive work across "structure" (i.e., syntagmatic organisations) and "choice" (i.e., paradigmatic organisations). A shortcoming for parsing, however, is that SFL has been primarily concerned with the paradigmatic axis of language, and accounts of the syntagmatic axis of language, such as the syntactic structure, have been put in the background.

Moreover, parsing with features that depart from directly observable grammatical variations towards increasingly abstract semantic features comes at the cost of high computational complexity, which still presents today the biggest challenge in parsing broad coverage texts with full SFGs.Previous research has discussed how each successive attempt to construct parsing components using SFL then led to the acceptance of limitations either in grammar size or in language coverage.

One of the main contributions of this thesis is the investigation to what degree cross-theoretical bridges can be established between Systemic Functional Linguistic (SFL) and other theories of grammar, in particular Dependency Grammar, in order to compensate for the limited syntagmatic accounts. A second main contribution is to research how suitable predefined graph patterns are for detecting systemic features in the constituency structure in order to reduce the complexity of identifying increasingly abstract grammatical features.

The technical achievement of this thesis lies in the development and evaluation of a SFG parser, named Parsimonious Vole. The implementation follows a pipeline architecture comprising two major phases: (a) creation of the constituency structure

from Dependency graphs and (b) structure enrichment with the systemic features using graph pattern matching techniques.

The empirical evaluation is based on two manually annotated corpora. First one covers constituency structure and Mood features, and second corpora covers the more abstract Transitivity features. The parser accuracy at generating constituency structure (76%) is slightly lower than that achieved in previous research, while the accuracy to detect Mood (60%) and Transitivity (42%) could not be compared to any previous works because either such features are missing or the results are not comparable.

The current work concludes that (a) reusing parse results with other grammars for structure creation and (b) employing graph patterns for enrichment with systemic features constitutes a viable solution to create feature-rich constituency structures in SFL style.

Table of contents

Chapter 1

Introduction

1.1 On artificial intelligence and computational linguistics

In 1950 Alan Turing in a seminal paper (Turing 1950) published in Mind was asking if "machines can do what we (as thinking entities) can do?" He questioned what intelligence was and whether it could be manifested in machine actions indistinguishable from human actions.

He proposed the famous *Imitation Game* also known as the *Turing test* in which a machine would have to exhibit intelligent behaviour equivalent or indistinguishable from that of a human. The test was set up by stating the following rules. The machine (player A) and a human (player B) are engaged in a written *natural language* conversation with a human judge (player C) who has to decide whether each conversation partner is human or a machine. The goal of players A and B is to convince the judge (player C) that they are human.

This game underpins the question whether "a computer, communicating over a teleprinter, (can) fool a person into believing it is human?", moreover, whether it can exhibit (or even appear to exhibit) human(-like) cognitive capacities (Harnad 1992). Essential parts of such cognitive capacities and intelligent behaviour that the machine needs to exhibit are of course the linguistic competences of comprehension (or "understanding") and generation of "appropriate" responses (for a given input from the judge C). The *Artificial Intelligence* (AI) field was born from dwelling on Turing's questions. The term was coined by McCarthy for the first time in 1955 referring to the "science and engineering of making intelligent machines" (McCarthy et al. 2006).

The general target is to program machines to do with language what humans do. Various fields of research contribute to this goal. Linguistics, amongst others, contributes with theoretical frameworks systematising and accounting for language in terms of morphology, phonology, syntax, semantics, discourse or grammar in general. In computer science increasingly more efficient algorithms and machine learning techniques are developed. Computational linguistics provides methods of encoding linguistically motivated tasks in terms of formal data structures and computational goals. In addition, specific algorithms and heuristics operating within reasonable amounts of time with satisfiable levels of accuracy are tailored to accomplish those linguistically motivated tasks.

Computational Linguistics (CL) was mentioned in the 1950s in the context of automatic translation (Hutchins 1999) of Russian text into English and developed before the field of Artificial Intelligence proper. Only a few years later CL became a sub-domain of AI as an interdisciplinary field dedicated to developing algorithms and computer software for intelligent processing of text (leaving the very hard questions of intelligence and human cognition aside). Besides *machine translation* CL incorporates a broader range of tasks such as *speech synthesis and recognition, text tagging, syntactic and semantic parsing, text generation, document summarisation, information extraction* and others.

This thesis contributes to the field of CL and more specifically it is an advancement in *Natural Language Parsing* (NLP), one of the central CL tasks informally defined as the process of transforming a sentence into (rich) machine readable syntactic and semantic structure(s). Developing a program to automatically analyse text in terms of such structures by involving computer science and artificial intelligence techniques is a task that has been pursued for several decades and still continues to be a major challenge today. This is especially so when the target is *broad language coverage* and even more when the desired analysis goes beyond simple syntactic structures and towards richer functional and/or semantic descriptions useful in the latter stages of *Natural Language Understanding* (NLU). The current contribution aims at a reliable modular method for parsing unrestricted English text into a feature rich constituency structure using Systemic Functional Grammars (SFGs).

In computational linguistics, broad coverage natural language components now exist for several levels of linguistic abstraction, ranging from tagging and stemming, through syntactic analyses to semantic specifications. In general, the higher the degree of abstraction, the less accurate the coverage becomes and, the richer the linguistic description, the slower the parsing process is performed.

Such working components are already widely used to enable humans to explore and exploit large quantities of textual data for purposes that vary from the most theoretical, such as understanding how language works or the relation between form and meaning, to very pragmatic purposes such as developing systems with natural language interfaces, machine translation, document summarising, information extraction and question answering systems to name just a few. Nevertheless there is still a long way to go before machines excel in these narrowly scoped tasks and even longer before machines start using language in the ways humans do.

1.2 Living in a technologically ubiquitous world

Human language has become a versatile highly nuanced form of communication that carries a wealth of meaning which by far transcends the words alone. When it comes to *human-machine* interaction this highly articulated communication form is deemed impractical. So far humans had to learn to interact with computers and do it in a formal, strict and rigorous manner via graphical user interfaces, command line terminals and programming languages. Advancements in *Natural Language Processing* (NLP) are a game changer in this domain. NLP starts to unlock the information locked in human speech and make it available for processing to computers. NLP becomes an important technology in bridging the gap between natural data and digital structured data.

In a world such as ours, where technology is ubiquitous and pervasive in almost all aspects of life, NLP becomes of great value and importance regardless of whether it materialises as a spell-checker, an intuitive recommender system, spam filters, (not so) clever machine translators, voice controlled cars, or intelligent assistants such as Siri, Alexa or Google Now.

Every time an assistant such as Siri or Alexa is asked for directions to the nearest Peruvian restaurant, how to cook Romanian beef stew or what is the dictionary definition for the word “germane”, a complex chain of operations is activated that allows ‘her’ to understand the question, search for the information you are looking for and respond in a human understandable language. Such tasks are possible only in the past few years thanks to advances in NLP. Until now we have been interacting with computers in a language they understand rather than us. The next challenge is to develop a technology that enables computers to interact with us in a language we understand.

1.3 NLP for business

NLP opens new and quite dramatic horizons for businesses. Navigating with limited resources stormy markets of competitors, customers and regulators and finding an optimal answer/action to a business question is not a trivial task. In this section I present a few example application areas and use them to discuss tasks that need to be accomplished for NLP in such contexts. These examples underline the ever growing need for NLP putting into perspective the need of ever deeper and richer linguistic analysis across a broad range of domains and applications.

Markets are influenced by information exchange and being able to process massive amounts of text and extracting meaning can help in assessing the status of an industry and play an essential role in crafting a strategy or a tactical action. Relevant NLP tasks for gathering market intelligence are *named entity recognition* (NER), *event extraction* and *sentence classification*. With these tasks alone one can build a database about companies, people, governments, places, events together with positive or negative statements about them and run versatile analytics to audit the state of affairs.

Compliance with governmental, European or international regulations is a big issue for large corporations. One question for addressing this problem is whether a product is a liability or not and if yes then in which way. Pharmaceutical companies for example, once a drug has been released for clinical trials, need to process the unstructured clinical narratives or patient's reports about their health and gather information on the side effects. The NLP tasks needed for this applications are primarily *NER* to extract names of drugs, patients and pharmaceutical companies and *relation detection* used to identify the context in which the side effect is mentioned. The NER task helps transforming a sentence such as "Valium makes me sleepy" to "(drug) makes me (symptom)" and relation detection will apply patterns such as "I felt (symptom) after taking (drug)" to detect the presence of side effects.

Many customers, before buying a product, check online reviews about the company and the product regardless of whether it is pizza or a smartphone. Popular sources for such inquiries are blogs, forums, reviews, social media, reports, news, company websites, etc. All of these contain a plethora of precious information that stays trapped in unstructured human generated text. This information if unlocked can play a great role in company's reputation management and decisions for necessary actions to improve it. The NLP tasks sufficient to address this business are *sentiment analysis* to identify attitude, judgement, emotions and intent of the speaker, and *co-reference resolution*, which connects mentions of things to their pronominal reference in the following or preceding text. These tasks alone can extract the positive and negative attitudes

from the sentence “The pizza was amazing but the waiter was awful!” and connect it to the following sentence “I love when it is topped with my favourite artichoke”, disambiguating the sentence so that it is clear that it is about pizza and not the waiter and so discover a topping preference.

NLP is heavily used in customer service in order to figure out what a customer means not just what she says. Interaction of companies with their customers contain many hints pointing towards their dissatisfaction and interaction itself is often one of the causes. Companies record, transcribe and analyse large numbers of call recordings for extended insights. They deploy chat bots for increased responsiveness by providing immediate answers to simple needs and also decrease the load on the help desk staff. NLP tasks that are essential in addressing some of the customer service needs are *speech recognition* that converts speech audio signal into text and *question answering* which is a complex task of recognising the human language question, extracting the meaning, searching relevant information in a knowledge base and generating an ineligible answer. Advances in deep learning allow nowadays skipping the need for searching in a knowledge base by learning from large corpora of question-answer pairs complex interrelations.

The above cases underline the increased need for NLP whereas the variation and ever increasing complexity of tasks reveal the need for deeper and richer semantic and pragmatic analysis across a broad range of domains and applications. Any analysis of text beyond the formal aspects such as morphology, lexis and syntax inevitably leads to a functional paradigm of some sort which can be applied not only at the clause level but at the discourse as a whole. This makes the text also an artefact with relation to the socio-cultural context where it occurs. Yet there is still much work to be done before the technology is capable to reach such complex levels of automatic analysis.

1.4 Linguistic framework

The present work is conducted under the premise that a theory of language is important and worth adopting. In current work the Systemic Functional (SF) theory of language is adopted because of its versatility to account for the complexity and phenomenological diversity of human language providing descriptions along multiple semiotic dimensions. It is possible, in NLP, to reach considerable results even without the adoption of such a framework. This is demonstrated by the advancements in (deep) machine learning. Such methods, however, fail to provide any explanation covering why or how a solution

is reached. This explanation is extended further in this section emphasising SFL strengths.

Any meaningful description or analysis involving language implies some theory about language's essential nature and how it works. A linguistic theory includes also goals of linguistics, assumptions about which methods are appropriate to approach those goals and assumptions about the relation between theory, description and applications (Fawcett 2000: 3).

In his seminal paper "Categories of the theory of grammar" (Halliday 1961), Halliday lays the foundations of *Systemic Functional Linguistic* (SFL) following the works of his British teacher J. R. Firth inspired by Louis Hjelmslev (Hjelmslev 1953) from the Copenhagen School of linguistics and by European linguists from the Prague Linguistic Circle. Halliday's paper constitutes a response to the need for a *general theory of language* that would be holistic enough to guide empirical research in the broad discipline of linguistic science:

> ... the need for a *general* theory of description, as opposed to a *universal* scheme of descriptive categories, has long been apparent if often unformulated, in the description of all languages (Halliday 1957: 54; emphasis in original) ... If we consider general linguistics to be the body of theory, which guides and controls the procedures of the various branches of linguistic science, then any linguistic study, historical or descriptive, particular or comparative, draws on and contributes to the principles of general linguistics (Halliday 1957: 55)

Embracing the *organon model* formulated by Bühler (1934), Halliday refers to the language functions as metafunctions or lines of meaning that offer a trinocular perspective on language through *ideational*, *interpersonal* and *textual* metafunctions. Thus, in SFL language is first of all an interactive action serving to enact social relations under the umbrella of the *interpersonal metafunction*. Then it is a medium to express the embodied human experience of inner (mental) and outer (perceived material) worlds via the *ideational metafunction*. Finally the two weave together into a coherent discourse flow whose mechanisms are characterised through the *textual metafunction*.

SFL regards language as a social semiotic system where any act of communication is regarded as a conflation of *linguistic choices* available in a particular language. Choices are organised on a *paradigmatic* rather than *syntagmatic* (structural) axis and represented as *system networks*. Moreover, in the SFL perspective language has evolved to serve particular *functions* influencing the structure and organisation of the language.

However, their organisation around the paradigmatic dimension leads to a significantly different functional organisation than those found in several other frameworks, as Butler (2003a,b) has extensively addressed. Also, making the paradigmatic organisation of language a primary focus of linguistic description decreases the importance of the formal structural descriptions which from this perspective appear as realisations of (abstract) features.

A linguistic description is then provided at various levels of granularity, which in SFL is called *delicacy*. Just as the resolution of a digital photo defines the clarity and the amount of detail in the picture, in the same way delicacy refers to how fine- or coarse-grained distinctions are made in the description of the language.

There is no distinction, in the SFL tradition, between lexicon and grammar. And to emphasise this fact the term *lexico-grammar* is used, which means the combination of grammar and lexis into a unitary body (see Section 3.1). A deeper description of the SFL theory of language is provided below in Chapter 3.

To the present two major variants of Systemic Functional Grammars (SFG) have been developed: the *Sydney Grammar* (Halliday & Matthiessen 2013b) and the *Cardiff Grammar* (Fawcett 2008). The latter, as Fawcett himself regards it, is an extension and a simplification of the Sydney Grammar (Fawcett 2008: xviii). Each of the two grammars has advantages and shortcomings (presented in Chapter 3) which I will discuss from the perspective of theoretical soundness and suitability to the goals of the current project.

Both the Cardiff and Sydney grammars have been used as language models in natural language generation projects within the broader contexts of social interaction. Some researchers (Day 2007; Kasper 1988; O'Donnell 1993; O'Donoghue 1991b; Souter 1996) consequently attempted to reuse the grammars for the purpose of syntactic parsing. I come back to these works in more detail in Section 2.

To sum up, in this thesis I adopt the Systemic Functional Linguistic (SFL) framework because of its versatility to account for the complexity and phenomenological diversity of human language providing descriptions along *multiple semiotic dimensions*, i.e. paradigmatic, syntagmatic, meta-functional, stratification and instantiation dimensions (Halliday 2003c) and at different *delicacy levels* of the *lexico-grammatical cline* (Halliday 2002; Hasan 2014). To what degree it is possible to produce analysis automatically and what the benefits of such descriptions are still remain to be explored. Moreover it is still unexplored how much of the SFL descriptive potential needs to be employed in practice in order to achieve useful results or solve problems as those exemplified in Section 1.3. The concepts introduced above and other elements of the SFL theory will

be addressed in Chapter 3 below. In order to provide a clearer picture on what the SFG analysis represents the next section provides an example.

1.5 A systemic functional analysis example

To provide a better intuition of the current work, this section describes an analysis of a simple sentence in Example 1. It will guide us starting from traditional "school grammar" concepts down to a detailed systemic functional description of the sentence. As stipulated in the previous section, SFL provides us with a variety of functions and features serving to express text meaning from several perspectives. Another source of the descriptive breadth is achieved through a practice of feature systematisation as mutually exclusive choices. The feature analysis provided here is partial and restricted to only two constituents (the clause and it's Subject) as this suffices to provide the reader with an intuition of what to expect from a full analysis.

(1) He gave the cake away.

School grammar teaches us how to perform a syntactic analysis of a sentence. So let's consider Example 1 in order to perform one. First we would assign a *part of speech* such as verb, noun, adjective etc. to each word; then we would focus on clustering words into constituents guided by the intuitive question "which words go together as a group". Following these actions we will arrive to a word clustering like the one in Figure 1.1.

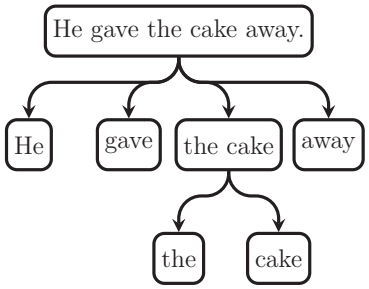


Fig. 1.1 Constituency diagram for Example 1

Figure 1.1 depicts a constituency division of Example 1.The nodes represent grammatical constituents and the edges stand for the *structure-substructure composition*. Next we can move on to assign constituent classes and grammatical functions. Here the sentence is formed of a single clause which has four constituting functional parts: a subject designating who the clause is about, a predicate indicating the action performed

by the subject, a complement denoting what was in the scope of the action and an adjunct describing its destination. Each of these functional parts is filled by a pronoun, a verb, a nominal group and an adverb, respectively. This analysis can be seen in Figure 1.2 as a constituency tree where the nodes carry classes and functions within parent units. In the figure, nodes have been split into three sections for clarity purposes. The first section is filled with text fragments, the second (in blue) with unit classes and the third (in red) with unit functions.

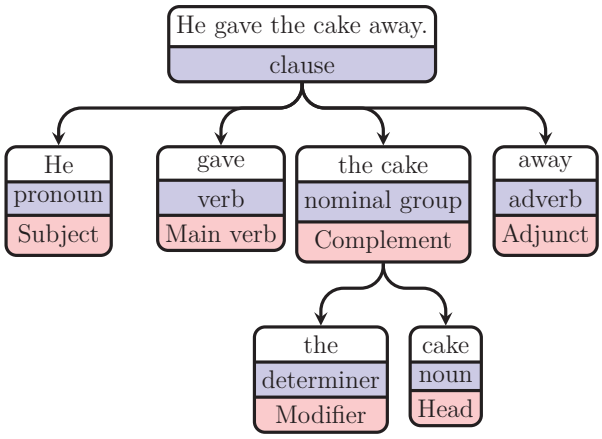


Fig. 1.2 Constituency analysis of Example 1 with unit classes and grammatical functions

Next each constituent can be assigned a set of relevant linguistic features. For example: the subject "He" is a pronoun whose features, well defined in traditional grammar, are: *singular*, *masculine*, and *3rd person*. For example *singular* means *non-plural*, *masculine* means *non-feminine* and 3rd *person* means *non*-1st and *non*-2nd. These are closed classes meaning that there is no 4th *person* or that there is no *common* grammatical gender in English as some other languages have - as for example Danish. These features can be systematised (see Figure 1.3) as three systems of mutually exclusive choices that can be assigned to pronominal units. Note that the gender is enabled for 3rd person singular pronouns which can be expressed as in Figure 1.3 below. This representation constitutes what in SFL is called a *system network* and will be formally introduce in Chapter 3.

In SFG the pronouns are systematised in the system network of Person from *Introduction to Functional Grammar* (Halliday & Matthiessen 2013b: 366) with a different structure, this is depicted in Figure 1.4. This systematisation reflects a semiotic perspective where language is placed into an interactive context. The (red) rectangles from the figure represent selections that are applicable to the Subject constituent "He" in the example above. These selections are the result of traversing a system network

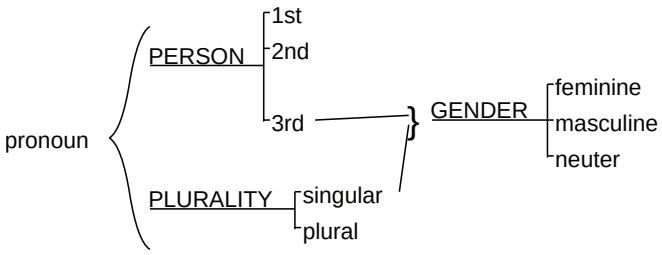


Fig. 1.3 The systematisation of three pronominal features in traditional grammar

deciding at each step which branch to follow and advancing to the next system in case one is available.

From the perspective of an agent generating the utterance in Example 1, to produce the pronoun "he" in the subject position that agent has to make a few choices in the system network. This process is called system network *traversal*. A simplified traversal for selecting the needed pronominal referent can be described as follows. For now, to make it simpler, the explanation of how the decisions are made is omitted focusing mainly on the traversal process itself. So, first the deciding agent chooses in the PERSON system whether the referent participates in the interaction or not (see Figure 1.4). In our example the referent does not participate so the *non-interactant* feature is selected and we proceeds towards the next system further distinguishing the type of *non-interactant*. It can be plural or, as in our case, singular leading to the *one-referent* feature. Next, the referent needs to be differentiated on the consciousness axis which, in our example, is a *conscious* thing. And finally conscious referents need to be distinguished by gender, which in this example is masculine and therefore *male* sex type is chosen. This path of choices uniquely identifies the pronoun "He" in a system network which also defines, just like the one in Figure 1.3, the boundaries of all choice possibilities.

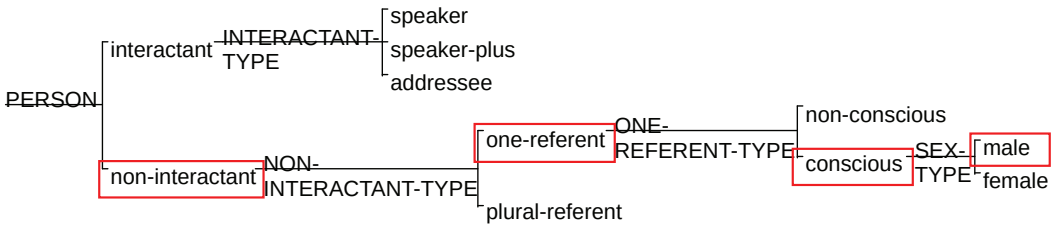


Fig. 1.4 The selections in Person system network from Halliday & Matthiessen (2013b: 366) for pronoun "He"

Lets take now the clause constituent that is the root of the constituency tree (see Figure 1.2) and see how SFL features can be applied to it. If in traditional grammar, the clause is usually ascribed relatively few features, e.g. as having *passive voice*,

positive polarity and *simple past tense*; in terms of SFL grammar the corresponding features are many more, i.e. *major, positive, active, effective, receptive, agentive, free, finite, temporal, past, non-progressive, non-perfect, declarative, indicative, mood-non-assessed, comment-non-assessed*. Figure 1.5 depicts the selections applicable to the clause constituent in Example 1 from a Mood system network that is an adaptation of the Mood network proposed in Halliday & Matthiessen (2013b: 162). These selections represent choices made by a natural language generation system when producing the utterance by a process similar to the one explained for the pronominal referent above (Matthiessen & Bateman 1991). The traversal description is omitted for brevity. Organisation of the linguistic features in system networks is one of the main things that distinguishes SFL from other linguistic traditions. I will formally introduce system networks, how they are structured and how they function, in Chapters 3 and 7 that follow below.

So far we have seen constituents assigned syntactic functions such as Subject, Complement, Adjunct etc. In SFL, they are elements of the *interpersonal metafunction* which will be explained in Chapter 3. SFL provides more linguistic features and functions depending on the kind of meaning it aims at describing. For example another view on the same clause can be provided from a perspective that in SFL is called *experiential* and roughly corresponds to what in traditional linguistics is known as *semantic roles*. It is systematised, in SFL, as Transitivity, which aims at providing domain independent *semantic frames* called *process configurations*. They describe semantic actions and relationships, along with *semantic roles* ascribed to their *participants*. These semantic frames generally are "governed" by verbs and more specifically by each (type of) verb meaning. The verb meanings, in SFL Transitivity, are not considered specific to lexical items as in traditional grammar. They are types of verb meanings defined by process configurations and each can manifest through a variety of lexical items. This is explained in detail in Chapter 3.

The clause in Example 1 corresponds to a Possessive semantic frame where "He" is the Agent and Carrier while "the cake" is the Affected and Possessed thing. Example 2 provides these annotations. These configurations and participant roles correspond to the Transitivity system network proposed by Neale (2002) in the context of the Cardiff grammar. As will be explained in Chapter 4, in the current work I combine elements of the Sydney and Cardiff grammars.

(2) [$_{Agent-Carrier}$ He] gave [$_{Affected-Possessed}$ the cake] away.

Most constituents of clause structure have more than one function, which is called a *conflation of elements*. For example in Example 2, "He" is the Agent(-Carrier) doing

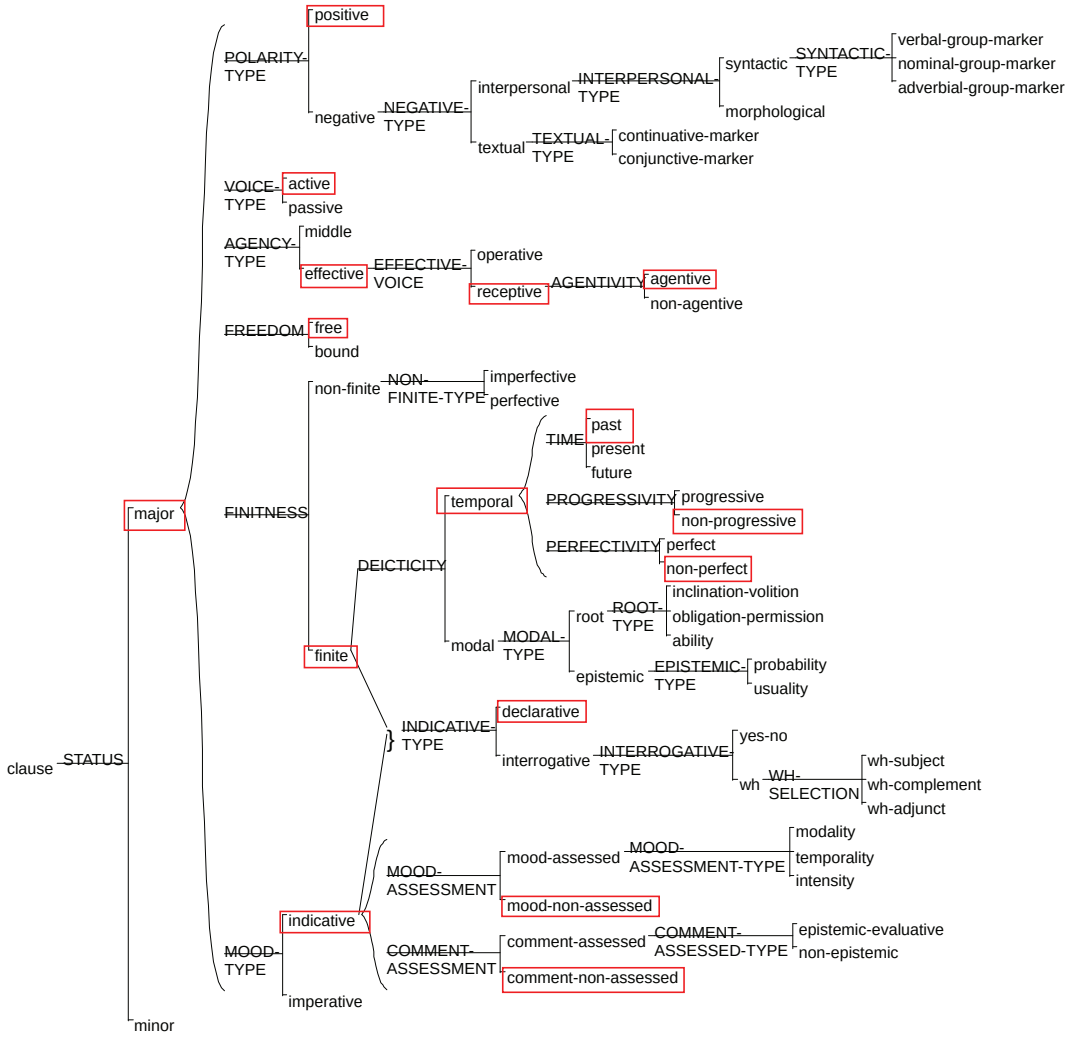


Fig. 1.5 The feature selections in the Mood system network for clause constituent in Example 1

the act of giving but also the Subject of the sentence. So we say that Actor and Subject functions are conflated in the constituent "He". This is where the concept of *metafunction* or *strand of meaning* comes most prominently into the picture. The Subject function is said to belong to the *interpersonal metafunction*, while the Agent(-Carrier) function belongs to the *experiential metafunction*. These concepts are addressed in detail in Chapter 3.

There are more functions and features that can be assigned to the constituents in Example 1 but this is sufficient for the current purposes of introduction. Figure 1.6 summarises everything discussed above into a partially filled constituency tree. The constituents that were not discussed are assigned only a few functions. The last (green) section of every node in the constituent tree is filled with a limited set of grammatical

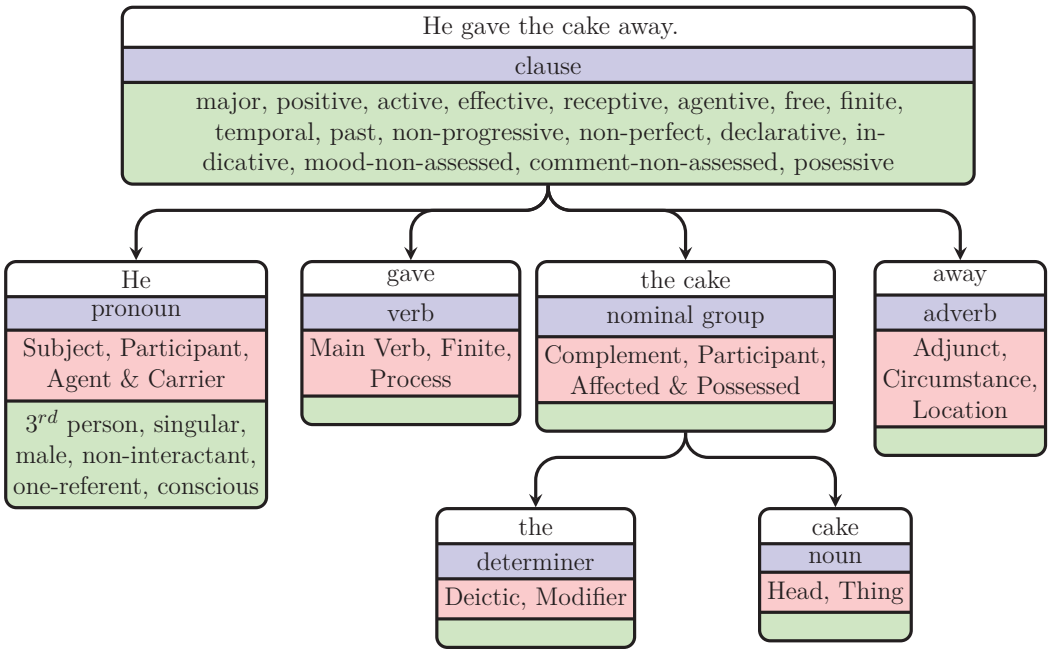


Fig. 1.6 Representation of Example 1 as feature rich constituency tree

features selected from system networks. In practice the feature set is much richer than those shown in the nodes in Figure 1.6; the restriction aims simply to avoid an over-crowded example and simplify the exposition. Important to underline here is the systemic functional anchoring of the features into system networks that is SFL practice.

Next I describe what opportunities and limitations exist in automatically producing rich SFL analyses as until now it has not been possible to use these detailed analysis in computational contexts. This makes them unavailable for corpus work, for training data in machine learning and other end-user application scenarios provided as motivation in Section 1.2 above.

1.6 Challenges of parsing with SFGs

In this section I describe the main challenges for using Systemic Functional Grammars (SFG) in computational contexts in general and parsing in particular. The first and the main challenge in parsing with SFGs is that of computational complexity. This problem stems partially from the manner in which grammars are structured and partially from the fact that paradigmatic descriptions have received most of the attention in SFL at the expense of the syntagmatic one. The second challenge is parsing with features that depart from directly observable grammatical variations towards increasingly abstract

semantic features. Next follows a detailed description of the main problems starting with the imbalance between paradigmatic and syntagmatic accounts in SFL. Then the computational aspects are brought into the picture as a comparison between the natural language generation and parsing tasks. Finally the problem of parsing abstract features is described drawing parallels to the *semantic role labelling* (SRL) task well-defined in mainstream computational linguistics (Carreras & Màrquez 2005).

1.6.1 Syntagmatic descriptions in SFL

Since it was established, SFL has been primarily concerned with the paradigmatic axis of language. Accounts of the syntagmatic axis of language, such as the syntactic structure, have been put in the background. Within SFL, as we will see in Chapter 3, structure is a syntagmatic ordering in language capturing regularities and patterns which can be paraphrased as *what goes together with what*. It has been placed on the theoretical map and defined in terms of *rank*, *unit*, *class* and *function*, but afterwards it received minimal attention.

Most of the descriptive work in SFL is carried paradigmatically via *system networks* (Definition 3.2.10) describing *what could go instead of what* (Halliday & Matthiessen 2013b: 22). Focusing on the paradigmatic organisation in language is in fact the feature that sets SFL apart from other approaches to study language. This has led to progress in accounting for how language works at all strata but little has been said about language constituency. This can be considered "unsolved" within SFL accounts leaving a "gap in what must be one the central areas of any characterisation of language" (Bateman 2008: 25).

If we attend to SFL literature, however, the syntagmatic dimension is implicit and present everywhere in the SFL literature, which makes the above claims sound surprising. For instance all example analyses in the *Introduction to Functional Grammar* (Halliday & Matthiessen 2013b) are predominantly syntagmatic. Moreover, Robin Fawcett for decades promotes the motto *no system network without realisation statements* (Fawcett 1988b: 9) which means that every paradigmatic description must be accompanied by precise rules how it is syntagmatically realised in text. Yet, despite these inducements, the situation could not have been more different. Bateman (2008) presents in detail why there is a severe imbalance between syntagmatic and paradigmatic axes in SFL, how it came to be this way and how it is especially damaging to the task of automatic text analysis, even if quite beneficial for the text generation task.

1.6.2 Computational complexity appears in parsing

O'Donnell & Bateman (2005) offer a detailed description to the long history of SFL being applied in computational contexts yielding productive outcomes on language theorising, description and processing (Bateman & Matthiessen 1988: 139). The transfer between SFL and computation typically involved a delay between the theoretical formulation and the computational instantiation of that formulation (Matthiessen & Bateman 1991: 19). The theoretically formulated ideas contain hidden pitfalls that are revealed only upon explicit formulations required in computation (Bateman 2008: 27).

The active exchange between SFL theory and computation has been almost entirely oriented towards automatic *natural language generation*. Such systems take abstract semantic specifications as input and use grammars to produce grammatically correct and well-connected texts.

Automatic analysis or *parsing* can be seen as a reverse problem of finding appropriate analysis within a search space of possible solutions. That is to identify, as accurately as possible, the meaning systematised in the grammar of a given natural language sentence. As seen in Section 1.5 above, an account of the sentence meaning would have to provide two things. First a description in terms of a formal structure of the sentence revealing the constituents plus their syntactic relations to each other. And second, a description in terms of a (complete) set of features, detailed to the extent that grammar permits, applicable to each constituent of structure.

One of the grammars successfully used in generation tasks is the Nigel grammar developed within the Penman generation project (Mann 1983). The efficiency in generation tasks is, in part, due to decomposition of language along the paradigmatic axis using functionally motivated sets of choices between functionally motivated alternatives (McDonald 1980). The Nigel grammar contains 767 grammatical systems defined over 1381 grammatical features, which Bateman evaluated in 2008 as "a very large computational grammar by current standards, although nowadays by no means the broadest when considered in terms of raw grammatical coverage" (Bateman 2008: 29).

The computational processes driving natural language generation relied heavily on the notion of *search*. A well defined search problem is defined in terms of a precise description of the search space which then helps a navigation process effectively to find solutions. The paradigmatic organisation of the *lexico-grammar* as system networks assumed within SFL turns out to organise the search space for possible grammatical units appropriately for expressing communicative goals in generation in an almost ideal manner (Bateman 2008: 28).

If, in the generation process, the abstract semantic specifications are increasingly materialised through choice making by traversing the system network towards finally generated text (see example in Section 1.5), then, in the parsing process, the reverse is the case. The process starts from a given sentence and aims to derive/search the feature choices in the system network applicable to each of the constituents. But if the paradigmatically organised lexico-grammatical resource is effective for generation it turns out, as we will see next, to be by far unsuitable for the analysis task because the size of the search space is too big to be computed in a reasonable time. Halliday himself mentions this problem when he asks *how big is a grammar?*

> Given any system network it should in principle be possible to count the number of alternatives shown to be available. In practice, it is quite difficult to calculate the number of different selection expressions that are generated by a network of any considerable complexity (Halliday 1996: 10).

The issue is that of handling a combinatorial space which emerges from the way connections and (cross-)classifications are organised in a system network. The orientation of systemic grammars towards choice means that a typical grammar includes many disjunctions, which leads to the problem of search complexity. Also the abstract nature of systemic features leads to a structural richness that adds logical complexity to the task (O'Donnell 1993). So estimating the size of the grammar would in fact mean estimating the potential number of feature combinations.

For example, if we consider a hypothetical network of 40 systems then the "size of the grammar it generates lies somewhere between 41 and 2^{40} (which is somewhere around 10^{12})" (Bateman 2008: 28). Moreover, it is not easy to calculate where the upper limit of a grammar would fall even when the configuration of relations of a particular system network is known. To parse with the Nigel grammar, mentioned above, would mean exploring a search space of approximately 3×10^{18} feature combinations (Bateman 2008: 35). A more detailed break down of the complexity by rank or primary class is provided in Table 1.1.

For the generation task the size is not an issue because the number of choice points is actually rather small. The paradigmatic organisation is, in fact, a concise and efficient way to express the linguistic choices where the possible feature selections are relevant only when they are enabled by prior paradigmatic choices and it is only those alternatives that need to be considered (Halliday 1996: 12–13). This property of gradual exposure of choices characterises the traversal of the system networks which starts from the root and gradually advances towards more delicate features down to a set of leaves.

rank or primary class	*size*
adverbial-group	18
words	253
quantity-group	356
prepositional-phrase	744
adjectival-group	1045
nominal-group	$>2 \times 10^9$
clause	$>3 \times 10^{18}$

Table 1.1 Size of major components of the Nigel grammar expressed in terms of the number of selection expressions defined (Bateman 2008: 35)

> In the analysis task, the paradigmatic context of choice that helps navigation during the generation process is no longer available. It is not known any longer which features of a systemic network are relevant and which are not. This leads to a radical asymmetry between the two tasks. That is: in generation, the simple traversal of the network finds only the compatible choices because that is what the network leads to; whereas in analysis it is not evident in advance which path to follow and therefore the task is to explore the entire search space in order to discover which features apply to the text. This means that any path is potentially relevant and needs to be checked leading to evaluation of the system network as a whole. There is then no way to restrict the search space on solely paradigmatic grounds as in the case of generation (Bateman 2008: 29).

1.6.3 Parsing with semantic features

Another difficulty in parsing with SFGs lies in the fact that, as the analysis moves away from directly observable grammatical variations towards more abstract semantic variations, the difficulty of generating an accurate account increases drastically. The Transitivity system network for example consists of such semantic features and it is comparable to the task of (shallow) *semantic parsing* or *Semantic Role Labelling* (SRL) (Carreras & Màrquez 2005).

SRL is the process that assigns labels to words or phrases in a sentence that indicate their semantic role in the sentence, such as that of an agent, goal, or result. The main challenge of SRL, well explained in Gildea & Jurafsky (2002: 245–250), remains the same since Winograd (1972): *moving away from the domain specific, hand-crafted semantic specifications towards domain independent and robust sets of*

semantic specifications. Significant contribution to this challenge was undertaken in several projects to build large broad-scope lexico-semantic databases such as FrameNet (Baker et al. 1998; Fillmore et al. 2003; Johnson & Fillmore 2000) and VerbNet (Kipper et al. 2008; Schuler 2005). A similar database exists for the Transitivity system network as described in Fawcett (forthcoming) called the *Process Type Database* (PTDB) (Neale 2002). It is worth mentioning WordNet (Fellbaum & Miller 1998) as well, which organises the meanings of nouns, adjectives and adverbs.

Such databases provide domain independent *semantic frames* (Fillmore 1985), known in SFL as *configurations* or *figures*, e.g. Action, Cognition, Perception, Possession etc. They describe semantic actions and relationships between *participants* each playing a distinct *semantic role* within the frame e.g. Agent, Carrier, Possessed, Phenomena etc. For instance the perception frame contains *Perceiver* and *Phenomenon* roles annotated in Example 3.

(3) [$_{Agent-Perceiver}$ Jacqueline] glanced [$_{Phenomenon}$ at her new watch].

One challenge in this work is to implement a semantic parsing process for the Transitivity systemic network employing PTDB as the lexical-semantic resource.

1.6.4 Covert elements

Besides the challenge of identifying configurations and their participants in text, the problem with semantic features goes one step further. Sometimes the participant roles correspond to constituents that are displaced or not realised in the text, which are called *covert constituents*(Fawcett 2008: 115,135,194), *gaps* (Ross 1967), *empty elements* (Müller 2018: 557–575) or *null elements* (Chomsky 1981, 1982, 1986). This increases the challenge of identifying frames and assigning roles correctly and next is explained why.

For a frame to be considered correctly realised in text, at least its mandatory roles must be filled by constituent units. This requirement constitutes a minimal semantic completeness constraint. This can be demonstrated by erasing parts of the text in Example 3. If we take the Agent-Perceiver away as in Example 4 the texts is perceived as incomplete because it is not possible to interpret its meaning. It leaves us with the question *Who* glanced at her new watch? Similarly, if we delete the Phenomenon as in Example 5, we are unable to resolve the meaning of the text without first answering the question *what* or *who* did Jacqueline glance at? This shows that configurations need to satisfy the minimal semantic completeness condition when realised in text. Conversely,

one of the fundamental assumptions in this thesis, although perhaps too exigent, is that the input text is well-formed and the completeness condition is satisfied.

(4) glanced at her new watch

(5) Jaqueline glanced

Consider now Example 6 consisting of a sentence that has three non-auxiliary verbs: seem, worry and arrive. According to the Cardiff grammar (introduced in Chapter 3) it corresponds to three clauses *embedded* into each other. Table 1.2 provides the constituency analysis in the Cardiff style of Example 6.

(6) She seemed to worry about missing the river boat.

<table>
<tr><td>She</td><td>seemed</td><td>to</td><td>worry</td><td>about</td><td>missing</td><td>the</td><td>river</td><td>boat.</td></tr>
<tr><td colspan="9">clause</td></tr>
<tr><td>Subject</td><td>Main Verb</td><td colspan="7">Complement</td></tr>
<tr><td></td><td></td><td colspan="7">clause</td></tr>
<tr><td></td><td></td><td>Infinitive Element</td><td>Main Verb</td><td colspan="5">Complement</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">clause</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Binder</td><td>Main Verb</td><td colspan="3">Complement</td></tr>
</table>

Table 1.2 SF constituency analysis in Cardiff grammar style of Example 6

Table 1.3 provides the participant role configurations (i.e. the semantic frames) these verb meanings bring about. Usually the first role corresponds to the Subject function and the second role is filled by a Complement unit.

The verb meaning $seem_1$ corresponds to an Attributive configuration that distributes Carrier and Attribute roles to the Subject "She" and the Complement "to worry about missing the river boat". In the case of *worry about*$_1$ and $miss_1$ the first roles provided by the Cardiff grammar are *compound*, i.e. composed of two simple ones. In the example above, *worry about*$_1$ distributes the Phenomenon to the Complement "about missing the river boat" and the Agent-Cognizant role to an empty Subject that is said to be *non-realised*, *covert* or a *null element*. A similar situation holds for $miss_1$ that assigns an Affected-Carrier role to the empty Subject and the Possessed role to the Complement "the river boat".

Those unrealised Subjects in the embedded clauses are recoverable from the immediate syntactic context (i.e. no need for discourse) and correspond, in this case, to the Subject in the higher clause. This is annotated in Examples 7 and 8. We can just mark the places of the null Subjects in the embedded clause in order to be able to assign the semantic labels this way ensuring that the minimal completeness constraint

Verb meaning	Semantic configuration	Participant role distribution
$seem_1$	Attributive	Carrier + Attribute
$worry\ about_1$	Two Role Cognition	Agent-Cognizant + Phenomenon
$miss_1$	Possessive	Affected-Carrier + Possessed (thing)

Table 1.3 Semantic role configurations according to Fawcett (forthcoming); Neale (2002)

is fulfilled; otherwise the frame cannot be assigned to the constituents and another one must be searched for instead. Notice also an index i to highlight that the null elements correspond to the higher clause Subject "She".

(7) *She* worried about missing the river boat.

(8) *She* missed the river boat.

(9) She$_i$ seemed [*null-Subject*$_i$ to worry [about *null-Subject*$_i$ missing the river boat]].

Now that the places of the covert constituents are explicitly marked in Example 9 and the recoverable constituents coindexed, we can distribute the semantic role configurations from Table 1.3 as provided in Table 1.4.

She$_i$	*seemed*	$\emptyset_i$	*to*	*worry*	*about*	$\emptyset_i$	*missing*	*the*	*river*	*boat.*
Attributive configuration										
Agent		Attribute								
		Two role cognition configuration								
		Agent & Cognizant			Phenomenon					
					Possessive configuration					
						Affected & Carrier			Possessed	

Table 1.4 Transitivity analysis in Cardiff grammar style (Fawcett forthcoming; Neale 2002) of Example 6

In language there are cases where constituents are empty but recoverable from the immediate vicinity by relying in most cases on syntactic means, while in a few others additional lexical-semantic resources are needed. In SFL, Fawcett describes these elements in the context of the Cardiff grammar (Fawcett 2008: 115,135,194) but provides no means to recover them. The Government and Binding Theory (GBT) developed in Chomsky (1981, 1982, 1986) and based on phrase structure grammar, provides a detailed account of mechanisms to detect and resolve the empty constituents. GBT explains how some constituents can *move* from one place to another, where the places of *non-overt constituents* are and what constituents they refer to, i.e. what their *antecedents* are. Such accounts of empty elements are useful in determining the correct distribution of participant roles across the clause constituents.

1.6.5 Problem summary

This section has shown the main challenges related to parsing with SFG, which can be summarised as follows. First, the parsing task cannot be treated as a reversible generation task because the methods that have been shown to work for generation are not usable for parsing as such due to a high computational complexity. Second, the parsing task, regardless of the grammar, should first and foremost account for the sentence structure on the syntagmatic axis and only afterwards for the (semantic) features selected on the paradigmatic axis. The syntagmatic account in SFL is insufficient for the parsing task. Third, the syntagmatic account alone does not provide enough clues for assignment of semantic features (like in Table 1.3) and requires a lexical-semantic account within the grammar or as a separate resource. Moreover, semantic parsing can be aided by identification of places where covert constituents are said to exist.

Next I will describe how these problems have been addressed in the current work, what the goals of the thesis are and what has been left for future work.

1.7 Goals and scope of the thesis

This thesis aims at a modular method for parsing unrestricted English text into a Systemic Functional constituency structure using fragments of Systemic Functional Grammar (SFG) and dependency parse trees.

The computational complexity, the lack of proper syntagmatic description in SFL and perhaps other hidden reasons, have led to the results of parsing with SFGs so far to not be usable in real world applications. This conclusion is drawn from past attempts such as Kasper (1988), Kay (1985), O'Donoghue (1991b), O'Donnell (1993) and Day (2007), to mention just a few, none of which managed to parse broad coverage English with full SFG without aid of some sort. A detailed account of the current state of the art in parsing with SFGs is provided in Chapter 2. Some parsing approaches use a syntactic backbone which is then fleshed out with an SFG description. Others use a reduced set or a single layer of SFG representation; and the third group use an annotated corpus as the source of a probabilistic grammar. Each had to accept limitations either in grammar or language size and eventually used simpler syntactic trees as a starting point.

Some linguistic frameworks, other than SFL, have been shown to work well in computational contexts solving problems similar to the ones identified above. For the purposes of this thesis I selected Dependency Grammar (DG) and, in addition,

accounting for covert elements according to GBT. And instead of attempting to find novel solutions within the SFL framework, an alternative approach, I argue in the next section, is to establish cross-theoretical and inter-grammatical links and to enable integration of the existing methods, resources and solutions in order to maximise reuse of positive outcomes.

The process developed in this thesis follows a pipeline architecture (see Section 1.7.4) comprising of two major phases: *structure creation* and *structure enrichment*. The structure creation phase aims to account for the syntagmatic dimension of language. The structure enrichment phase aims at discovering and assigning systemic features (accounting for the paradigmatic dimension of language) stacking to each of the nodes constituting the structure.

1.7.1 On theoretical compatibility and reuse

In the past decades much significant progress has been made in natural language parsing framed in one or another linguistic theory, each adopting a distinct perspective and set of assumptions about language. The theoretical layout and the available resources influence directly what is implemented into a parser and each implementation approach encounters challenges that may or may not be common to other approaches in the same or other theories.

Parsers implementing some theoretical framework may face common or different challenges to those implementing another theoretical framework. The converse can be said of the solutions. When a solution is achieved using one framework it becomes potentially reusable in other ones provided a degree of adaptation. Thus the successes and achievements in any school of thought can be regarded as valuable for other ones to the degree cross theoretical links and correspondences can be established. In this thesis reusing components that have been shown to work and yield "good enough results" is a strong pragmatic motivation in the present work which brings us to Research question 1.

Research question 1 (Reuse positive results)**.** To what extent can resources and techniques from other areas of computational linguistics be reused for SFL parsing and how?

In this thesis three linguistic frameworks are employed, namely *Systemic Functional Linguistics*, *Dependency Grammar* and *Government & Binding Theory*. SFL has already been motivated as the target analysis framework in Section 1.4. The other

two frameworks are employed because their accomplishments in those domains carry answers to the above stated problems.

In the past decade *Dependency Grammar* (Tesniere 2015) has become quite popular in the natural language processing world and is favoured in many projects and systems. The small grammar size and the modern algorithms implemented into dependency parsers such as the Stanford Dependency Parser (Marneffe et al. 2006), MaltParser (Nivre 2006), MSTParser (McDonald et al. 2006) and Enju (Miyao & Tsujii 2005) are increasingly efficient and highly accurate. Among the variety of dependency parsing algorithms, a special contribution is made by *machine learning* methods such as those described in McDonald et al. (2005), McDonald & Pereira (2006), Carreras (2007), Zhang & Nivre (2011), Pei et al. (2015) to name just a few.

Research question 2 (Compatibility of DG and SFG)**.** To what degree are the syntactic structures of the Dependency Grammar and Systemic Functional Grammar compatible to undergo a transformation from one into the other?

The dependency parse structures provide information about functional dependencies between words and grants direct access to the predicate-argument relations. This information may be sufficient to supplement the missing syntagmatic account in SFL. In addition, it provides some functional information that may help to reduce the complexity of system network traversing. These hypotheses, formulated as Research question 2, are investigated at the theoretical level in Chapter 5 and are then empirically evaluated in Chapter 10 based on Stanford Dependency parser version 3.5 (Marneffe et al. 2014; Marneffe & Manning 2008a,b).

Research question 3 (Compatibility of GBT and SFG)**.** How can Government and Binding Theory be used for detecting places of null elements in the context of SFL constituency structure?

The problem of accounting for *null elements*, mentioned above, is not addressed either in SFL or in Dependency Grammar. It is, however, addressed in detail in the Government and Binding Theory (GBT) (Chomsky 1981; Haegeman 1991b), which is one of Chomsky's families of Transformational Grammars (Chomsky 1957). One other goal in this thesis is to investigate, as formulated in Research question 3, to which degree GBT accounts of null elements can be reused as DG or SFG structures to support a cross-theoretic transformation enabling those accounts in DG or SFG contexts. Chapter 6 introduces GBT and investigates this hypothesis providing some

of the cross-theoretic and inter-grammatical links to Dependency and SFL grammars that, as we will see in Chapter 9, benefits the Transitivity analysis.

1.7.2 Towards the syntagmatic account

The problem of structure construction can be outsourced for parsing with other grammars. This is done in the work of Kasper (1988) and of Honnibal (2004) and Honnibal & Curran (2007), who used phrase parse structures of the Chomskian style grammars. This approach is known in the SFL literature as *parsing with a syntactic backbone*. In this case, the problem changes into creating a transformation mechanism to obtain the SFL constituency structure rather than building it from scratch.

Research question 4 (Suitability of Stanford DG)**.** How compatible are the grammatical categories and practices in the Stanford Dependency grammar with the requirements of SFGs?

This thesis addresses the problem of constituency structure building by parsing the text with the Stanford Dependency parser version 3.5 (Marneffe et al. 2014; Marneffe & Manning 2008a,b) and then transforming the parse result into an SFG constituency tree. The degree to which Stanford dependencies are suitable to serve as a syntactic backbone is one of the questions addressed in this thesis (Research question 4). An account of the correspondence between linguistic primitives or configurations of primitives in the dependency grammar to SFG primitives is provided at the end of Chapter 5 along with an analysis of the Stanford dependency grammar. A detailed description of the structure generation process is provided in the Chapter 8.

1.7.3 Towards the paradigmatic account

Once the constituency structure is in place it serves as a foundation and informs the following process of feature enrichment. The configurations of units carrying grammatical categories and functions into *structural patterns* serve as "hooks" to guide the traversal of system networks in a way resembling the realisation rules.

The system network fragment in Figure 1.7 contains realisation rules inscribed in rectangular boxes positioned below some features. These realisation rules indicate what will be reflected in the structure when a specific feature is selected (as discussed in Section 1.6). The converse is also true: if structure contains a certain pattern then it is a (potential) manifestation of a given feature.

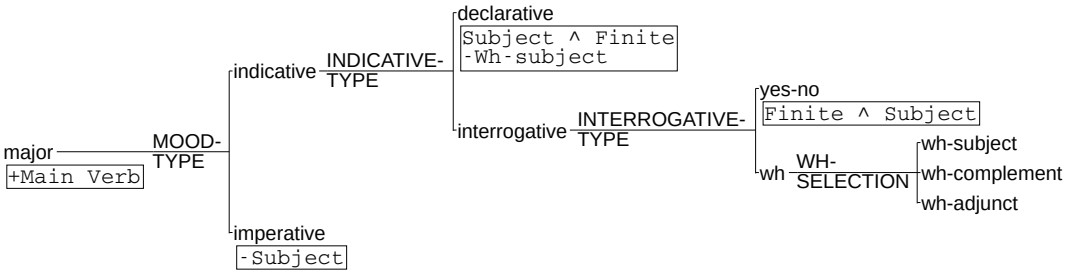


Fig. 1.7 A fragment of mood system from Halliday & Matthiessen (2013b: 366)

For example, the structure of a *major* clause needs to have a predicate or Main Verb element realised. In the parsing process, testing whether there is a unit functioning as Main Verb below the clause node suffices to assign the feature *major* to that clause. Next, if the clause has no unit functioning as Subject then it should be assigned the *imperative* feature, otherwise the *indicative* one. Further the INDICATIVE-TYPE system is enabled. Here the test is whether a Subject node is positioned in front of the Finite node and whether the Subject does not contain the pronoun "who". This sort of query on the structure can be formulated in terms of *structure patterns* (see Section 7.3), which are associated with features in the system network in the same manner as the realisation rules.

Such patterns can be identified in the instance structure, which means that the features can be identified through associated structure patterns. In the current parsing method, pattern recognition plays an essential role for fleshing out the constituent backbone with systemic features. The structural patterns are tested to see whether they *match* (see Section 7.4) anywhere in the constituency structure and if so then the matched nodes are enriched with the features provided in the pattern (described in Section 7.5). This process is detailed in Section 9.2.

The structure patterns in this thesis are expressed as *graph patterns* (described in Section 7.3). Note that I employ the concept of *graph* and not that of a tree because the latter are too restrictive for the purpose of the current work. While most of the time they are hierarchically structured as a tree, there are a few patterns that involve sibling connections or nodes with multiple parents. In both cases the tree structure is broken. The graph construct allows a wide range of structural configurations including trees. This comes with the cost of higher computational power and is subject for optimisations in future work.

Most of the graph patterns in this thesis have been manually created. Because this is laborious exercise only a few system networks have been covered in the implementation of the parser. Nonetheless they suffice for claims of feasibility and deriving sufficient

insights regarding the parsing approach. Future work may investigate how graph patterns can be generated automatically from the realisation rules of large grammars such as Nigel.

Research question 5 (Coverage of syntactic patterns)**.** What degree of systemic delicacy can be reached using syntactic patterns alone without any lexical-semantic resources?

The pattern may consist solely of syntactic specifications or it can also carry lexical-semantic descriptions. The two main system networks targeted in this thesis are MOOD and TRANSITIVITY (described in Chapter 4). One hypothesis contained in Research question 5 is that the MOOD network is composed of syntactically identifiable features and so the graph patterns need involve no more than unit classes and functions available in the constituency structure.

Research question 6 (PTDB suitability)**.** How suitable is the Process Type Database as a resource for SFL Transitivity parsing?

Performing semantic parsing, with the method employed in this thesis, requires graph patterns covering the semantic features of the TRANSITIVITY network. This thesis employs the Process Type Database (PTDB) (Neale 2002) to aid generation of such patterns. The appropriateness of PTDB for these tasks is interrogated by Research question 6 and addressed in Chapters 4 and 9. In the next section an overview is presented of how these processes fit together in a uniform parsing process.

1.7.4 Parsimonious Vole architecture

The current thesis is accompanied by a software implementation called the Parsimonious Vole parser. It is programmed in the Python language and is available as an open source distribution[1]. It takes the text of an English sentence as input and outputs a rich systemic functional constituency structure. This section explains the implemented parsing process architecture.

The parser follows the pipeline architecture depicted in Figure 1.8. Three types of boxes are used here: (a) the red rounded rectangles in the middle represent parsing steps, (b) the green trapezoid boxes represent input and output data and (c) the orange double framed trapezoid boxes represent external resources involved in the parsing process, e.g. system network, graph patterns, lexical-semantic databases etc.

[1] https://bitbucket.org/lps/parsimonious-vole

The parsing steps linearly flow from one to the next via green trapezoid boxes on the left-hand side of the diagram. This means that the output data of a step constitutes the input for the next one. On the right-hand side are positioned double edged orange trapezoids representing fixed resources needed by some operations. For example, the *graph normalisation* step takes a set of graph patterns that serve as normalisation rules indicating how to update the input.

Two green vertical arrows are provided on the far right of the diagram delimiting parsing phases: *Graph Building* (spanning the first three process steps) that accomplishes construction of the constituency backbone (motivated in Section 1.7.2 above), and the second phase, *Graph Enrichment* (spanning the last three process steps), fleshes out the backbone with features (motivated in Section 1.7.3).

The parsing process starts from an English text which is sent to the Stanford Dependency parser (Chen & Manning 2014) version 3.5[2] to produce a Dependency parse graph of that text. The output is a sequence of dependency graphs corresponding to sentences delimited by punctuation marks.

The dependency graphs often contain errors. Some of these errors are predictable and so easy to identify and correct. Also, some linguistic phenomena are treated in a slightly different manner than that proposed in the current thesis. Therefore, dependency graphs produced by the Stanford parser are *Corrected and Normalised* against a collection of known errors and a set of normalisation rules using pattern matching techniques.

Afterwards, the normalised dependency graph is ready to guide the *building process* of the systemic functional constituency graph. Through a traversal of the dependency graph the constituency graph is constructed in parallel guided by a *Rule Table*. This table contains the mapping of structural context fragments from the dependency grammar (i.e. node type, edge type, combinations of the two etc.) to constituency graph nodes. The structural mappings are accompanied by operation specifications to perform during each traversal step. The output of this step constitutes the syntactic backbone on which the subsequent enrichment phases are performed.

Next follows the phase where each constituent node of the syntactic backbone is *enriched* with features. Some of these are syntactic in nature and others are lexical-semantic. In between these enrichment phases there is an additional construction process adding where needed *empty constituents* that play an important role in semantic enrichment. The enrichment steps use *system networks*, *feature rich lexicons*, *graph patterns* and the PTDB *semantic database* as additional resources. The *null element*

[2] https://nlp.stanford.edu/software/nndep.html

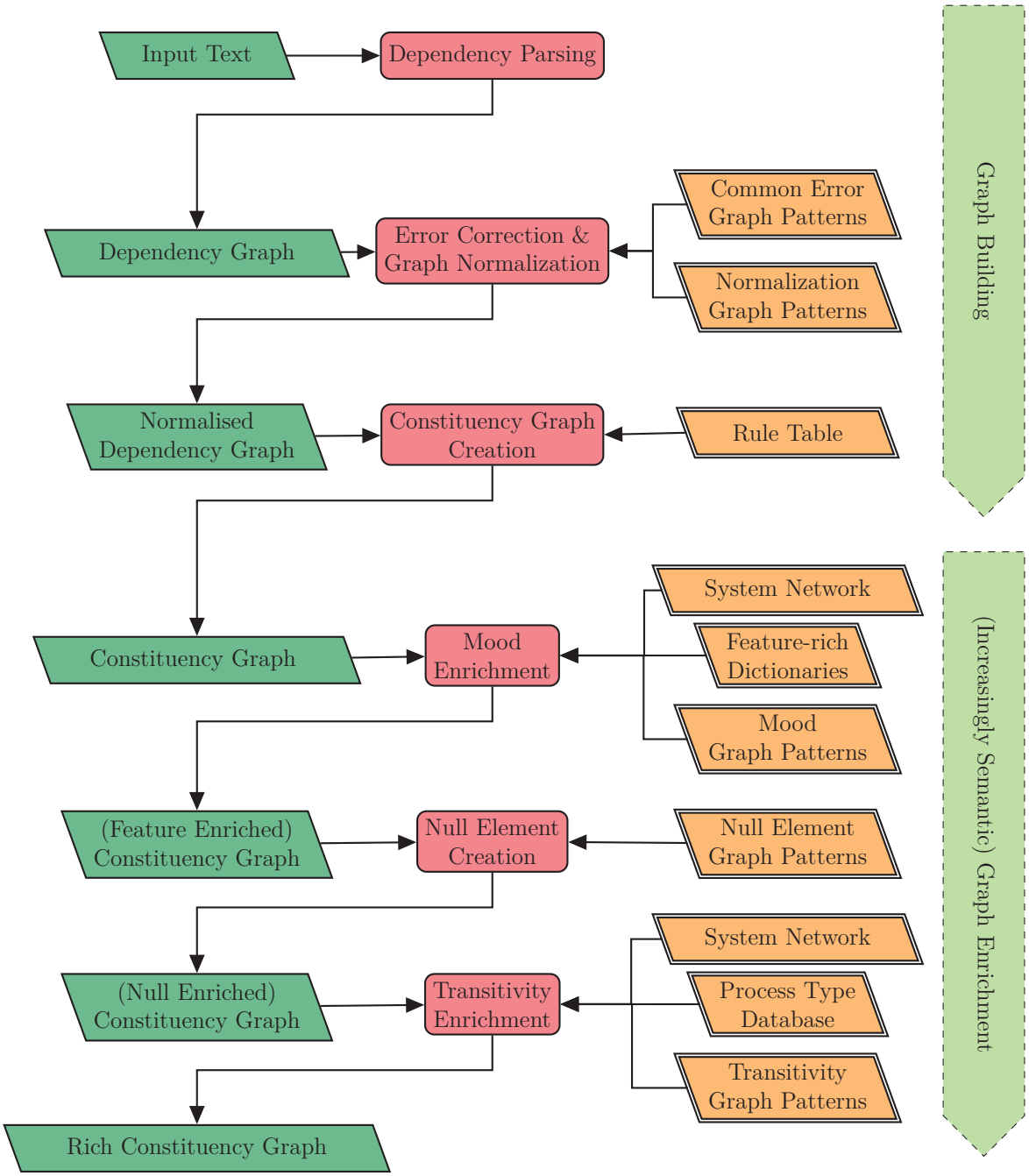


Fig. 1.8 The parsing process pipeline

creation process also needs a collection of graph patterns for identifying where and what kind of null elements occur (motivated in Section 1.6 and explained in detail in Chapter 6). The final result of the process is a *Rich Constituency Graph* of the original text comprising a substantial set of systemic feature selections associated with constituting units of structure.

The detailed parser implementation choices and developed algorithms are presented in Chapters 8 and 9. The next section lays out the thesis structure indicating the important contributions of each chapter.

1.8 Thesis overview

Chapter 1 has provided an introduction to the work described in this thesis. It has indicated the areas to which it seeks to contribute, and described the motivation of work from an applied and a theoretical perspective. Chapter 2 presents a brief list of selected works on parsing with SFG.

Chapter 3 provides an overview of the SFL theoretical foundations. There are two outstanding traditions in SFL, each providing a theory of grammar. The first is developed in Sydney by Halliday, Matthiessen, Hassan, Martin, Rose and others. The second is developed in Cardiff by Fawcett, Tucker, Tench and others. I present both schools in the first two sections of the chapter and then, in the third section, I provide a comparative critical discussion of both theories of grammar, motivating relaxation of the rank scale, an approach to structure formation, unit classes and a few other concepts relevant to the current work.

Chapter 4 provides a description of the grammar implemented in the Parsimonious Vole parser. This grammar contains a selection of unit classes from both the Sydney and Cardiff grammars following the theoretical motivation from the previous chapter. Here is also presented a selection of two system networks: MOOD and TRANSITIVITY, that were selected to demonstrate how the current parsing method works. The former system network is tightly linked to the syntagmatic variations in the structure whereas, the latter describes ideational choices of the semantic structures and, thus, is farther from surface variations. In order to integrate this system network, I use the lexical database of verb meanings called the Process Type Database (Neale 2002).

Chapter 5 introduces Dependency Grammar (Tesniere 1959), starting with its origins and foundations, evolution into its modern form, its applications in computational contexts particularly highlighting the Stanford grammatical model and parser. The usage of dependency grammar and dependency parse graphs was motivated in 1.7.2 as the primary input into the current parsing pipeline for creating the constituency structure. The last part of the chapter provides a set of principles and generalisations to establish a cross-theoretical bridge from DG towards SFG which is implemented into the Parsimonious Vole parser.

Chapter 6 starts with an introduction to Government and Binding Theory (GBT) explaining where empty constituents occur in sentences. These constituents were motivated in Section 1.6 and are a part of the solution for parsing with the TRANSITIVITY system network. The second section of the chapter provides an inventory of different null elements and the last section provides, just as in the previous chapter, a cross theoretical overview, this time from GBT phrase parse structures into Stanford dependency grammar. This chapter provides a theoretical translation of the principles from GBT into DG constituting the theoretical foundations for the technical solutions, given in Section 9.3, for how to create null elements in DG and SFG graphs.

Chapter 7 provides the building blocks of the algorithms of this thesis. It makes the transition from linguistic theoretic presentations towards the computer science foundations introducing necessary typed sets, feature structures and graphs. These concepts are employed in the chapters that follow to represent linguistic constructs described in the previous chapters. An important role, in the current work, is played by the pattern graphs and the operations enabled by using them presented in Sections 7.3 – 7.5. The pattern graphs, as will be presented later, constitute a flexible and expressive method to represent systemic feature realisation rules. Also in this chapter, the system networks are defined in a simplified form corresponding to how they are currently used along with a simple strategy for choice propagation.

The first phase of the parsing pipeline (see Figure 1.8) concerning the constituency graph building is entirely covered by Chapter 8. This chapter presents how the input dependency graphs are first corrected, normalised and then rewritten into constituency graphs. The implementation of Parsimonious Vole also contains a full set of mapping rules between Stanford Dependency v3.5 to SFG constituency structure enumerated in Appendix E.

The second phase of the pipeline (see Figure 1.8) concerning the enrichment of the constituency graph with increasingly more semantic features is described in Chapter 9. This chapter addresses two main system networks, that of MOOD and TRANSITIVITY as introduced in Chapter 4. The MOOD features are close to syntactic variation of text and can be addressed via graph patterns alone; this is described in the first part of the chapter. The TRANSITIVITY features are semantic in nature and require additional lexical-semantic resources from which graph patterns are generated first and then applied to enrich the constituency graph. The work presented in this chapter comprises a set of syntactically grounded graph patterns covering Mood and a few other small system networks. It provides a clean machine-readable version of the PTDB along with a method to automatically transform PTDB records into semantically oriented

Transitivity graph patterns. Also, graph patterns and algorithms have been developed to capture several principles and mechanisms for detecting null elements in texts.

Chapter 10 describes how the Parsimonious Vole parser was evaluated. This evaluation was conducted on two corpora. One was created by Ela Oren and myself with the purpose of evaluating the syntactic features of this parser, while the other was provided by Anke Schultz covering the Cardiff Transitivity annotations. The chapter describes evaluation settings and results for syntactic and semantic parsing. Chapter 11 concludes the thesis by providing a thesis summary overview, indications for practical applications of the work and future directions to follow.

Chapter 2

An overview of selected work on parsing with SFG

There have been various attempts to parse with SFGs and this chapter covers the most significant attempts. The first attempt was made by Winograd (Winograd 1972) which was more than a parser, it was an interactive natural language understanding system for manipulating geometric objects in a virtual world.

Then, starting from early 1980s onwards, Kay, Kasper, O'Donnell and Bateman tried to parse with the Nigel Grammar (Matthiessen 1985), a large and complex natural language generation (NLG) grammar for English used in the Penman generation project. Other attempts by O'Donoghue (1991b), Weerasinghe (1994), Souter (1996) and Day (2007) aimed for corpus-based probability driven parsing within the framework of the COMMUNAL project, starting from the late 1980s.

In a very different style, Honnibal (2004) and Honnibal & Curran (2007) constructed a system to convert Penn Treebank structures into a corresponding SFGBank. This managed to provide a good conversion from phrase structure trees into systemic functional constituency trees covering sentence Mood and Theme structure. No systemic feature selections were assigned to any of the constituents. Also no Transitivity account was provided in their attempts. The current work follows a similar approach of converting parse structures and, in addition, providing a set of feature selections from system networks. The sections following provide more details on previous attempts to parse with SFGs.

2.1 Winograd's SHRDLU

SHRDLU is an interactive program for understanding (if limited) natural language written by Terry Winograd at MIT between 1968-1970. It supported a simple dialogue about a world of geometric objects in a virtual world. The human could ask the system to manipulate objects of different colours and shapes and ask questions about what had been done or the new state of the world.

SHRDLU is recognised as a landmark in natural language understanding demonstrating that a connection with artificial intelligence is possible. However, its success was not due to the use of SFG syntax but rather to the small size of every system component to achieve a fully functional dialogue system. Not only was it parsing the input but it was developing an interpretation of it, reasoning about it and generating appropriate natural language responses.

Winograd combined the parsing and interpretation processes such that the semantic interpreter was actually guiding the parsing process. The knowledge of syntax was encoded in the procedures of the interpretation program. He also implemented an ingenious backtracking mechanism where the program does not simply go back, like other parsers, to try the next possible combination choice but actually takes a decision on what shall be tried next.

Having data embedded into the program procedures, as Winograd did, makes it non-scalable for example in accommodation of larger grammars and knowledge bodies and unmaintainable in the long term as it becomes increasingly difficult to make changes (Weerasinghe 1994).

2.2 Kasper

Bob Kasper was involved in the Penman text generation project and in 1985 embarked on the mission of testing if the Nigel grammar, then the largest available generation grammar, was suitable for natural language parsing. Familiar with Functional Unification Grammar (FUG), a formalism developed by Kay and tested in parsing (Kay 1985) which caught in popularity in computational linguistics regardless of Kay's dissatisfaction with results, Kasper decided to re-represent the Nigel grammar in FUG.

Faced with unacceptable computational complexity, Kasper (1988) decided to create the phrase-structure of the sentences with hand-written rules which were mapped onto a parallel systemic tree structure. Kasper was the first one to parse with a context-free backbone (Kasper 1988). He first parsed each sentence with a Phrase Structure Gram-

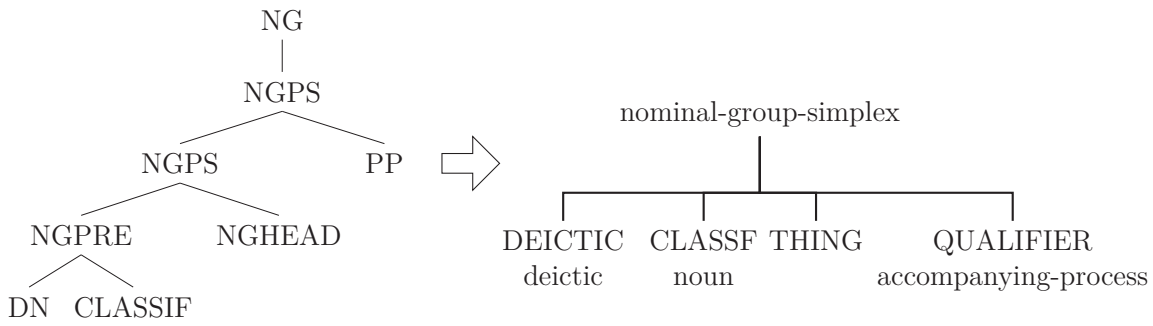


Fig. 2.1 Transformation from phrase structure into systemic constituency structure. Rule example from O'Donnell & Bateman (2005).

mar (PSG), typical to Chomsky's Generative Transformational Linguistics (Chomsky 1957). He created a set of rules for mapping the phrase structure (PS) into a parallel systemic tree like the one depicted in Figure 2.1. When all possible systemic trees were created they were further enriched using information from the Nigel grammar (Matthiessen 1985).

Once the context-free phrase-structure was created using a bottom-up chart parser it was further enriched from the FUG representation of the Nigel grammar. This approach to parsing is called *parsing with a context-free backbone* as phrase-structure is conveyed as simplistic skeletal analysis, fleshed out by the detail-rich systemic functional grammar.

Even though Kasper's system represents the first attempt to parse with a full Hallidayan grammar, its usability is lowered, as O'Donnell & Bateman (2005) point out, by the reliance on a hand built phrase structure grammar.

2.3 O'Donnell

Since 1990, Mick O'Donnell experimented with several parsers for small Systemic grammars, but found difficulty when scaling up to larger grammars. While working in the EDA project, funded by Fujitsu, he recompiled a subset of the Nigel grammar into two resources: the set of possible function bundles allowed by the grammar (along with the bundles of preselections) and a resource detailing which functions can follow a particular function (O'Donnell 1993, 1994).

This parser was operating without a syntactic backbone directly from a reasonable scale SFG. However when scaled to the whole Nigel grammar, the system became very slow because of the sheer size of the grammar and the inherent complexity introduced by multiple parallel classifications and functional combinations - a problem well described

by Bateman (2008). Then O'Donnell wrote his own grammar of Mood that was more suitable for the parsing process but less complex than the recompiled Nigel.

In 2001, while working in a Belgian company, O'Donnell came to the conclusion that dependency grammars are very efficient for parsing. Together with two colleagues, he developed a simplified systemic grammar where elements were connected through a single function hence avoiding (functional) conflation. Also the ordering of elements was specified relative to the head of phrase rather than relative to each other.

More recently, O'Donnell in the UAM Corpus Tool embedded a systemic chart parser (O'Donnell 2005) with a reduced systemic formalism. He classifies his parser as left to right and bottom up with a custom lexicon where verbs are attributed features similar to Hallidayan process types and nouns receive a unique semantic category like thing-noun, event-noun, location-noun etc.

Because of previously reported complexity problems with systemic grammars (O'Donnell 1993), the grammatical formalism is reduced to a singular functional layer of Mood-based syntactic structure (Subject, Predicate, Object etc.) ignoring the Transitivity (Actor/Goal, Sensor/Phenomenon etc.) and Textual (Theme/Rheme) analyses. O'Donnell removes conflation except for the verbal group system network. He also employs a slot based ordering, where elements do not relate to each other but rather to the group head, simplifying the number of rules and complexity.

O'Donnell (2005) does not provide a parser evaluation so its accuracy is still unknown. The lexicon that was created is claimed to deal with word semantic classes but is strongly syntactically based, assigning a single sense to nouns and verbs ignoring language polysemy. Moreover the framework within which the semantic classes have been generated is not very clear.

2.4 O'Donoghue

O'Donoghue proposes a corpus based approach to parsing using *Vertical Strips* (O'Donoghue 1991b). Strips are defined as a vertical path of nodes in a parse tree starting from the root down to the lexical items but not including those. He extracted a set of vertical strips from a corpus called the Prototype Grammar Corpus together with their frequencies and probability of occurrence. This approach differs from the traditional one with respect to the kind of generalisation it concerned: specifically, traditional approaches are oriented towards horizontal order while the vertical strip approach is concerned with vertical order in the parse tree.

To solve the order problem O'Donoghue uses a set of probabilistic collocation rules extracted from the same corpus indicating which strips can follow a particular strip. He also created a lexical resource indicating for each word which elements can expand it.

The parsing procedure is a simple lookup of words in the lexical resource selecting all possible elements that can expound by each word; and then selecting possible strips starting with the elements expounded by each word. Advancing from left to right, for each sentence word more strips compatible with the previously selected ones are selected within the collocation network constraints. The parser finds all possible combinations of strips composing parse trees representing possible output parses.

The corpus from which the vertical strips were extracted consists of 100,000 sentences and was generated with Fawcett's natural language generation system and was tested on the same corpus leaving unclear how the parser would behave on a real corpus. In 98% of cases the parser returns a set of trees (between 0 and 56) that included the correct one with an average of 6.6 trees per parse.

Actually, using a larger corpus could potentially lead to a combinatorial explosion in the step that looks for vertical strips. It would then decrease the accuracy of the parse because of the higher number of possible trees per parse.

2.5 Honnibal

Honnibal (2004; 2007) describes how the Penn Treebank can be converted into a SFG Treebank. Before assigning to parse tree nodes syntactic features such as mood, tense, voice and negation he first transforms the parse trees into a form that facilitates the feature extraction.

The scope of the SFG corpus was limited to a few Mood and Textual systems leaving aside Transitivity because of its inherently lexico-semantic nature. He briefly describes how he structurally deals with verb groups, complexes and ellipses as functional structures that are much flatter than those exhibited in the original Treebank. Then he describes how some of the MOOD systemic features (such as mood type, clause status, polarity, tense, voice etc.) are identified.

The drawback of this approach is that the Python script performing the transformation does not derive any grammar but rather implements directly these transformations as functions and so falls into the same class of problems as Winograd's SHRDLU. By doing so the program is non-scalable for accommodation of larger grammars and knowledge bodies as the complexity and the size of the program would grow significantly

as well. This is unmaintainable in the long term as making changes would becomes increasingly difficult.

2.6 Summary

In this chapter several relevant attempts to parse with Systemic Functional Grammars were presented. All of them needed to reduce the grammar size or use toy grammars in order to compute results in a reasonable amount of time. The main problem in using SFGs for parsing is that they are much more complex than post-Chomskian grammars: the grammar contains both paradigmatic and syntagmatic aspects of language, the system networks represent large numbers of simultaneous combinations of features, and multiple layers of function structure are conflated together. The issue of complexity is described in (Bateman 2008). Some parsing approaches use a syntactic backbone which is then fleshed out with SFG descriptions. Others use a reduced set or a single layer of SFG representation or an annotated corpus as the source of a probabilistic grammar. Regardless of approach, each limits the SFG in one way or another, balancing the depth of description with language coverage: that is either deep description but a domain specific language or shallow description but broad language coverage.

The current approach is aligned with the works of Honnibal, Kasper and O'Donnell with respect to using a backbone structure and enriching it with syntactic and semantic features. The current method employs rules for graph traversal in order to build a parallel backbone constituency tree and rules for graph matching to enrich it with systemic features.

Parsing with the Transitivity system is a task similar to Semantic Role Labelling and requires a large lexico-grammatical resource describing verb meanings in terms of their process type and participant roles, which were introduced in Sections 1.5 and 1.7.3. O'Donnell approaches this by providing possible process types directly for the verb by employing a self constructed lexicon where each word has syntactic and semantic features. The current approach uses the PTDB (Neale 2002), which provides entire process configurations (semantic frames) for each verb sense and the feature assignment is simultaneous, if matched, to the entire configuration of process and its participants. One major advantage, as compared to Honnibal's approach is that the grammar and the program are carefully disconnected so that the code is maintainable and scalable with respect to the size of the grammar.

The next chapter will introduce the structure of Systemic Functional Grammars and draw some parallels between the Sydney and Cardiff schools.

Chapter 3

Systemic functional theory of grammar

Any description of language requires a theory that provides the frame, scope and concepts necessary. Having a solid theory of grammar contributes to explaining what language is and how it works. It also frames how language ought to be analysed by either human or machines.

In his seminal paper Halliday (1961), Halliday addresses the ardent need of the time for a general theory of language and partially answers the proposal for a universal theory of language. He sets out what was known at the time as Scale and Category Grammar. In such a model *units* are set up to account for pieces of language which carry grammatical patterns. They are seen as arranged on a hierarchical *rank* scale of words, groups and clauses. These and other foundational concepts are covered in the first part of this chapter.

There are two variants of Systemic Functional Grammars: the *Sydney Grammar* started in 1961 by Halliday (2002) and the *Cardiff Grammar* proposed by Fawcett (2008), which is a simplification and an extension of the Sydney Grammar. To understand the underlying common motives and how they are different we shall start by looking at their theories of grammar. They also have quite different historical developments.

The Sydney and Cardiff grammars have been formalised to the point where they could be computationally applied to natural language generation. They have been implemented in the PENMAN (Mann 1983; Penman Project 1989a) and COMMUNAL (Fawcett 1990) projects respectively. While the Cardiff style grammar has been primarily used for for English, the Sydney style grammar has been implemented for over twelve languages in the KPML text generation system (Bateman 1996a,b, 1997). The major

component of PENMAN is a computer model of Halliday's SF grammar described by Mann & Matthiessen (1983), Matthiessen & Bateman (1991), Matthiessen (1995) and others. COMMUNAL is the computer implementation of the Cardiff grammar described by Fawcett (1988a), Fawcett (1993) and others.

This chapter first sets out the basic organisational dimensions for each of the theories and then discusses comparatively Halliday's (Halliday 2002) and Fawcett's (Fawcett 2000) versions of SFL.

3.1 A word on wording

Before going into deeper discussion, I first make terminological clarifications on the terms: *grammar*, *grammatics*, *syntax*, *semantics* and *lexico-grammar*. I start with definitions adopted in "mainstream" generative linguistics and then present how the same terms are discussed in systemic functional linguistics.

Radford, a generative linguist, in the "Minimalist Introduction to Syntax" (1997), starts with a description of grammar as a field of study, which, in his words, is traditionally subdivided into two inter-related areas of study: syntax and morphology.

Definition 3.1.1 (Morphology (Radford))**.** Morphology is the study of how words are formed out of smaller units (traditionally called morphemes) (Radford 1997: 1).

Definition 3.1.2 (Syntax (Radford))**.** Syntax is the study of how words can be combined together to form phrases and sentences. (Radford 1997: 1)

Halliday, in the context of the *rank* scale discussion (see Definition 3.2.1 and 3.2.2), refers to the traditional meaning of syntax as the *grammar above the word* and to morphology as *grammar below the word* (Halliday 2002: 51). Such a distinction, he states, has no theoretical status and is deemed as unnecessary. Halliday adopts this position to motivate the architecture of grammar he was developing, inherited from his precursor, Firth. As he puts it:

> . . . the distinction between morphology and syntax is no longer useful or convenient in descriptive linguistics. (Firth 1957: 14)

Radford adds that, traditionally, grammar is not only concerned with the principles governing formation of words, phrases and sentences but also with principles governing their interpretation. Therefore *structural aspects of meaning* are said to be also a part of grammar.

Definition 3.1.3 (Grammar (Radford))**.** [Grammar is] the study of the principles which govern the formation and interpretation of words, phrases and sentences. (Radford 1997: 1)

Interestingly Definition 3.1.3 makes no mention at all to the lexicon. This is because the formal grammars focus primarily on unit classes and how they are accommodated in various structures and so in early formal linguistics the lexicon was often disconnected from the grammar. Systemic grammar, on the other hand, along with formal descriptions of grammatical categories and structures, includes the lexicon as part of grammar to form a *lexico-grammar* as has been done in Lexical Functional Grammar (LFG), Head Phrase Structure Grammar (HPSG), Combinatory Categorial Grammar (CCG) and others.

Another important aspect to notice is that the grammar may be defined as a field of study rather than a set of rules. The divergence in perspective on the subject led Halliday, since his early papers, to emphasise the difference between a study of a phenomenon with the phenomenon itself. By analogy to language as phenomenon and linguistics as the study of the phenomenon, discussed in (Halliday 1997), Halliday adopts the same wording for *grammar* as phenomenon and *grammatics* as the study of grammar; the same distinction holds for *syntax* and *syntactics* in semiotics.

Definition 3.1.4 (Grammatics (Halliday))**.** Grammatics is a theory for explaining grammar (Halliday 2002: 369)

Moravcsik, another generative linguist, stresses the same distinction in her "An introduction to syntax" (Moravcsik 2006), and presents two ways in which the word *syntax* is used in the literature: (a) in reference to a particular aspect of grammatical structure and (b) in reference to a sub-field of descriptive linguistics that describes this aspect of grammar. In her words:

> . . . syntax describes the selection and order of words that make well-formed sentences and it does so in as general a manner as possible so as to bring out similarities among different sentences of the same language and different languages and render them explainable. . . . syntax rules also need to account for the relationship between strings of word meanings and the entire sentence meaning, on one hand, and relationships between strings of word forms and the entire sentential phonetic form, on the other hand. (Moravcsik 2006: 25)

In her definition of grammar she includes the lexicon and semantics which is a somewhat more explicit statement than Radford's *interpretation*. She is also getting, in Definition 3.1.5, somewhat closer to what grammar stands for in SFL - Definition 3.1.6.

Definition 3.1.5 (Grammar (Moravcsik))**.** ... maximally general analytic descriptions, provided by descriptive linguistics, [are] called grammars. A grammar has five components: phonology (or, depending on the medium, its correspondent e.g. morphology), lexicon, syntax and semantics (Moravcsik 2006: 24–25).

Definition 3.1.6 (Grammar (Halliday))**.** To Halliday, lexico-grammar, or for short, simply grammar, is a part of language and it means the wording system – the "lexical-grammatical stratum of natural language as traditionally understood, comprising its syntax, vocabulary together with any morphology the language may display [...]" (Halliday 2002: 369).

The last point I want to mention is the approach to semantics. Formal grammars aim to account for the realisation variations, that is formation of words, phrases and sentences along with their arrangements, and mention of semantics is often restricted to what may be termed the *formal aspect of meaning*.

By contrast, a systemic grammar is a functional grammar, which means (among other things) that it is considered semantically motivated, i.e. "natural". So the fundamental distinction between formal and functional grammars is the semantic basis for explanations of structure.

Also, in SFL, the meaning is approached from a semiotic perspective, placing the linguistic semantics in perspective with the linguistic expression and the real world situation. In this respect, Lemke (1993) offers a well formulated theoretical foundation that "human communities are eco-social systems that persist in time through ongoing exchange with their environment; and the same holds true for any of their sub-subsystems [...]" including language. The social practices constituting such systems are both material and semiotic, with a constant dynamic interplay between the two (Halliday 2002: 387).

To Halliday, the term *semiotic* accounts for an orientation towards meaning rather than sign. In other words, the interaction is between *the practice of doing and the practice of meaning*. As the two sets of practices are strongly coupled, Lemke points out that there is a high degree of redundancy in the *material–semiotic interplay*. This resonates perfectly with Firth's idea of *mutual expectancy* between the text and the situation. The idea of interplay is incorporated in SFL as *language stratification*

(Taverniers 2011) and is graphically represented in Figure 3.1. The axis stratification is a useful dimension for relating formal grammars and the systemic functional grammars.

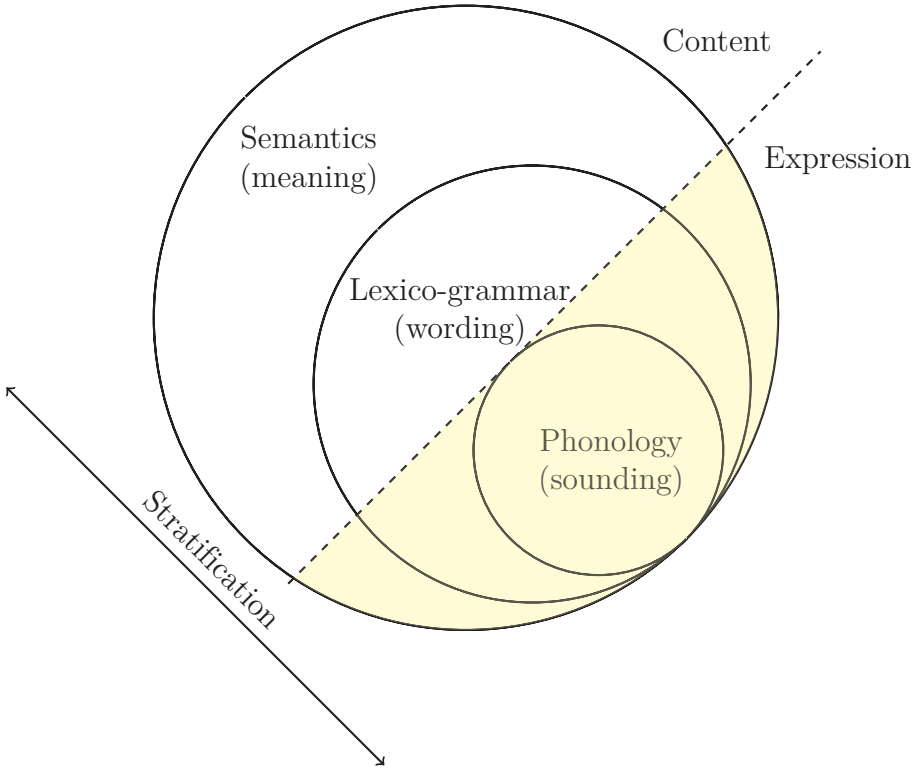


Fig. 3.1 The levels of abstraction along the realisation axis

The SFL model defines language as a resource organised into three strata: phonology (sounding), lexico-grammar (wording) and semantics (meaning). Each is defined according to its level of abstraction on the realisation axis. The realisation axis is divided into two planes: the expression and the content planes. Although debate about the precise division continues, for current purposes it is sufficient to see the first stratum (i.e. phonology) belongs to the *expression plane* and the last two (lexico-grammar and semantics) belong to the *content plane*. In this context, the formal grammar could be localised mostly within the expression plane, including the phonology/morphology, syntax, lexicon while formal semantics belongs mostly in the content plane.

3.2 Sydney theory of grammar

I start introducing the terms of SFL theory with the Sydney grammar as this is in accordance with the historical development originating with Halliday (2002) defining

the categories of the theory of grammar. He proposes four fundamental categories: *unit*, *structure*, *class* and *system*. Each of these categories is logically derivable from and related to the other ones in a way that they mutually define each other. These categories relate to each other on three scales of abstraction: *rank*, *exponence*, *delicacy*. Halliday also uses three scale types: *hierarchy*, *taxonomy* and *cline*.

Definition 3.2.1 (Hierarchy)**.** Hierarchy [is] a system of terms related along a single dimension which involves some sort of logical precedence. (Halliday 2002: 42).

Definition 3.2.2 (Taxonomy)**.** Taxonomy [is] a type of hierarchy with two characteristics:

1. the relation between terms and the immediately following and preceding one is constant

2. the degree is significant and is defined by the place in the order of a term relative to following and preceding terms. (Halliday 2002: 42)

Definition 3.2.3 (Cline)**.** Cline [is] a hierarchy that instead of being made of a number of discrete terms, is a continuum carrying potentially infinite gradations. (Halliday 2002: 42).

The concept of cline may not necessarily originate in SFL but it is used quite extensively in the SFL literature. Next I define and introduce each category of *grammatics* and the related concepts that constitute the theoretical foundation for the Sydney Theory of grammar.

3.2.1 Unit

Language is a patterned activity of meaningful organisation. The patterned organisation of substance (*graphic* or *phonic*) along a linear progression is called *syntagmatic order* (or simply *order*).

Definition 3.2.4 (Unit)**.** The unit is a grammatical category that accounts for the stretches that carry grammatical patterns (Halliday 2002: 42). The units carry a fundamental *class* distinction and should be fully identifiable in description (Halliday 2002: 45).

Generalisation 3.2.1 (Constituency principles)**.** The five principles of constituency in lexico-grammar are:

1. There is a scale or rank in the grammar of every language. That of English (typical of many) can be represented as: clause, group/phrase, word, morpheme.

2. Each unit consists of *one or more* units of rank next below.

3. Units of every rank may form complexes.

4. There is potential for rank shift, whereby a unit of one rank my be down-ranked to function in a structure of a unit of its own rank or of a ranks below.

5. Under certain circumstances it is possible for one unit to be enclosed within another, not as a constituent but simply in such a way as to split the other into two discrete parts (Halliday & Matthiessen 2013b: 9–10).

For example, down-ranking (Point 4) can be observed in nominal groups that incorporate a relative clause functioning as qualifier. In example 10 *that I got for Christmas* is a relative clause specifying which books are being referred to. The unit split (Point 5) can be encountered in the instances of Wh-interrogative clauses containing a preposition at the end which in fact belongs to the Wh-group. In Example 11 the prepositional phrase *Who . . . about* is gapped and has an inverted order of constituents.

(10) I haven't read any books *that I got for Christmas*.

(11) *Who* are you talking *about*?

(12) I am talking about George.

One of the principal relations between units, in SFL, is that of consistency for which we say that a unit *consists of* other units. The scale on which the units are ranged is the *rank scale*. The rank scale is a levelling system of units supporting unit composition regulating how units are organised at different granularity levels from clause, to groups/phrases to words. The units of a higher rank scale consist of units of the rank next below. Table 3.1 presents a schematic representation of the rank scale and its derived complexes.

Generalisation 3.2.2 (Rank scale constraints)**.** The rank relations are constrained as follows:

1. in general elements of clauses are filled by groups, the elements of groups by words and the elements of words by morphemes,

2. downward *rankshift* is allowed, i.e. the transfer of a given unit to a lower rank,

Rank scale ↓	**Complexing**
	Clause complex
Clause	
	Group(/phrase) complex
Group(/phrase)	
	Word complex
Word	
	(Morpheme complex)
(Morpheme)	

Table 3.1 Rank scale of the (English) lexico-grammatical constituency

3. upward rankshift is not allowed,

4. only whole units can enter into higher units (Halliday 2002: 44).

Generalisation 3.2.2 taken as a whole means that a unit can include, in what it consists of, a unit of rank higher than or equal to itself but not a unit of rank more than one degree lower than itself; and not in any case a part of any unit (Halliday 2002: 42).

Following the rank scale constraints above, the concept of *embedding* can be defined as follows.

Definition 3.2.5 (Embedding)**.** Embedding is the mechanism whereby a clause or phrase comes to function as a constituent within the structure of a group, which is itself a constituent of a clause (Halliday & Matthiessen 2013b: 242).

Halliday states that embedding is a phenomena that occurs only when a phrase/group or clause functions within the structure of another group or clause (Halliday 1994: 242). The above definition of embedding only permits clauses and groups to function as elements of other groups which means that a clause cannot fill the elements of another clause (Fawcett 2000: 237). The latter phenomena is described in terms of *clause complex* where *taxis relations* (Definition 3.2.14) come into play.

3.2.2 Structure

Definition 3.2.6 (Structure)**.** The structure (of a given unit) is the arrangement of *elements* that take places distinguished by the order relationship (Halliday 2002: 46).

Definition 3.2.7 (Element)**.** Element is defined by the place stated as absolute or relative position in sequence and with reference to the unit next below (Halliday 2002: 47).

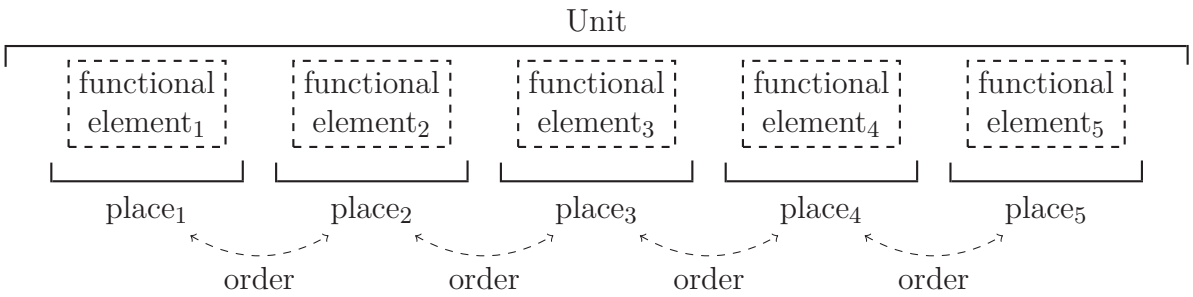


Fig. 3.2 The graphic representation of (unit) structure

We say that a unit is composed of elements located in places and that its internal structure is accounted for by elements in terms of functions and places taken by the lower (constituting) units or lexical items. The graphic representation of the unit structure is depicted in Figure 3.2. The unit structure is referred to in linguistic terminology as *constituency* (whose principles are enumerated in Generalisation 3.2.1). In the unit structure, the elements resemble an array of empty slots that are *filled* by other units or lexical items.

For example to account for the English clause structure four elements are needed: *subject*, *predicator*, *complement* and *adjunct*. They yield the distinct symbols, S, P, C, A as the inventory of elements. They then can be arranged in various orders falling in particular places, say SPC, SAPA, ASPCC etc. The places of elements are important with respect to the structure of the whole unit but also with respect to the relative ordering between these elements. In English, for example, S fronts P in non interrogative clauses, C is fronted by P unless the clause realises a Wh-interrogative whereas A is quite free and can occur anywhere in the unit structure.

3.2.3 Class

To each place in the structure there corresponds one occurrence of the unit next below. This means that there will be a certain grouping of members identified by the functional element they take in the structure. The patterning of such groupings leads to the emergence of *classes* of units.

In the clause structure example, elements in the unit are occupied by units of lower rank and of a particular class. The relation between the element and the class is

mutually determined. In each of these elements a lower rank unit is placed, whose class is constrained to a few possibilities accepted by the element. For instance, the S element can be filled by a *noun*, *nominal group*, *pronoun* or another *clause* that will be a down-ranking situation (as defined above). No other unit types are allowed.

Definition 3.2.8 (Class)**.** The class is that grouping of members of a given unit which is defined by the functional element in the structure of the unit next above (Halliday 2002: 49).

Halliday defines class (Definition 3.2.8) as likelihood of the same rank *phenomena* to occur together in the structure. He adopts a top-down approach stating that the class of a unit is determined by the *function* (Definition 3.2.13) it plays in the unit above and not by its internal structure of elements. In SFG the structure of each class is well accounted for in terms of syntactic variation recognising six unit classes: *clause*, *nominal*, *verbal*, *adverbial* and *conjunction* groups and *prepositional phrase*. The Sydney unit structure model is briefly summarised in Appendix A.

Halliday identifies the concept of *grammatical metaphor* defined in Definition 3.2.9 and it plays an important role in the Sydney model of grammar as a whole for accounting for the versatility of natural language. It is typically found in adult language where one type of unit may be expressed with the grammar of another.

Definition 3.2.9 (Grammatical metaphor)**.** Grammatical metaphor involves the substitution of one grammatical class or structure for another, often resulting in a more compressed expression.

(13) The fifth day saw them at the summit.

(14) On the fifth day they arrived at the summit.

(15) Guarantee limited to refund of purchase price of goods.

(16) We guarantee only to refund the price for which the goods were purchased.

Examples 13 and 15 are instances of grammatical metaphor whereas Examples 14 and 16 are their non metaphorical counterparts. In Examples 13 and 14 the temporal circumstance of an action expressed through a prepositional phrase becomes the nominal agent of a perception process. Children's speech is largely free of such kind of metaphors; in fact this is the main distinctions between the two (Halliday & Matthiessen 2013b).

3.2.4 System

As described above, structure is a syntagmatic ordering in language capturing regularities and patterns which can be paraphrased as *what goes together with what*. However in SFG most of the descriptive work is carried not syntagmatically but paradigmatically via *system networks* (Definition 3.2.10) describing *what could go instead of what* (Halliday & Matthiessen 2013b: 22). The paradigmatic-syntagmatic axes date back to the works of Saussure (1959 [1915]) and both are important for completing a linguistic description. Here lies one of the main differences between SFL and other approaches: SFL takes the paradigmatic path whereas many others take the syntagmatic path to language, representing it as an inventory of structures. The structure of course is a part of language description but it is only a syntagmatic manifestation of the systemic choices and SFL holds that one needs to account for both (Halliday & Matthiessen 2013b: 23).

Definition 3.2.10 (System)**.** A system is a mutually exclusive set of terms referring to meaning potentials in language and are mutually defining. A system is considered self-contained, closed and complete and has the following characteristics:

1. the number of terms is finite,
2. each term is exclusive of all others,
3. if a new term were added to the system it would change the meaning of all the other terms (Halliday 2002: 41).

The concept of a system as presented in Definition 3.2.10 has its roots in the works of Saussure (1959 [1915]) and Hjelmslev (1953). Halliday generalises the concept and cements it into the SFL architecture of grammar.

Going back to the notion of class previously defined as a grouping of items identified by functions in the structure, it must be stressed that class is not a list of formal items but an abstraction from them. By an increase in *delicacy*, a class is then broken into secondary classes.

Definition 3.2.11 (Delicacy)**.** Delicacy is the scale of differentiation or depth of detail whose limit at one end is the primary degree of categories of structure and class and on the other end, theoretically, is the point beyond which no further grammatical relations obtain (Halliday 2002: 58).

The terms forming system networks refer to abstract categories. We say that a category is refined into more subtle distinctions or subcategories which form a system as

defined above. Subsequently those distinctions of subcategories can be further refined in other systems. This relationship between two systems is one of delicacy where the second one is more delicate than the first and together they form a *system network*.

The graphical notations introduced by Halliday & Matthiessen (2013b) are useful in reading and writing system networks in this thesis. Figure 3.3 is a system network with a simple *entry condition*, a *system network grouping* that shares the same entry condition is show in in Figure 3.4: a system network with a *disjunctive* and *conjunctive* entry conditions is show in Figures 3.5 and 3.6.

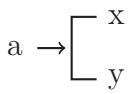


Fig. 3.3 A system with a single entry condition: if a then either x or y

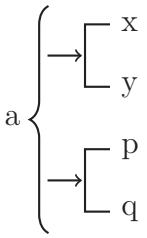


Fig. 3.4 Two systems grouped under the same entry condition: if a then both either x or y and, independently, either p or q

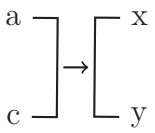


Fig. 3.5 A system network with a disjunctive entry condition: if either a or c (or both), then either x or y

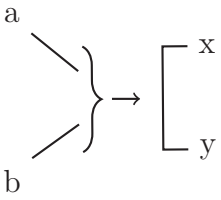


Fig. 3.6 A system with a conjunctive entry condition: if both a and b then, either x or y

It is worth noting that when a piece of language is analysed, it can be approached at various levels of delicacy. We say that delicacy is variable in description, and

one may choose to provide coarse-grained analysis without going beyond primary grammatical categories or one can dive into fine grained categorial distinctions, still being comprehensive with regards to the rank, *exponence* and grammatical categories.

Definition 3.2.12 (Exponence)**.** Exponence is the scale which relates the categories of theory with a high degree of abstraction to formal items on a low degree of abstraction. Each exponent can be linked directly to the formal item or by taking successive steps on the exponence scale and changing rank where necessary Halliday (2002: 57).

3.2.5 Functions and metafunction

Above, when talking about structure, I described a unit as being composed of elements accounted for in terms of *functions* and places taken by the lower (constituting) units or lexical items.

Definition 3.2.13 (Function)**.** The functional categories or functions provide an interpretation of grammatical structure in terms of the overall meaning potential of the language (Halliday & Matthiessen 2013b: 76).

Most constituents of clause structure, however, have more than one function, which is called a *conflation of elements*. For example in the sentence "Bill gave Dolly a rose", "Bill" is the Actor doing the act of giving but also the Subject of the sentence. So we say that Actor and Subject functions are conflated in the constituent "Bill". This is where the concept of *metafunction* or *strand of meaning* comes most prominently into the picture. The Subject function is said to belong to the *interpersonal metafunction*, while the Actor function belongs to the *experiential metafunction*.

Metafunction	**Definition(kind of meaning)**	**Corresponding status in clause**	**Favored type of structure**
experiential	construing a model of experience	clause as representation	segmental (based on constituency)
interpresonal	enacting social relationship	clause as exchange	prosodic
textual	creating relevance to context	clause as message	culminative
logical	constructing logical relations	complexes (taxis & logico-semantic type)	iterative

Table 3.2 Metafunctions and their reflexes in the grammar

Halliday identifies three fundamental dimensions of structure in the clause: *experiential*, *interpersonal* and *textual*. He refers to them as *metafunctions* and they account for the functions that language units take on in communication. Table 3.2 presents the metafunctions and their reflexes in grammar as proposed by Halliday & Matthiessen (2013b: 85).

Across the rank scale, with respect to structure and metafunctions, Halliday formulates the general principle of *exhaustiveness* (Generalisation 3.2.3) saying that clause constituents have at least one and may have multiple functions in different strands of meaning; however this does not mean that it must have a function in all of them. For example interpersonal Adjuncts such as "perhaps" or textual Adjuncts such as "however" play no role in the clause as representation.

Generalisation 3.2.3 (Exhaustiveness principle)**.** Everything in the wording has some function at every rank but not everything has a function in every dimension of structure (Halliday 2002; Halliday & Matthiessen 2013b).

This principle implicitly relates to the property of language meaning that there is nothing meaningless and thus every piece of language must be explained and accounted for in the lexico-grammar. Also this principle implies that each metafunction has its own structure or that text is analysed through a multi-structural approach.

At the very top of the rank scale, clauses may form complex structures. Halliday employs systematically the concepts of *taxis* and *logico-semantic relations* to describe inter-clausal relations.

Definition 3.2.14 (Taxis)**.** *Taxis* represents the degree of inter-dependency between units systematically arranged in a linear sequence where *parataxis* means equal and *hypotaxis* means unequal status of units forming a *nexus* or a *unit complex* together (Halliday & Matthiessen 2013a: 440).

The concept of taxis is very useful for describing unit relations not only at the group and clause ranks but all the way down to the smallest linguistic units such as morphemes and phonemes. I will also refer to it when describing the Cardiff theory of grammar and also briefly in the discussion of dependency relations in Section 5.6.

The elements of logical paratactic structure are notated left to right (1,2,...) while those of hypotactic structure with Greek letters $(\ldots,\beta,\alpha)$ in the same order or right to left depending on the position of the dominant element. The tactic relations can be of two types: that of expansion which relates phenomena of the same order of experience and that of projection which relates phenomena of one order of experience

(usually saying or thinking) to an order of experience higher (what is said or thought). Projection can be of two types: *idea* (' single quote) and *locution* (" double quotes).

Expansion is further divided into three subcategories: *elaborating* (= equals), *extending* (+ is added to) and *enhancing* (× is multiplied by). Elaboration is a way to restate the same thing, exemplify, comment or specify in detail. Extending is the way to add new elements to give an exception or offer an alternative. And finally enhancing is the way to qualify something with some circumstantial feature of time, place, cause, intensity or condition.

3.2.6 Lexis and lexico-grammar

In SFL the terms *word* and *lexical item* are not really synonymous. They are related but they refer to different things. The term *word* is reserved (in early Halliday) for the grammatical unit of the lowest rank whose *exponents* are lexical items.

Definition 3.2.15 (Lexical Item)**.** In English, a lexical item may be a *morpheme*, *word* (in traditional sense) or *group (of words)* and it is assigned to no rank (Halliday 2002: 60).

Examples of lexical items are the following: "'s" (the possessive morpheme), "house", "walk", "on" (words in traditional sense) and "in front of", "according to", "ask around", "add up to", "break down" (multi-word prepositions and phrasal verbs).

Although some theories treat grammar and lexis as discrete phenomena, Halliday brings them together as opposite poles of the same cline. He refers to this merge as *lexico-grammar* where they are paradigmatically related through the delicacy relation. Hasan (2014) explores the feasibility of what it would mean to turn the "whole linguistic form into grammar". This then implies an assumption that lexis is not form and that its relation to semantics is unique, which in turn challenges the problems of polysemy.

3.3 Cardiff theory of grammar

As presented in the introduction and explained by Bateman (2008), the accounts along the syntagmatic axis had received little attention so far in the Sydney grammar leaving unresolved how to best represent the structure of language at the level of form with the level of detail needed for computational work. This section presents the theory of systemic functional grammar as conceived by Robin Fawcett at the University of Cardiff. His book "A theory of syntax for Systemic Functional Linguistics" (Fawcett 2000)

presented a proposal for a *unified syntactic model* for SFL that contrasts with several aspects of Hallidayan grammar but shares the same set of fundamental assumptions about language; it is an extension and a simplification in a way.

Fawcett questions the status of multiple structures in the theory and whether they can finally be integrated into a simpler sole representation. A big difference to Hallidayan theory is renouncing the concept of the rank scale and this has an impact on the whole theory. Another is the bottom-up approach to unit definition as opposed to the top-down one advocated by Halliday. It also appears that the bottom-up approach is more favourable for the parsing task while the top-down suits perfectly the language generation task. These two and a few other differences have important implications for the overall theory of grammar and consequently for the grammar itself. As a consequence, to accommodate the lack of a rank-scale, Fawcett adapts the definitions of the fundamental concepts and changes his choice of words (for example "class" and "unit" turn into "class of unit" treated as one concept rather than two distinct ones).

Fawcett (2000) proposes three fundamental categories in the theory of grammar: *class of unit*, *element of structure* and *item*. Constituency is a relation accounting for the prominent compositional dimension of language. However a unit does not function directly as a constituent of another unit but via a specialised relation which Fawcett breaks down into three sub-relations: *componence*, *filling* and *exponence*. Informally it is said that a unit is composed of elements which are either filled by another unit or expounded by an item. He also proposes three secondary relations of *coordination*, *embedding* and *reiteration* to account for a more complete range of syntactic phenomena.

3.3.1 Class of units

Fawcett's theory of language assumes a model with two levels of *meaning* and *form* corresponding to *semantic units* and *syntactic units* which are mutually determined (which is the case for any sign in a Saussurean approach to language).

Definition 3.3.1 (Class of Unit)**.** The class of unit [...] expresses a specific array of meanings that are associated with each one of the major classes of entity in semantics [...and] are to be identified by the elements of their internal structure (Fawcett 2000: 195).

For English Fawcett proposes four main kinds of semantic entities: situations, things, qualities (of both situations and things) and quantities. Each of these semantic units corresponds to five major classes of syntactic units: *clause*, *nominal group*, *prepositional*

group, *quality group* and *quantity group*. In addition he recognises two more minor classes: the *genitive cluster* and the *proper name cluster* (Fawcett 2000: 193–194).

Fawcett's classification is based on the idea that the syntactic and semantic units are mutually determined and supported by grammatical patterns. However those patterns lie beyond the syntactic variations of the grammar and so blend into lexical semantics.

In the Sydney theory the class is determined by the function it plays in the unit above. By contrast, in Cardiff theory, the class of unit is determined based on its internal structure i.e. by its *elements of structure* (and not by the function it plays in the parent unit).

3.3.2 Element of structure

The terms *element* and *structure* have roughly the same meaning as defined in the Sydney theory of grammar (defined in Section 3.2) but with two additional stipulations presented below.

Definition 3.3.2 (Element of Structure)**.** Elements of structure are immediate components of classes of units and are defined in terms of their *function* in expressing meaning and not in terms of their absolute or relative position in the unit. (Fawcett 2000: 213–214).

Following the definition above two important properties of elements are formulated as follows.

Generalisation 3.3.1 (Element functional uniqueness)**.** Every element in a given class of unit serves a function in that unit different from the function of the sibling elements (Fawcett 2000: 214).

Even if for example, different types of *modifiers* in English nominal group seem to have very slight differences in functions, they are still there.

Generalisation 3.3.2 (Element descriptive uniqueness)**.** Every element in every class of unit will be different from every element in every other class of unit (Fawcett 2000: 214).

Thus the terms of modifier and head shall not be used for more than one class of unit. In English grammar the head and modifier are used for nominal group only. And in other groups the elements of structure may seem similar to modifier and head, they still receive different names such as *apex* and *temperer* in the quality group. From the

Sydney school perspective, this may be seen as a loss of syntagmatic generalisation but the extent to which it applies is limited to few unit classes.

The elements (of structure) are functional slots which define the internal structure of a unit but still they are *located* in *places*. One more category that intervenes between element and unit is the concept of *place* which become essential for the generative versions of the grammar.

There are two ways to approach place definition. The first is to treat places as positions of elements relative to each other (usually previous). This leads to the need for an *anchor* or a *pivotal element* which may not always be present/realised.

The second is to treat places as a linear sequence of locations at which elements may be located, identified by numbers "place 1", "place 2" etc. This place assignment approach is absolute within the unit structure and makes elements independent of each other. This approach was used in the COMMUNAL (Fawcett 1990) project and the relative order of elements is employed in the PENMAN (Mann 1983) project.

3.3.3 Item

Definition 3.3.3 (Item)**.** The item is a lexical manifestation of meaning outside syntax corresponding to both words (in the traditional sense), morphemes and either intonation or punctuation (depending whether the text is spoken or written). (Fawcett 2000: 226–232).

Items correspond to the leaves of syntactic trees and constitute the raw *phonetic* or *graphic* manifestation of language. The collection of items of a language is generally referred to as *lexis*.

Since items and units are of different natures, the relationship between an element and a (lexical) item must be different from that to a unit. We say that items *expound* elements and not that they *fill* elements as units do.

Definition 3.3.4 (Exponence (restricted))**.** Exponence is the relation by which an element of structure is realised by a (lexical) item (Fawcett 2000: 254).

Whereas in the Sydney model exponence (Definition 3.2.12) is a relation that links abstract grammatical category to the data, in the Cardiff model it has a restricted meaning referring to a relation between items and elements only.

3.3.4 Componence and obscured dependency

Definition 3.3.5 (Componence)**.** Componence is the part-whole relationship between a unit and the elements it is composed of (Fawcett 2000: 244).

Note that componence is not a relationship between a unit and its places; the latter, as discussed in Section 3.3.2, simply relates locationally elements of a unit to each other.

Componence intuitively implies a part-whole constituency relationship between the unit and its elements. But this is not the only view. Another perspective is the concept of *dependency* (which I will address in Chapter 5) or strictly speaking the *sister* or *sibling dependency* (not parent-child). It is suitable for describing relations between elements of structure within a unit.

(17) the man with a stick

For example the componence of the nominal group in Example 17, according to the Cardiff grammar, is (*dd h q*), which are symbols for (*determiner head qualifier*). The same can be expressed in terms of sibling dependency relations as depicted in Figure 3.7. The relations from *stick* to *with a* are not depicted because they belong in the description of the prepositional group *with a stick*.

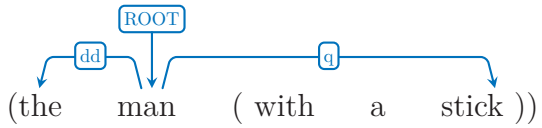


Fig. 3.7 Sibling dependency representation for “the man with a stick”

In both SFL theories, *sister dependency* relations are considered a by-product or second-order concept that can be deduced from the constituency structure and so is unnecessary in the grammar model. I will come back to this point because the current work relies on this dual view on elements of structure and relation to the whole unit.

The (supposed) dependency relation between a modifier and the head in the framework of SFG is not a direct one. The simple assumption is that the modifier modifies the head. Here, however, the general function of the modifiers is to contribute to the meaning of the whole unit which is anchored by the head.

In the nominal group from Example 17, the *determiner* and *qualifier* are modifiers that contribute to the description of the referent stated by the *head*. So the head realises one type of meaning that relates the *referent* while the modifier realises another one. Both of them describe the referent via different kinds of meaning; therefore,

according to Fawcett, they are related indirectly to each other because the modifier does not modify the head but the referent denoted by the head. From this point of view, whether the element is dependent on a sibling element such as the head or on the parent unit is beside the point because in syntax we can observe its realisation in system networks (Fawcett 2000: 216–217). Next I move towards one last concept in Cardiff model, *filling*, which is a relation between the elements of structure and the units below.

3.3.5 Filling and the role of probabilities

Definition 3.3.6 (Filling)**.** Filling is the probabilistic relationship between an element and the unit lower in the tree that operates at that element (Fawcett 2000: 238, 251).

Fawcett replaces the rank scale with the concept of *filling probabilities*. The probabilistic predictions are made in terms of a filling relationship between a unit and an element of structure in a higher unit in the tree rather than being a relationship between units of different ranks. This moves the focus away from the fact that a unit is for example a group, and towards what group class it is.

In this line of thought, some elements of a clause are frequently filled by groups, but some other elements are rather *expounded* by items. The frequency varies greatly and is an important factor for predicting or recognising either the unit class or the element type in the filling relationship.

Filling may add a *single unit* to the element of structure or it can introduce *multiple coordinated units*. Coordination (Example 18) is usually marked by an overt *Linker* such as *and*, *or*, *but*, etc. and sometimes is enforced by another linker that introduces the first unit such as *both*.

Definition 3.3.7 (Coordination)**.** Coordination is the relation between units that fill the same element of structure (Fawcett 2000: 263).

(18) she is (friendly, nice and polite)

(19) she is (very very) nice!

Coordination is thought of by Fawcett as being not between syntactic units but between mental referents. It always introduces more than one unit which are syntactically and semantically similar (somehow) resulting in a *syntactic parallelism* which often leads to *ellipsis*.

Definition 3.3.8 (Reiteration)**.** Reiteration is the relation between successive occurrences of the same item expounding the same element of structure (Fawcett 2000: 271).

Reiteration (see Example 19) is often used to create the effect of emphasis. Like coordination, reiteration is a relation between entities that fill the same element of the unit structure, which I discuss further in Section 3.4.6 because it appears problematic.

Filling also makes possible the embedding relation which Fawcett treats as a general principle in contrast to the more specific Definition 3.2.5 from the Sydney model.

Definition 3.3.9 (Embedding (generic))**.** Embedding is the relation that occurs when a unit fills (directly or indirectly) an element of the same class of units; that is when a unit of the same class occurs (immediately) above it in the tree structure (Fawcett 2000: 264).

(20) (To become an opera singer) takes years of training.

(21) The girl (whom he is talking to) is an opera singer.

In Example 20 we can see an occurrence of direct embedding where a non-finite clause acts as the subject of another clause. In Example 21 the embedding is indirect as the relative clause is part of the nominal group which functions as the subject in the parent clause. In both cases we say that a lower clause is embedded (directly or indirectly) in a higher or parent clause. I will further discuss this in the context of the rank-scale concept in Section 3.4.1.

A situation converse to reiteration and coordination where an element is filled by more than one unit is known as *conflation*, where a unit can take more than one function within another.

Definition 3.3.10 (Conflation)**.** Conflation is the relationship between two elements that are filled by the same unit having the meaning of "immediately after and fused with" and function as one element (Fawcett 2000: 249–250).

Conflation is useful in expressing the multi-faceted nature of language when for example syntactic and semantic elements/functions are realised by the same unit. For example the Subject "the girl whom he is talking to" is also a *Carrier* while the Complement "an opera singer" is also an *Attribute*. Also conflation relations frequently occur between syntactic elements as well such as for example the *Main Verb* and *Operator* or *Operator* and *Auxiliary Verb*.

The Cardiff Grammar in case of both coordination and embedding relations deals without *hypotaxis* and *parataxis* relations described in the Sydney Grammar.

Note also that filling and componence are two complementary relations that occur in the syntactic tree down to the level when the analysis moves out of abstract syntactic categories to more concrete categories of items via the relationship of exponence.

3.4 Critical discussion of both theories: consequences and decisions for parsing

The two sections above cover the definitions and fundamental concepts from each of the two systemic functional theories of grammar. The work in this thesis uses a mix of concepts from both theories and this section discusses in detail what is being adopted and why a pragmatic reconciliation is attempted for the purposes of achieving a parsing system rather than a theoretical debate. Next I draw parallels and highlight correspondences between the Sydney and Cardiff theories of grammar and where they differ I present the position on the matter adopted in this thesis.

3.4.1 Relaxing the rank scale

The *rank scale* proposed by Halliday (2002) became over time a controversial concept in SFL literature. The discussion whether it is suitable for grammatical description or not still continues. The historic development of this debate is documented in some detail in Fawcett (2000: 309–338).

In this section I present a few cases highlighting when the rank scale as defined by Sydney is too rigid. As a consequence for the purpose of this thesis I will drop the *rank scale constraints* as enunciated in Generalisation 3.2.2. Also the *rankshift* operation, exceptionally employed to accommodate special cases, is overridden by a broad definition of the *embedding* operation (Definition 3.3.9) treated as naturally occurring phenomena in language at all ranks. I do not entirely dismiss the concept of the rank scale as proposed by the Cardiff school as I still find it useful in classification of units.

(22) some very small wooden ones

Consider the nominal group 22. Here the modifying element, the Epithet “very small”, is not a single word but a group (Halliday & Matthiessen 2013b: 390–396). However, the rank scale constraints mentioned above state that the group elements need

to be filled by words, or, therefore, word complexes. To account for this phenomena, Halliday introduces a *substructure* of modifiers and heads leading to a logical structure analysis as the one in Table 3.3. In such a structure the modifier is further broken down into a Sub-Head and Sub-Modifiers.

some	*very*	*small*	*wooden*	*ones*
Modifier				Head
δ	γ		β	α
	Sub-Modifier	Sub-Head		
	$\gamma\beta$	$\gamma\alpha$		

Table 3.3 Sydney logical structure analysis of Example 22

The corresponding experiential structure analysis is provided in the Table 3.4 Halliday & Matthiessen (2013b: 391). Accordingly, the Epithet "very small" is composed of a quality adjective "small" and an enhancer modifier "very".

some	*very*	*small*	*wooden*	ones
Deictic	Epithet		Classifier	Thing
	Sub-Modifier	Sub-Head		

Table 3.4 Sydney experiential analysis of Example 22

As you can see, the elements are further broken down into sub-elements composing in a way a structure of their own. This is possible because of the poly-structural and multi functional approach to clause analysis which in this case leads to a complex structure of a nominal group. This kind of intricate cases can be simplified by allowing elements of a group to be filled by other groups or expounded by words. This way, instead of having a sub-modifier construction one simply considers that the Epithet is filled by an adjectival or nominal group which in turn has its own structure. I mention adjectival or nominal group here because in the Sydney grammar the adjectival group is considered as a nominal group with covert Thing, where the Epithet acts as Head (Halliday & Matthiessen 2013a: 391); this however is a discussion beyond the point I make here.

The same example analysed with Cardiff grammar would look as in Table 3.5. It follows precisely the above suggestion of filling the Epithet with another unit, in this case a Quality Group which in turn has its own internal structure.

(23) Indians had originally planned to present the document to President Fernando Henrique Cardoso.

some	*very*	*small*	*wooden*	*ones*
Quantifying Determiner	Modifier		Modifier	Head
	Quality Group			
	Degree tamperer	Apex		

Table 3.5 Cardiff analysis of Example 22

Indians	*had*	*originally*	*planned to present*	*the document*	*to President Fernando Henrique Cardoso*
Mood		Residue			
Subject	Finite	Adjunct	Predicator	Complement	Adjunct
nominal group		adverbial group	verbal group	nominal group	prepositional phrase

Table 3.6 Sydney grammar Mood analysis of Example 23

Another case that deems the rank scale constraints too strict for the present work is in the case of Finite element in the Clause. Consider example 23 where the Finite and Predicator elements are filled by a single unit which is the verbal group which is against the constituency principles which restricts the composition relation to engage only with whole units.

Alternatively, if the unit filling the Finite element is considered separate from the verbal group filling the Predicator then it is always a single word, a modal verb, and never a verbal group. This again is a breach in the rank scale constraints as originally set out which postulates that a unit may be composed of units of equal rank or a rank higher and cannot be composed of units that are more than one rank lower and so it is not permitted to have clause elements expounded by words directly.

The two cases above I use to demonstrate how the rank scale construct as defined by the Sydney grammar is too rigid and thus unsuitable for the current work. I drop the constituency constraints hence allowing the flexibility for elements to be filled by other units or, in other words, allow unit *embedding*. This approach removes the need of sub-structures in the unit elements, reducing thus the structural complexity as seen in Table 3.5.

The weakening of constituency constraints makes embedding a regular (broadly defined in Definition 3.3.9) rather than an exceptional phenomena (strictly defined in Definition 3.2.5).

An approach to describe units outside the rank-scale was suggested by Fawcett (2000) and Butler (1985). Fawcett proposes replacing it with the filling probabilities to guide the unit composition simply mapping elements to a set of legal unit classes that may fill it. Units are carriers of a grammatical pattern and can be described in terms of their internal structure instead of their potential for operation in the unit above.

Nonetheless I do not abandon the rank scale completely and I use it as the top level classifier of grammatical units (see Figure 3.10) falling in line with more traditional syntactic classes.

3.4.2 Approach to structure formation

The *unit* and *structure* are two out of the four fundamental categories in systemic theories of grammar. The Sydney and Cardiff theories vary in their perspectives on *unit* and *structure* influencing how units are defined and identified.

For Halliday, the *structure* (Definition 3.2.6) characterises each unit as a carrier of a pattern of a particular order of *elements*. The order is not necessarily a linear realisation sequence but a theoretical relation of relative or absolute placement. This perspective has been demonstrated to be useful in generation where unit placement emerges out of the realisation process.

The Cardiff School takes a bottom up approach and defines class in terms of its internal structure describing a relative or absolute order of elements. This sort of syntagmatic account is precisely what is deemed useful in parsing and is the one adopted in this thesis. In this work, as motivated in the Introduction, generation of the constituency structure is derived from the Stanford dependency parse trees. As it consists of words and relations between them the intuitive approach to form groups, clauses and complexes is by working them out bottom up.

The method is to let the unit class emerge from recognition of constituent word classes and dependency relations between, or sequences, of already formed lower units. The exact mechanism how this is done I explain in Chapter 8. What is important to note here is the bottom-up approach which is in line with Cardiff way of defining unit classes in contrast to top-down approach of Sydney school.

3.4.3 Relation typology in the system networks

As a system is expanded in delicacy to form a systemic network of choices, choice of a feature in one system becomes the *entry condition* for choices in more delicate systems below. Halliday states that the relation on the systemic cline of delicacy is essentially one of *sub-categorisation* (see Definition 3.2.11). In this subsection I argue for occurrences of multiple kinds of inter-systemic relations. I also call them *activation relations* because in the traversal process from less to more delicate systems, when choices are made in the former then choice making is enabled or *activated* in the latter.

Next I present a distinction between two activation relations: *sub-categorisation* and *choice enabling*, which are of interest in the present thesis but by no means exhaust the possibilities; more work is needed here.

Lets take as example the polarity system represented in figure 3.8. It contains two choices, either positive or negative. An increase in delicacy can be seen as a taxonomic "is a" relationship between features of higher systems and lower systems as in the case of POLARITY TYPE and NEGATIVE TYPE in Figure 3.8 and in fact for the rest of the network as well. As a side note, the delicacy in a system network is akin to the sub-classification relation, which was originally the intended one and the predominant one. In practice, however, a few kinds of abstraction relations can be encountered (e.g abstraction as information reduction, as approximation, as idealisation etc.) extensively treated by Saitta & Zucker (2013). This discussion however is beyond the scope of the current work.

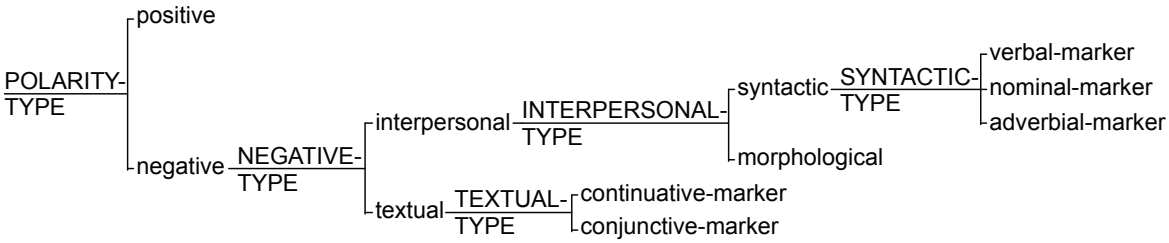


Fig. 3.8 System network of POLARITY

The activation relation among systems in the cline of delicacy is not always taxonomic. However, another relation is "enables selection of" without any sub-categorisation implied. As an example see the FINITENESS system in Figure 3.9 where in case that the finite option is selected then what this choice enables is not sub-types of finite but merely other systems that become available i.e. DEIXIS and INDICATIVE TYPE. The latter is there because selection of finite implies also selection of indicative feature in a sibling of FINITENESS system, MOOD-TYPE (depicted in Figures 1.5 and 1.7) comprised of options indicative and imperative.

The distinction in the systemic relations is incorporated into the technical data structure definitions and traversal algorithms proposed in Chapter 7.

3.4.4 Unit classes

In SFL at large there is the consensus that linguistic forms and meanings are intertwined and mutually determined just like for any sign in a Saussurean approach to language. Both Halliday (quote below) and Fawcett (Definition 3.3.1) adopt this position.

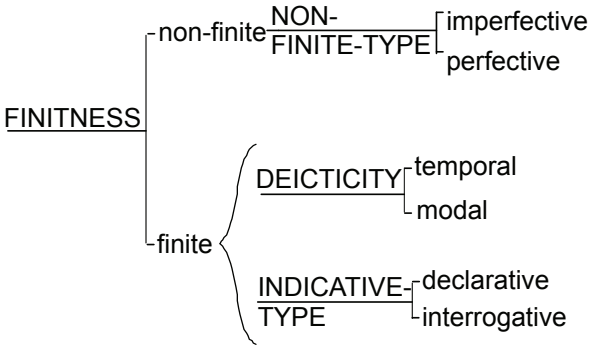


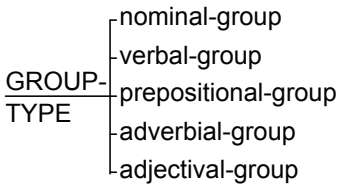
Fig. 3.9 A fraction of the FINITENESS system where increase of delicacy is not a "is a" relation

> . . . something that is distinctly non-arbitrary [in language] is the way different kinds of meaning in language are expressed by different kinds of grammatical structure, as appears when linguistic structure is interpreted in functional terms (Halliday 2003a).

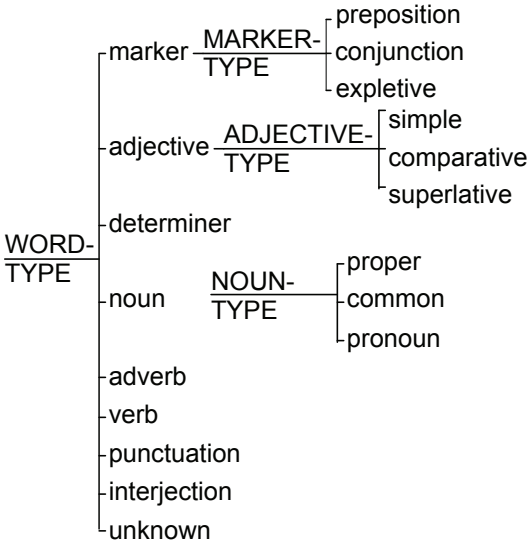
When it comes to establishing the lexico-grammatical classes the two schools diverge. Halliday adopts the traditional grammar *word classes* or *parts of speech*: noun, verb, adjective etc. He then derives a set of groups (e.g. nominal group, verbal group, adverbial group etc.) that share properties of the word classes. In fact the class, in Halliday's words, "indicates in a general way its potential range of grammatical functions" (Halliday & Matthiessen 2013b: 76). For example the nominal group is a formation that functions as a noun may do and expresses the same kind of meaning.

Following the idea that major semantic classes of entities (situations, things, qualities and quantities) correspond to the major syntactic units, Fawcett decided to mirror them in the lexico-grammar. This led to a semantically based classification of syntactic units: clause, nominal group, prepositional group, quality group and quantity group (Fawcett 2000: 193–194) along with a set of minor classes such as genitive and proper name clusters. This is, in a way, a tight coupling of the grammatical units with an ontology which may be subject to change in the future. The converse may also be stated that the traditional parts of speech are disconnected from the semantics in the sense that there is no one to one correspondence (as Fawcett attempts) but rather a complex set of mappings. Establishing the exact interface of syntax and semantics is a hot ongoing theoretical exploration across the entire linguistic discipline and a difficult task in practice. This discussion however is beyond the scope here. In the current work, as will be reiterated in Chapter 4, I adopt the Sydney classification of syntactic units that is close in line with traditional syntactic classifications (Quirk et al. 1985). I

adopt the clause as a unit plus the four group classes of the Sydney grammar depicted in Figure 3.10a.



(a) The group classes



(b) The word classes

Fig. 3.10 The group and word classes

The word classes or part of speech tags that I adopt here are those of the Penn tag set (Marcus et al. 1993) which, like Sydney word classes (depicted in Figure 3.10b), are also in line with traditional grammar. This tag set has become a widely accepted standard in mainstream computational linguistics and there are multiple implementations of part of speech taggers. The Stanford Parser which plays an important role in the software implementation of this thesis described in Chapter 5, employs precisely the Penn tag set.

The Penn tag set was developed to annotate the Penn Treebank corpora (Marcus et al. 1993). It is a large, richly articulated tag set that provides distinct codings for classes of words that have distinct grammatical behaviour.

The Penn tag set is based on the Brown Corpus tag set (Kucera & Francis 1968) but differs in several ways. First, the authors reduced the lexical and syntactic redundancy. In the Brown corpus there are many unique tags to a lexical item. In the Penn tag set the intention is to reduce this phenomenon to a minimum. Also distinctions that are recoverable from lexical variation of the same word such as verb or adjective forms or distinctions recoverable from syntactic structure are reduced to a single tag.

Second, the Penn Corpus takes into consideration the syntactic context. Thus the Penn tags, to a degree, encode syntactic functions when possible. For example, *one* is

tagged as NN (singular common noun) when it is the head of the noun phrase rather than CD (cardinal number).

Third, the Penn POS set allows multiple tags per word, meaning that the annotators may be unsure of which one to choose in certain cases. There are 36 main POS and 12 other tags in the Penn tag set. A detailed description of the schema, the design principles and annotation guideline is given in Santorini (1990). Figure 3.10b depicts a classification summarising the Penn tag set.

3.4.5 Syntactic and semantic heads

In SFG heads may be motivated by semantic or syntactic criteria (simply called here semantic or syntactic heads). In most cases they coincide but there are exceptions when they differ and diverge. This topic is especially important in the discussions of the *nominal group* structure (continued in Section 4.1.3) on which Halliday & Matthiessen (2013b) offers a thorough examination and Fawcett (2000) provides a more generic perspective.

In this discussion I show a few examples when the syntactic and semantic heads diverge and argue my position on the group formation on two points. First, the class of the Head (in the Sydney school) or pivotal element (in the Cardiff school) is not always raised to establish the group class but the whole underlying structure determines the group class. Second, syntactically motivated heads are easy to establish because they are based solely on formal grounds whereas semantic heads require an evaluation at the level of an entire group, once one is established, employing additional lexical semantic resources. This can be a two step process but in the current implementation reported here only the group structure on syntactic grounds is provided.

As mentioned before in Section 3.2.5, the Sydney grammar follows the exhaustiveness principle (Generalisation 3.2.3) through multiple parallel structures while the Cardiff grammar puts the principle of a single syntactic structure resembling a mixture of the former.

Let's briefly return to Example 22 analysed with the Sydney grammar in Tables 3.3 and 3.4 that reflect the nominal group logical and experiential structures (Halliday & Matthiessen 2013b: 391). When the Head (called here the *syntactic head* of the nominal group) coincides with the Thing (called here the *semantic head*) we say that they are conflated (Definition 3.3.10) and examples such as this one may lead to the assumption that the Head, which is motivated by syntactic criteria, is also always the Thing, which is motivated by the semantic criteria, but this is not so.

The logical structure is a Head-Modifier structure and "represents the generalised logical-semantic relations that are encoded in the natural language" (Halliday & Matthiessen 2013b: 388). The experiential structure of the nominal group as a whole has the function of specifying the class of things, through the Thing element, and some category of membership in this class, through the rest of the elements. In the nominal group there is always a Head but the Thing may be missing and so the Head element is conflated with either Epithet, Numerative, Classifier or Deictic instead.

(24) (Have) a cup of tea.

(25) The old shall pass first.

(26) I'll give you three.

Consider Example 24 analysed with the Sydney and Cardiff grammars in Table 3.7. In the Sydney Grammar the semantic and the syntactic heads differ. In the experiential analysis the semantic head is "tea" which functions as Thing, while in the logical analysis the syntactic head is "cup" which functions as Head. The Cardiff Grammar does not offer multi-structural analysis and there is no Head/Thing distinction. The functional elements are already established based on semantic criteria and this is further discussed in Section 4.1.3.

		a	*cup*	*of*	tea
Sydney Grammar	experiential	Numerative			Thing
	logical	Pre-Modifier	Head	Post-Modifier	
Cardiff Grammar		Quantifying Determiner		Selector	Head

Table 3.7 Analysis of Example 24 with Sydney and Cardiff grammars: diverging semantic and syntactic heads.

In the nominal group "The old" which is Subject in Example 25, the Head is the adjective "old" and not a noun as would normally be expected. The noun modified by the adjective "old", also the *pivotal element* of the group defined in Section 3.3.2, is left covert and it should consequently be recoverable anaphorically or cataphorically from the context. We can insert a generic noun "one" to form a canonical noun group "the old one". In such cases when the pivotal noun is missing, the logical Head is conflated with the other element in this case the Epithet. The group class is not raised from the word class to quality group but is identified by internal structure of the whole group and in this case the presence of determiner signals a nominal class. Similarly, in Example 26, "three" in the Sydney grammar is a nominal group where the Thing is missing and the Head has shifted left towards the Numeral. With examples such as

these, Fawcett argues that none of the constituting elements of the unit is mandatorily realised, even the so called pivotal element which is the group defining element. An in depth description of the recovering mechanisms for covert nominal elements at the level of the clause is provided in Chapter 6.

In this work I adopt the principles for establishing the logical structure of the Sydney Grammar. It resonates closely with the traditional "semantically blinded" grammars because it always provides a Head element even if it differs from the syntactically motivated pivotal element in the Cardiff Grammar. Moreover these logical Heads correspond to dependency heads established in the Stanford dependency parse. Chapter 5 provides the grounds for cross-theoretical mappings and the empirical evaluation in Chapter 10 validates this.

It is not unusual in languages to have nominal groups with the Thing missing or elliptic clauses with the Main verb missing; therefore no rigid correspondence can be established between the logical Head and unit class. In this work the structure creation is performed in two steps: first establishing the group boundaries and the unambiguous unit elements through a top down perspective (that is Sydney approach to unit creation), and second for each established group evaluating the internal structure in order to establish the group class (that is the Cardiff approach to group formation). This process is detailed in Chapter 8.

The evaluation in the second step, besides finalising the syntactically motivated unit structure, can as well assign semantically motivated unit structure. This part however is omitted in the current thesis for the groups and only the clauses receive semantic role labels and process types as described in Chapter 9.

3.4.6 Coordination as unit complexing

In the Sydney Grammar unit complexes fill an important part of the grammar along with the *taxis relations* (Definition 3.2.14) which express the interdependency relations in unit complexes. *Parataxis* relations bind units of equal status while the *hypotaxis* ones bind the dominant and the dependent units. Fawcett bypasses the taxis relations replacing them with coordination and embedding (Fawcett 2000: 271) and leading to abandonment of unit complexing entirely. While embedding elegantly accounts for the depth and complexity of syntax, this approach to coordination is problematic.

Hereafter I discuss the utility and even necessity of keeping unit complexes in parsing. In particular I address the treatment of group and clause *coordination* but the same principle applies to other fixed structures such as *comparatives*, *conditionals* or *appositions*.

Treatment of the coordination phenomena is a challenge not only for SFL but for other linguistic theories as well. The Sydney Grammar approaches it through unit complexing and taxis relations while the Cardiff Grammar treats this phenomena as multiple distinct units filling or expounding the same element.

Table 3.8 illustrates an example Sydney style analysis where the Complement is filled by a homogeneous nominal group complex held together through *paratactic extension* where the first element is a nominal group and the second is a nominal group together with the conjunction which is not part of the experiential structure but remains only in the logical structure of the nexus.

Ike	*washed*	*his*	*shirt*	*and*	*his*	*jeans*
Subject	Predicate/Finite	Complement				
		1			+2	
		Deictic	Thing		Deictic	Thing

Table 3.8 Clause with nominal group complex

In Table 3.9 the Epithet is filled by a nexus of paratactic extension. The first element of the nexus is the word "immediate" and the second element is the sequence of words "and not so far distant". The "not so far distant" is an adverbial group with a logical structure of sub-modifiers already discussed in Section 3.4.1 and the conjunction "and" is left implicitly part of the logical structure of the nexus creating a gap in the structure that is addressed in this discussion. Also note that, in the Sydney Grammar, the coordination is described as a unit complex ensuring that only one unit fills an element of the parent, in contrast, as we will see below, to the Cardiff Grammar.

the	*immediate*	*and*	*not*	*so*	*far*	*distant*	*future*
Modifier							Head
γ	β						α
Deictic	Epithet						Thing
	1	+2					
			Sub-Modifier			Sub-Head	
			δ	γ	β	α	

Table 3.9 Nominal group with word complex from (Halliday & Matthiessen 2013b: 564)

Table 3.10 presents an example of analysis with the Cardiff Grammar. The Complement is filled by two *sibling* nominal groups "his shirt" and "and his jeans", both of which fill the same element in accordance to Definition 3.3.7. The conjunction "and" is described directly as part of the nominal group structure.

Ike	*washed*	*his*	*shirt*	*and*	*his*	*jeans*
Subject	Main Verb	Complement				
		Deictic Determiner	Head	&	Deictic Determiner	Head

Table 3.10 Coordination analysis in Cardiff Grammar

Opinions are divided (between the Sydney and Cardiff schools) whether to accept the notion of a complex unit to handle coordination or not. If we side with the Cardiff grammar and dismiss the unit complex then we allow an element to be filled by more than one unit. And this is a problem because if we do not assign unit elements each in a unique place within the unit structure then we loose the capacity to order them. Therefore in this thesis I adopt the Sydney definition of structure (Definition 3.2.6) that constrains each element into a single place that is filled by another unit. Therefore the conjunction must be a nexus acting as a single unit filling a single element.

I argue for adoption of such a unit type in order to ensure that a maximum of one unit can fill the place of an element. In the theory of grammar, only units account for structure while elements can only be filled by a unit (see Figure 3.2). Allowing multiple units to fill an element requires accounting at least for the *order* if not also for the relation between the filler units. The structure as it is described in the theories of grammar by Halliday (Halliday 2002) and Fawcett (Fawcett 2000) is defined by the unit and not the element. There is no direct reference in the theory to the unit ordering. Instead, the order relation is handled in the structure through the concept of place, as define in the Cardiff Grammar. A unit has a specific possible structure in terms of places of elements which hold absolute position in the unit structure or relative one to each other. Therefore if an element is filled by two units simultaneously it constitutes a violation of the above principle as the order of those units is not accounted for but this matters as can easily be shown in the following examples.

(27) (Both my wife and her friend) arrived late.

(28) * (And her friend both my wife) arrived late.

(29) I want the front wall (either in blue or in green).

(30) * I want the front wall (or in green either in blue).

If the order would not have mattered then we could say that the conjunctions from Example 27 can be reformulated into 28 and the one from 29 into 30. But such reformulations are grammatically incorrect. Obviously the places do matter and they need to be handled in the unit structure as one element per place with no more than a single unit filling it.

I turn now to the role and position of lexical items signalling the conjunction which I consider to have no place in the structure of the conjoined units but lies outside of them, that way forming together a higher order unit, the *complex unit*. This is contrary to what is being described in the Cardiff and Sydney grammars for different reasons.

Fawcett presents the Linker elements (&) which are filled by conjunctions as parts of virtually any unit class placed in the first position of the unit. For example in the "or in green" the presence of "or" signals the presence at least of one more unit of the same nature and does not contribute to the meaning of the prepositional group but to the meaning outside the group requiring presence of a sibling. Even more, the lack of a sibling most of the time would constitute an ungrammatical formulation. The only potential objection here is for the perfectly acceptable cases of clauses/sentences starting with a conjunction such as "and" or "but". In those cases the conjunction plays a textual function and still invites the presence of a sibling clause/sentence preceding the current one to be resolved in a clause complex or at the discourse level.

Halliday omits to discuss in IFG (Halliday & Matthiessen 2013b) the place of Linkers. He implicitly proposes the same as Fawcett through his examples of paratactic relations at various rank levels (Halliday & Matthiessen 2013b: 422, 534, 564, 566) that the lexical items signalling conjunction are included in the units they precede in the logical structure but not the experiential one. The main insufficiency here is that the logical structure does not provide any meaningful elements or unit class but some sort of proto-elements that resemble rather places than functions. In this sense I consider treatment of conjunctions insufficiently accounted for in IFG.

So conjunctions and pre-conjunctions shall not be placed inside the conjoined units because they do not contribute to their meaning. They shall be enclosed as Linkers into unit complexes. But if we adopt the unit complexing then we need to define a unit structure. Hence I propose the following generic structure for the *coordination unit*.

Pre-Linker	Initiating Conjunct	... Conjunct ...	Linker	Conjunct
1		+ 2 ... + n-1	+ n	

Table 3.11 Generic structure of the coordination unit

In Table 3.11 the first row presents a series of Conjuncts where the first one is initiating or the head and the rest are continuation Conjuncts of the former. In the first place there may be a Pre-Linker element such as "both" or "either" for example, but it is optional and in the place before the last one the Linker element that determines the type of coordination is located. On the second row I provide, for orientation purposes, the Sydney logical structure of a paratactic expansion applied to the coordination

unit complex. Note that the Pre-Linker and the Linker elements are merged with the conjoined units.

Applying this structure to the previous example yields analysis such as in Table 3.12. The nominal group has the Epithet element filled by a coordination group formed of two Conjuncts and a Linker.

the	*immediate*	*and*	*not*	*so*	*far*	*distant*	*future*
Determiner	Epithet						Head
	Initiating Conjunct	Linker	Conjunct				

Table 3.12 Example analysis with coordination unit complex structure

Adopting the unit complex and in particular the coordination unit requires two more clarifications: (1) does the complex unit carry a syntactic class, and if so according to which criteria is it established? (2) Does it have any intrinsic features or are all of them inherited from the conjuncts?

Zhang states in her thesis that the coordinating constructions do not have any categorial features and so there is no need to provide a new unit type. Instead the categorial properties of the conjuncts are transferred upwards (Zhang 2010). For example if two nominal groups are conjoined then the complex receives the nominal class.

This principle holds for most of the cases; however, there are rare cases when the units are of different classes. Consider 31 analysed in Table 3.13 where the conjuncts are a nominal group "last Monday" and a prepositional group "during the previous weekend".

(31) I lost it (either last Monday or during the previous weekend).

either	*last*	*Monday*	*or*	*during*	*the*	*previous*	*weekend*
Pre-Linker	Initiating Conjunct		Linker	Conjunct			

Table 3.13 Coordination group with mixed class conjuncts

In this case there are two unit types that can be raised and it is not clear how to resolve this case. Options are (a) to leave the generic class *coordination complex*, (b) transfer the class of the first unit upwards, or (c) semantically resolve the class as both represent temporal circumstances even if they are realised through two different syntactic categories (unless using the Sydney model then the resolution is grammatical). This means that if no sub-classification is provided based on the constituent units

below than there is no need to project/transfer upward the class of the conjunct units. In this work I decided to leave the class generic and leave for the future an extensive unit complex classification.

I turn now to the last issue of this discussion, specifically whether the complex unit may have intrinsic features emerging from the conjunct elements.

In Examples 32 and 33 the conjunction of two singular noun groups requires plural agreement with the verb. Even though semantic interpretation is that only one item is selected at a time, syntactically both items are listed in the clause and attempting third person singular verb forms as in Examples 34 and 35 is grammatically incorrect. This leads to the conclusion that the coordination complex can have categorial features which none of the constituting units have.

(32) A pencil or a pen *are* equally good as a smart-phone.

(33) A fork and knife *have* to be placed on the sides of each plate.

(34) * A pencil or a pen *is* equally good as a smart-phone.

(35) * A fork and knife *has* to be placed on the sides of each plate.

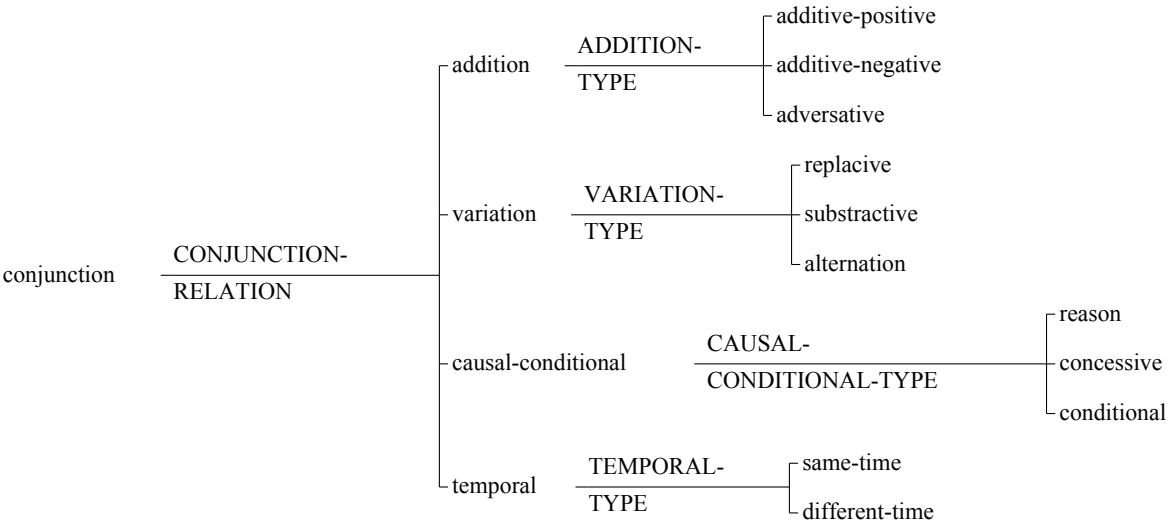


Fig. 3.11 Systemic network of coordination types

In the case of nominal group conjunction we can see that the plural feature emerges even if each individual unit is singular. For other unit classes it is not so obvious whether there are any linguistic features that emerge at the conjunction level. The meaning variation is semantic as for example conjunction of two verbs or clauses might mean very different things - such as consecutive actions, concomitant actions or presence of two states at the same time and so on. This brings us to another feature

of the coordination complex - the type of the relationship it constructs. The lexical items expounding the Linker and Pre-Linker (e.g. *and*, *or*, *but*, *yet*, *for*, *nor* or *so*) are indicators of relationship among the conjuncts and together can be systematised as the relationship types in the systemic network in Figure 3.11.

This section laid out how and why I treat the coordination phenomena in parsing. I adopt the unit complexing mechanism with taxis relations described in the Sydney grammar in order to provide a new unit class, the *coordination unit*. I do that to ensure that each element of a unit is filled by no more than one other unit, contrary to what the Cardiff grammar proposes (see Definition 3.3.7). But taxis relations in the Sydney grammar are represented via logical structures which are not rich enough to account for internal structure of the coordination unit. Therefore I also propose here a unit structure in terms of ordered functional elements just as for the rest of the unit classes.

3.5 Summary

This chapter has introduced the basic notions of systemic functional linguistics and presented a consideration of the Sydney and Cardiff theories of grammar with respect to the task of parsing.

First, in Section 3.2, I introduced the Sydney theory of grammar that gave rise to SFL. Then, in Section 3.3, I introduce the Cardiff theory of grammar. This builds on top of the Sydney school but differs in several important ways from it. Finally, in Section 3.4, I conducted a critical discussion of important aspects of both grammars such as unit, class, function, element, rank scale, unit heads and structure. This discussion settles my position on some elements of the theory of grammar that will be necessary in the next chapter for presenting the grammar currently implemented into the Parsimonious Vole parser.

Chapter 4

Parsimonious Vole grammar

Now that the main theoretical foundations have been covered, I describe the structure of grammatical units and system networks adopted in this thesis and implemented in the Parsimonious Vole parser. Some of them are from the Sydney and others from the Cardiff grammars. There are many common parts but also differences in parts of their paradigmatic and syntagmatic descriptions.

First I discuss the structural differences between main units in the Sydney and the Cardiff grammars: the clause, the verbal group, nominal group, the adjectival and adverbial groups. Then, I focus on two important system networks: TRANSITIVITY and MOOD. The first is adopted from the Cardiff grammar and the second belongs to the Sydney grammar.

4.1 Grammatical units

The general principle for selection is that some unit structures are closer to traditional syntactic analysis and so possible to connect the elements of the Dependency grammar. There are some units in both Sydney and Cardiff grammars that fit this purpose and some others that are semantically grounded and are more difficult to capture in structural variance, requiring additional lexical-semantic resources. This section discusses choices made for the current work.

4.1.1 Verbal group and clause boundaries

In the Sydney Grammar the verbal group is described as an expansion of a verb just like the nominal group is the expansion of the noun (Halliday & Matthiessen 2013b: 396). There are certainly words that are closely related and syntactically dependent

on the verb all together forming a unit that functions as a whole. For example the auxiliary verbs, adverbs or the negation particles are words that are directly linked to a lexical verb. The verb group functions as Finite + Predicator elements of the clause in Mood structure and as Process in Transitivity structure.

In the Cardiff Grammar the verb group is dissolved, moving the Main Verb to the pivotal element of the Clause unit. All the elements that form clause structure and those that form verb group structure are brought together to the same level as elements of a clause. The clause structure in the Cardiff Grammar comprises elements with clause related functions (like Subject, Adjunct, Complement etc.) and other elements with Main Verb related functions (Auxiliary, Negation particle, Finite operator etc).

Regarded from the Hallidayan rank scale perspective, merging the elements of the verb group into clause structure is not permitted because the units are at different ranks. However this is not a problem for the relaxed rank scale version presented in Section 3.4.1. This in fact is also the approach taken in the Nigel grammar (Penman Project 1989b). The reason for adopting such an approach is best illustrated via complex verb groups with more than one non-auxiliary verb as in Examples 36–38.

I begin by addressing the impact of this merger on (a) the clause structure (b) the clause boundaries and (c) the semantic role distribution within the clause.

(36) (The commission *started to investigate* two cases of over-fishing in Norway.)

(37) (The commission *started* (*to investigate* two cases of over-fishing in Norway.))

(38) (The commission *started* (*to finish* (*investigating* two cases of over-fishing in Norway.)))

In the Sydney Grammar "started to investigate" (in Example 36) is considered a single predicate of investigation which has specified the aspect of event incipiency despite the fact that there are two lexical verbs within the same verbal group. The "starting" doesn't constitute any kind of process in semantic terms but rather specifies aspectual information about the investigation process. This is argued by looking at the conditions on participants and it is equivalent in a formal approach to looking at where the selection restrictions for complements come from. The boundaries of the clause governed by this predicate stretch to the entire sentence.

Semantically it is a sound approach. Despite the presence of two lexical verbs there is only one event. However, allowing such compositions leads to unwanted syntactic analysis for multiple lexical verb cases in examples such as 38. To solve this kind of problem Fawcett dismisses verb groups and merges their elements within clause structure. He proposes the syntactically elegant principle of *one main verb per clause*

(Fawcett 2008). Applying this principle to the same sentence yields a structure of two clauses illustrated in example 37 where the main clause is governed by the verb "to start" and the embedded one by the verb "to investigate". Note the conflict of "one main verb per clause" with Halliday's principle that only whole units form the constituency of others (the (c) principle of rank scale described in Section 3.4.1). So allowing incomplete groups into the constituency structure would breach the entire idea of unit based constituency.

Semantically the clause in SFL is a description of an event or situation as a figure with a process, participants and eventually circumstances where the process is realised through a lexical verb. Looking back to our examples, the question is then does the verb "to start" really describe a process or merely an aspect of it? Halliday treats such verbs as aspectual and when co-occurring with other lexical verbs they are considered to form a single predicate. Accommodating Fawcett's stance, mentioned above and contradicting Halliday's approach, requires weakening the semantic requirement and allowing aspectual verbs to form clauses that contribute *aspectually or modally* to the embedded ones. I mention also the modal contribution because some verbs like *want, wish, hope* and others behave syntactically like the aspectual ones. Moreover, Fawcett introduces into the Cardiff Grammar Transitivity network an *influential* process type including all categories of meanings that semantically function as process modifiers: tentative, failing, starting, ending etc.

I adopt here Fawcett's "one main verb per clause" principle, which as a consequence changes the way clauses are partitioned, leads to abolition of the verbal group and introduces the "influential" process type. Next I discuss the impact of this verb group abolition on the structure of clause units.

4.1.2 Clause

It is commonly agreed in linguistic communities that the unit of the clause is one of the core elements in human language. The main clause constituents are roughly the same in SFL as the ones in traditional grammar (Quirk et al. 1985), transformational grammar (Chomsky 1957) and indirectly in dependency grammar (Hudson 2010).

I adopt the Cardiff Grammar clause structure where *Main Verb* is the pivotal element of the unit. The clause is formed of the *Subject*, *Finite*, *Main Verb*, up to two *Complements* and a various number of *Adjuncts*. All the elements that in the Sydney grammar are part of the verbal group, such as Auxiliary Verbs, Main Verb Extensions, Negators etc. are considered part of the clause structure. For a complete list see Appendix A.

(39) They were in the bar, *Dave in the restroom and Sarah by the bar.*

Although there is no element that is obligatorily realised in English, I consider in the current work that every non-auxiliary lexical verb is a Main Verb and thus flags presence of a clause unit. There are clauses, in SFL, without a main verb, such as minor clauses (exclamations, calls, greetings and alarms) that occur in conversational contexts and elliptical clauses Halliday & Matthiessen (2013b) such as the one in Example 39, none of which are covered in the present work.

4.1.3 Nominal Group

The nominal group expresses things, classes of things or a selection of instances in a class. This section argues for adoption of the Sydney grammar noun group structure with a slight modification. The elements of the nominal group can be filled, in addition to word units, by group units as well. This possibility is opened by the rank scale relaxation (Section 3.4.1) and the Cardiff embedding principle (Definition 3.3.9). Cardiff's nominal units would be more difficult to process because of their semantic nature and are left out of the current implementation for further work. Nonetheless, I argue below for working towards semantic and syntactic heads in two steps: first create the structure with the syntactic one (the Head) and then derive the semantic one (the Thing), eventually arriving at the Cardiff nominal structure.

those	*two*	*old*	*electric*	*trains*	*from Luxembourg*
Pre-Modifier				Head	Post-Modifier
Deictic	Numerative	Epithet	Classifier	Thing	Qualifyier
determiner	numeral	adjective	adjective	noun	prepositional phrase

Table 4.1 An example of a nominal group in the Sydney Grammar (Halliday & Matthiessen 2013b: 264)

In Table 4.1 an example analysis is presented of the nominal group proposed in the Sydney grammar (Halliday & Matthiessen 2013b: 364–369). The Sydney nominal group is constituted by a head nominal item modified by descriptors or selectors such as: *Deictic*, *Numerative*, *Epithet*, *Classifier*, *Thing* and *Qualifier*. Each element has a fairly stable correspondence to the word classes expected to be expounded by lexical items. Table 4.2 presents the mappings between the elements of nominal group and the word classes.

Inspired from the Cardiff grammar, in addition to word classes the elements of the nominal group can also be filled by the group classes corresponding to each word class

Experiential function in noun group	**class (of word or unit)**
Deictic	determiner, predeterminer, pronoun, adjective
Numerative	numeral(ordinal or cardinal)
Epithet	adjective
Classifier	adjective, noun
Thing	noun
Qualifier	prepositional phrase, clause

Table 4.2 Mapping of noun group elements to classes (Halliday & Matthiessen 2013b: 379)

above. This way the Numerative, in addition to words, can be filled by a noun group, Epithet by an adjectival group, Classifier by an adjective or noun group and finally each of the elements can be filled by a coordination group as discussed in Section 3.4.6.

The elements in the Cardiff Grammar differ from those of the Sydney Grammar. Table 4.3 exemplifies a noun group analysed with the Cardiff Grammar covering all the possible elements. Table 4.4 provides a legend for the Cardiff Grammar acronyms along with mappings to unit and word classes that can fill each element.

or	*a photo*	*of*	*part*	*of*	*one*	*of*	*the best*	*of*	*the*	*fine*	*new*	*taxis*	*in Kew*	,
pre-modifiers												head	post-modifiers	
&	rd		v	pd	v	qd	v	sd or od	v	dd	m	m	h	q	e

Table 4.3 The example of a nominal group in Cardiff Grammar

The elements in the Cardiff Grammar are based on semantic criteria supported by lexical and syntactic choices. Consequently some elements cannot be derived on solely syntactic criteria, requiring semantically motivated lexical resources. The challenging semantically bound elements from the Cardiff grammar are the following determiners *Representational, Partitive, Fractional, Superlative, Typic Determiners*, while the rest of the elements: *Head, Qualifier, Selector, Modifier and Deictic, Ordinative and Quantifying Determiners* can be determined solely on syntactic criteria. The latter correspond fairly well to the Sydney version of the nominal group, which is adopted in the present work. In addition the relaxed rank scale discussed in Section 3.4.1 permits replacing the nominal group sub-structures from the Sydney grammar with embedded units just like in the Cardiff grammar simplifying the syntactic structures.

Another simplification is renouncing the distinction between the Head and Thing (Halliday & Matthiessen 2013b: 390–396) discussed in Section 3.4.5. Thus if the logical Head of the nominal group is a noun then it is labelled as the Thing leaving the

sym-bol	function meaning	class (of word or unit)
rd	representational determiner	noun, noun group
v	selector “of”	preposition
pd	partitive determiner	noun, noun group
fd	fractional determiner	noun, noun group, quantity group
qd	quantifying determiner	noun, noun group, quantity group
sd	superlative determiner	noun, noun group, quality group, quantity group
od	ordinative determiner	noun, noun group, quality group
td	tipic determiner	noun, noun group
dd	deictic determiner	determiner, pronoun, genitive cluster
m	modifier	adjective, noun, quality group, genitive cluster
h	head	noun, genitive cluster
q	qualifier	prepositional phrase, clause
&	linker	conjunction
e	ender	punctuation mark

Table 4.4 The mapping of noun group elements to classes in Cardiff grammar

semantic discernment as a secondary process and out of the current scope. Otherwise, in cases of nominal groups without the Thing element, if the Head is a pronoun (other than personal), numeral or adjective (mainly superlatives), then it functions as Deictic, Numerative or Epithet. So, as will be described in Chapter 8, I propose to parse nominal groups in two steps: first determine the main constituting chunks and assign functions to the unambiguous ones and, second, perform a semantically driven evaluation for the less certain units.

Next I explain this two step process, using for illustration cases when the Thing is present but is different from the Head as in examples 40–42.

(40) (a cup) of (tea)

(41) (some) of (those youngsters)

(42) (another one) of (those periodic eruptions)

These nominal groups can be analysed in two ways. They are either about the “cup”, “some” or “another one”, leading to a structure where the first noun is the head succeeded by a prepositional phrase Qualifier, or about “tea”, “youngsters” and

"eruptions", where the second noun is the head and so adopting a structure with complex determiners.

Table 4.5 shows on the first row an analysis with syntactic head, i.e. the Head defined in the Sydney grammar, and on the second row an analysis with semantic head, i.e. the Head defined in the Cardiff grammar that also coincides with the Thing from the Sydney grammar.

At a top level of structural embedding, the syntactic Head is always the first noun in the nominal group. In the semantic evaluation phase special attention is given to Qualifiers filled by prepositional phrases starting with preposition "of" and whether the nominal group may function as qualifying, quantifying, ordination or other type of determiner.

The Cardiff Grammar weakens the assumption that every prepositional phrase acts as Qualifier in a nominal group and treat the preposition "of" as a special case. This preposition is allowed to act not as the element introducing a prepositional phrase but as a end mark of a determiner-like selector. When such a selector is present the preceding noun group functions as a Determiner (of some sort) to the noun or nominal group as can be seen in Table 4.5.

The nominal groups that contain a prepositional phrase Qualifier introduced by the preposition "of" receive special attention because they may qualify the special case explained earlier. If the above condition is satisfied then, in a second phase of nominal group analysis aiming at semantic evaluation, the prepositional phrase Qualifier is disassembled, the preposition "of" is ascribed a Selector function of the parent nominal group, being transferred upwards in the structure, and the preceding nominal group (syntactically headed) becomes one of the determiners. This approach shifts the noun group head into the position of a semantically based Thing and evades the discrepancy problem between them.

	a	*cup*	*of*	tea
1st step	Determiner	Head	Qualifier	
2nd step	Quantifying Determiner		Selector	Head/Thing

Table 4.5 Example analysis with syntactic and semantic heads performed in two steps

The above explanation is not a straightforward solution. The distinction between cases when the proposition "of" introduces a Qualifier or ends a Selector/Deictic requires a lexical-semantic informed decision answering the question "what is the Thing that this nominal group is about?". And there is a lot of space for variations in the

syntactic structure. For example in example 43 (where Head/Thing is marked in italic) the preposition "of" introduces Qualifiers.

(43) He was the *confidant* of the prime minister.

(44) It was the *clash* of two cultures.

This section has discussed the problem of semantic and syntactic heads (started in Section 3.4.5) applied to nominal groups in particular and how to approach parsing them. I conclude that it is fairly unambiguous and straightforward to determine the structure of nominal groups according to the Sydney grammar yielding a syntactically based structure. Once such a structure is available it serves as basis for deriving the semantic structure in terms of the Cardiff grammar. The current implementation of the parser considers only the generation of syntactic structure leaving the semantically motivated noun groups for future works.

4.1.4 Adjectival and Adverbial Groups

This section introduces how the adverbial and adjectival groups are handled by the Sydney grammar and then how their equivalent quality groups are structured in the Cardiff grammar. As the structure of the quality group is semantically motivated some elements may be identified still at the syntactic level whereas others require a more sophisticated lexical-semantic resource. In the last part of the section I estimate the complexity of parsing some of the quality group elements.

Following the rationale of head-modifier similarly to the case of nominal groups, the adjectives and adverbs function as pivotal elements to form groups. The structure of adverbial and adjectival constructions is briefly covered in the Sydney grammar in terms of head-modifier logical structures without an elaborated experiential structure as in the case of nominal groups. While the adverbial group is recognised as a distinct syntactic unit, the adjectival group is treated as a special case of nominal group.

(45) You're *a very lucky boy.*

(46) You're *very lucky.*

(47) *The very lucky (one)* is you.

In the environments where nominal group functions as Attribute, typically in the attributive clauses such as Example 45, it can take also more contracted forms without the Thing and Deictic where the Head moves left onto the Epithet as in example 46. One particularity of these nominal groups which here are distinguished

as *adjectival group* units is that they cannot function as subject. For Example 47 to be grammatical, where the Attribute is in the Subject position, a determiner and eventually an unspecified nominal Head must be added.

The adverbial group in the Sydney Grammar has an adverb as Head which may or may not be accompanied by modifying elements (Halliday & Matthiessen 2013b: 419). The adverbial groups may fill modal and circumstantial adjunct elements in a clause corresponding to the eight semantic classes of time, place, four types of manner and two types of assessment. The adverbial pre-modifiers express polarity, comparison and intensification along with only one comparison post-modifier (Halliday & Matthiessen 2013b: 420–421). The adjectival and adverbial group are covered by the *quality group* unit in the Cardiff grammar.

A thorough systemic functional examination in terms of lexis was provided for the first time by Tucker (1997, 1998), materialised as a lexical-grammatical systematisation of adjectives and the fine grained structure of quality groups. Tucker avoids naming the group according to the word class (adjective or adverb) but rather refers to the semantic meaning of what both groups express, i.e. the quality of things, situations or qualities themselves. The qualities of things have adjectives as their head while the qualities of situations adverbs.

In the Cardiff Grammar, the head of the quality group is called *Apex* while the set of modifying elements are *Quality Group Deictic, Quality Group Quantifier, Emphasizing Temperer, Degree Temperer, Adjunctival Temperer, Scope* and *Finisher*. The quality group most frequently fills complements and adjuncts in clauses and fill modifiers and superlative determiners in nominal groups.

Just as in the case of nominal group, the adverbial and adjectival groups in the Cardiff grammar are semantically motivated. To automatically identify elements of the quality group would according to this scheme therefore require lexico-semantic resources. No such resources were considered in the current thesis so this task is left for future work.

I turn now to discuss some relevant affinities concerning the adverbial groups. Some adverbs are different from others at least because not all of them can be heads of the adverbial group. Usually the adverbs that cannot act as heads, such as for example *very, much, less and pretty*, function as Emphasizing and Degree Temperers. The same ones can also act as adjectival modifiers. A naive attempt to identify these Temperers would be to use a list of frequent words found in these functions.

Other elements of the quality group, like the *Scoper* or *Finisher*, are more difficult to identify and localise as part of the group only by syntactic cues and/or lists of words

because of their inherent semantic nature. The Scopers and Finishers are known to be prepositional phrases most of the time. And so the semantic resolution is reduced to detecting whether a prepositional phrase fills a Qualifier element in the preceding nominal group or fills a Complement or an Adjunct in the clause.

Another issue is continuity. The question is whether a grammar should allow at least at a syntactic level discontinuous constituents or not. And then if so, how to detect all the parts of the group even if they do not stand in proximity to each other. For example, comparatives, a complex case of a quality group, could be realised in a continuous or discontinuous form. Compare the analyses presented in Tables 4.6 and 4.7. In the first case the comparative structure is a continuous quality group. In the second case the comparative is dissociated and analysed as separate adjuncts.

On one hand it is not a problem treating them as two adjuncts because that is what they are from the syntactic point of view. However, semantically as Fawcett proposes, there is only one quality group with a discontinuous realisation whose Scope element is placed in a thematic position before the Subject.

I	*am*	*much*	*smarter*	*today*	*than*	*yesterday*
Subject	Main Verb	Adjunct				
pronoun	verb	quality group				
		Emphasizing Temperer	Apex	Scope	Finisher	

Table 4.6 Comparative structure as one quality group adjunct

Today	*I*	*am*	*much*	*smarter*	*than*	*yesterday*
Adjunct	Subject	Main Verb	Adjunct			
adverb	pronoun	verb	quality group			
			Emphasizing Temperer	Apex	Finisher	

Table 4.7 Comparative structure split among two adjuncts

For an automatic process to identify a complex quality group is a difficult task. It needs to pick up cues like a comparative form of the adjective followed by the preposition “than” and then look for two terms being compared. Given some initial syntactic structure such patterns could be modelled and applied but only as a secondary semantically oriented process.

Since both the adverbial and adjectival groups have similar structures, it is syntactically feasible to automatically analyse them in terms of head-modifier structures in a first phase followed by a complementary process which assigns functional roles

to the quality group components. This is the solution that is implemented in the Parsimonious Vole parser.

4.2 System networks

The previous section described the units of structure adopted in the current work. I turn now to describe two system networks selected for detailed treatment. MOOD system network, adopted from the Sydney grammar, is close to terms and concepts of syntactic structure in traditional grammar such as role and definition of Subject, Complement and other functional elements. TRANSITIVITY, adopted from the Cardiff grammar, is a semantically motivated system network and constitutes a good challenge addressed in the current work. More details are presented below.

4.2.1 MOOD

One of the first system networks presented in the Introduction to Functional Grammar (Halliday & Matthiessen 2013b) is that of MOOD (a reduced version is depicted in Figure 4.1). This system is introduced in the discussion of the interpersonal metafunction of language. In this view a clause is conceptualised as a message exchanged between dialogue interactants. A range of grammatical features from traditional grammar such as *mood*, *modality*, *aspect*, *mode*, *polarity*, *tense* etc. are conveyed by this system network.

The terms in SFL literature are steadily capitalised to distinguish system names, functions and features. Note that here the *MOOD* (all capital) refers to the name of the system network; the *Mood* (first capital) is an element of clause structure formed of the Subject and Finite elements which, in fact, is not used in this work because of a general orientation towards the Cardiff approach to structure; and the *mood* (no capital) is a type of feature carried by finite clauses (e.g. imperative, indicative, interrogative etc.)

Figure 4.1 presents the MOOD system network employed in the current implementation of the Parsimonious Vole parser. This MOOD system is to a large extent similar to the one from Halliday & Matthiessen (2013b: 162). It has a few adaptations that were introduced during development with respect to the test corpus described in Chapter 10. The adaptations consist of the adoption of a few traditional grammar features such as *tense* and *voice* and simplification of the Hallidayan modality.

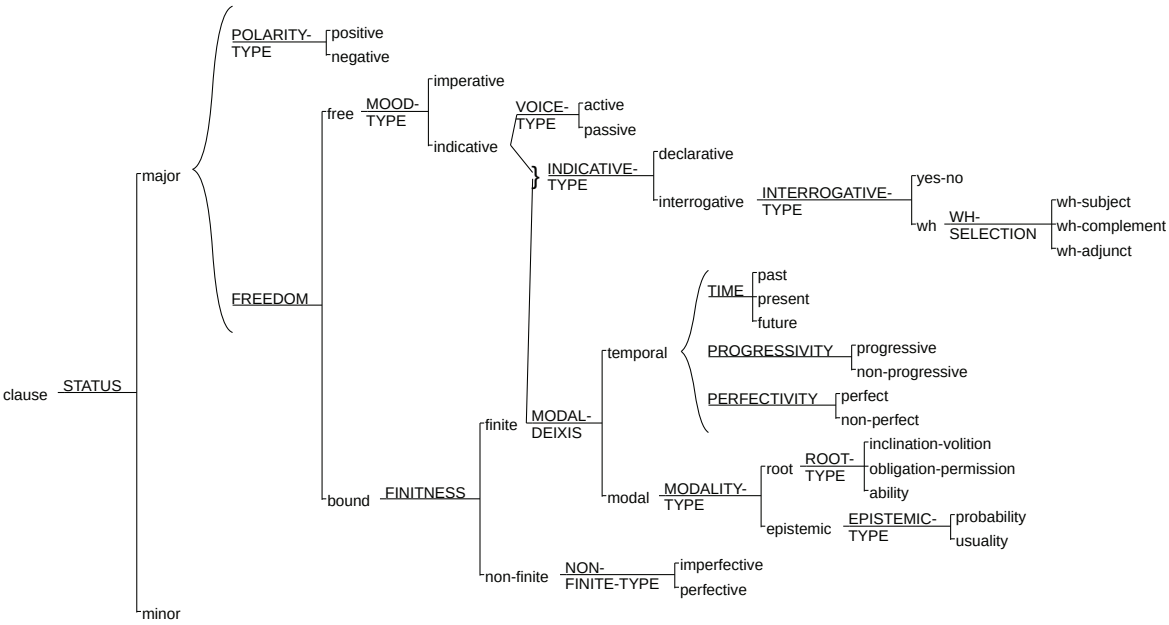


Fig. 4.1 An adaptation of the MOOD system network (Halliday & Matthiessen 2013b: 162)

The features of this feature network apply to units of clause class only. Even if some features may be intuitive I iterate briefly over each of them providing cues for identifying it.

The POLARITY system indicates whether the clause is affirmed or negated. The negative polarity is indicated, in English, by the presence of a clausal particle *not* or *n't*. Negation in general can also be signalled by similar negative markers in other clause elements such as the subject (e.g. "None of the kids came to play."), adjunct (e.g. "He is never coming back.") or complement (e.g. "She loves no one."). In the present work I consider the clausal negative marker only.

VOICE in traditional grammar indicates, for transitive verbs, whether the subject acts (*active* voice) or is acted upon (*passive* voice). In passive voice the subject and complement change position and the former is introduced by the preposition *by*.

The semantics of the FREEDOM system is to indicate whether the clause is *free* and realises a proposition or proposal and serves to develop an exchange in a dialogue either by initiating or responding to a speech act. On the other hand *bound* clauses are not open to negotiation and serve as supporting information to be taken as established. Structurally, the bound clauses usually depend on a dominant one that is free.

The FINITENESS system indicates whether the clause is *finite*, i.e. something that can be argued about. The way to make it arguable is by providing a point of reference

into the here and now (*temporal*) or into the speaker's judgement (*modal*). The latter two features constitute the MODAL-DEIXIS system.

The MODALITY-TYPE system is an adaptation from Halliday & Matthiessen (2013b: 689–692) that focuses on the usage of the modal verbs only and is organised into ROOT and EPISTEMIC modalities. The former one comprises *inclination-volition*, *obligation-permission* and *ability* while the latter has *usuality* and *probability* features.

The temporal feature indicates that the clause has a tense. For simplicity and ease of the implementation into Parsimonious Vole, I replaced the Sydney account for tense with that of the traditional grammar of English. The systematisation is on three systems, that of TIME (past, present or future), PROGRESSIVITY (progressive or non-progressive) and PERFECTIVITY (perfect or non-perfect). The Sydney account for tense remains to be implemented in the future work.

In addition to the MOOD system network I include into the parsing process the DEIXIS system network for the nominal groups determination depicted in Figure 4.2. The nominal DEIXIS system network is described in detail in IFG4 in the nominal group section (Halliday & Matthiessen 2013b: 364–396).

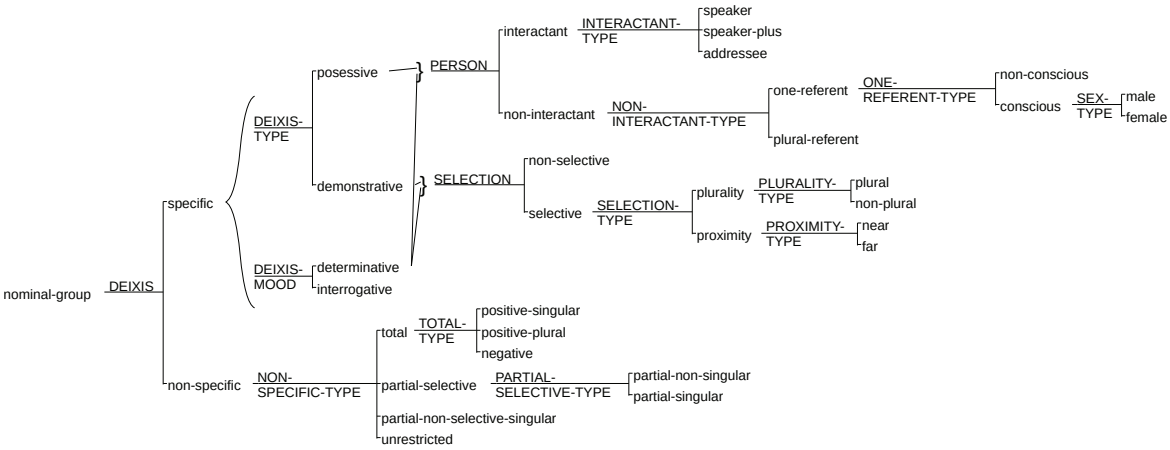


Fig. 4.2 The DEIXIS system network for nominal group determination (Halliday & Matthiessen 2013b: 366)

This system network is relevant for the current work because determining the systemic selections for the entire network can be unambiguously done based on lexical information only. In Section 9.2, we will see a dictionary lookup method in addition to graph pattern matching to determine systemic selections. Next is briefly described the system network of TRANSITIVITY.

4.2.2 TRANSITIVITY

In Section 3.2.5, I explained that SFL organises the lexico-grammar in three parallel metafunctions. This section briefly recounts of the experiential metafunction and introduces the TRANSITIVITY system network that systematises it.

In this perspective, "the clause construes a quantum of change in a flow of events as a *figure*, or a configuration of a *process*, *participants* involved in it and any attendant *circumstance*" (Halliday & Matthiessen 2013b: 212).

In traditional grammar the term *transitivity* refers to the property of verbs according to which they are classified into transitive and intransitive. In SFL the term transitivity is primarily concerned with clauses. It is most useful to refer to Halliday's TRANSITIVITY (Halliday 1968a, 1967, 1968b) that deals with Predicate, Subject, Complement, and Adjunct all of which are elements of the clause and are usually conflated with the Process, Participants and Circumstances.

The Sydney grammar makes a distinction between two types of experience: "inner" as experience inside ourselves and "outer" as experience in the world around us. The prototypical outer experience is that of actions and events. The inner experience is more difficult to sort but it is a kind of reply to the outer, recording it, reflecting on it, reacting to it, etc. Two grammatical categories that realise these two sorts of experiences are the *material* process and the *mental* process.

In addition to material and mental there is a third kind of process used in identifying, classifying and relating various kinds of experience. The grammatical category realising this type of link is the *relational* process. Then using the combinations of the three main processes above, Halliday defines *behavioural*, *verbal* and *existential* processes.

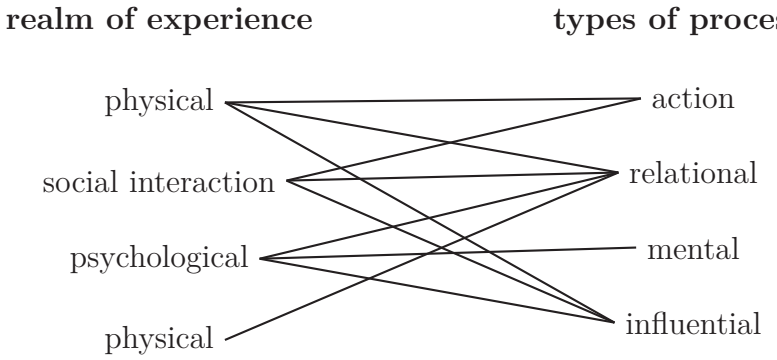


Fig. 4.3 The connections in Cardiff grammar between realms of experience and the process types

The Cardiff grammar employs similar process types, namely those of *action*, *relational*, *mental* and *influential*. In addition, it links these process types to realms of

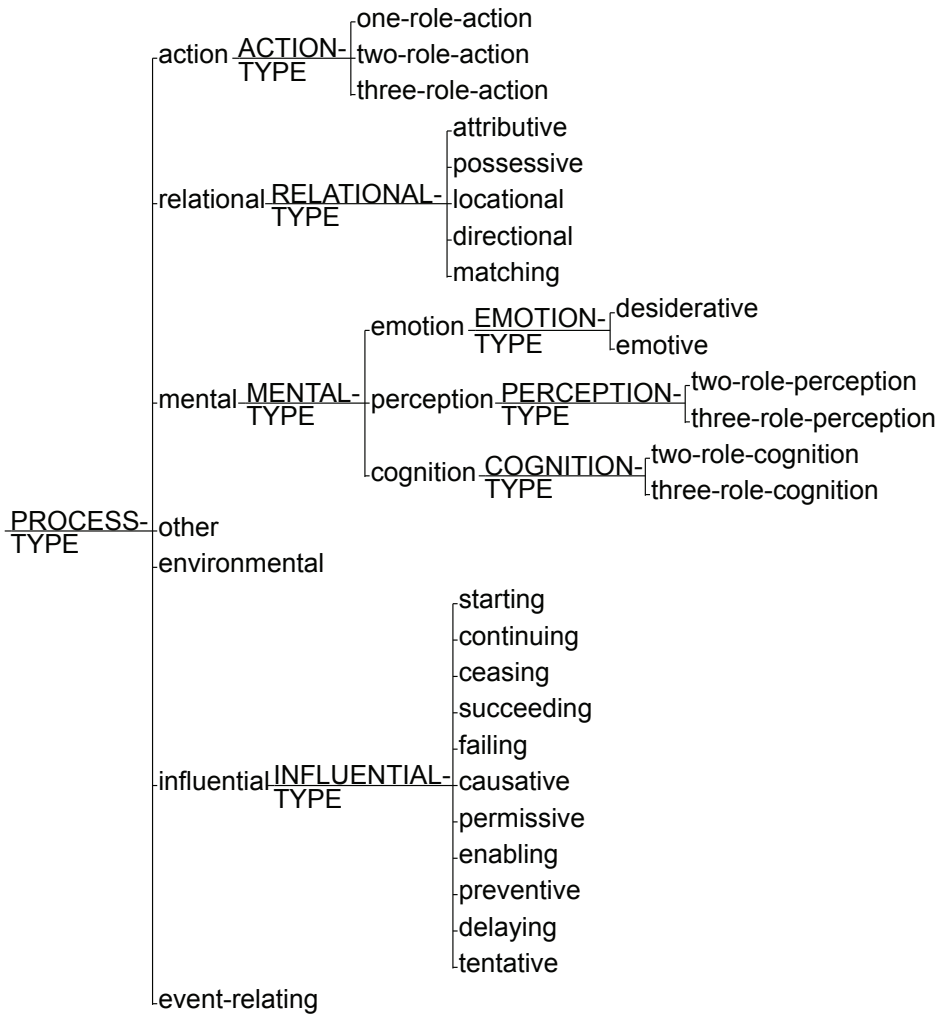


Fig. 4.4 Cardiff TRANSITIVITY system network

experience: *physical*, *social interaction*, *psychological* and *abstract*. Figure 4.3 provides the schematic connection between realms of experience and various process types that can realise that kind of experience (Fawcett forthcoming: 37).

Fawcett (1973, 1987, 1996) has written the most on the TRANSITIVITY of the Cardiff grammar. It is a model that evolved over time and is depicted in Figure 4.4 in its latest form. The first main process type is the *action*. It has been called "material process" in the past, but Fawcett returned to use the term "action" because there are many actions that are non-material, social for instance. The second main process is the *relational* one, that is subdivided into *attributive*, *possessive*, *locational*, *directional* and *matching*.

The third main distinction is the *mental* process that is divided into *emotion*, *perception* and *cognition* distinctions. *Environmental* processes, even if very rare, are

recognised as another main process type. *Influential* processes are unique to the Cardiff grammar and not accounted for elsewhere in the TRANSITIVITY system. The Cardiff grammar distinguishes the following influential processes: *starting, ceasing, continuing, succeeding, failing, causative, permissive, enabling preventing, delaying and tentative.* These processes have a structural similarity, that of having an embedded event in the matrix process, which is somehow influenced. The last process type is that of *event-relating* which is also a recent development specific to the Cardiff grammar. All the linguistic phenomena covered by this process are treated by Halliday as grammatical metaphors, but Fawcett considered they should be analysed as a distinct process type.

The TRANSITIVITY system is highly dependent on the lexical-semantics of the verbs. Therefore a broad account of verb senses and the participant configuration structures they command has to be provided in the grammar. Neale (2002) has pioneered such work in her thesis, which I introduce in the next section.

4.2.3 Process Type Database

The Process Type Database (PTDB) (Neale 2002) is the key resource in the automatic Transitivity analysis developed in this thesis and described in Chapter 9. It is also the source for creating the graph patterns used to enrich the constituency graph as described in the same chapter. The PTDB provides information on what possible process types and participants can correspond to a particular verb meaning. The PTDB is a dictionary-like dataset of verbs bound to an exhaustive list of verb senses and the corresponding Process Configuration for each of them.

This lexical-semantic database is comparable to the FrameNet (Fillmore 1982) and VerbNet (Kipper-Schuler 2005; Schuler 2005) projects, which are employed for semantic role labelling task.

In her work on PTDB Neale (2002) improved the TRANSITIVITY system of the Cardiff Grammar by systematising over 5400 senses (and process configurations) for 2750 most common English verbs. Table 4.8 presents a simplified sample of PTDB content.

The internal structure of the PTDB is detailed in Neale's PhD thesis (Neale 2002: 193–231). In present thesis only three columns are of interest for the parsing purposes: the *verb form* (1st), the Cardiff grammar *process type* (6th) and the participant role *configuration* (8th). The content of these columns is not uniform and so unsuitable for

verb form	informal meaning	process type	configuration
calculate	work out by mathematics (commission will then calculate the number of casted votes)	cognition	Ag-Cog + Ph
	plan (newspaper articles were calculated to sway reader's opinions)	two role action	Ag + Cre
catch	run after and seize (a leopard unable to catch its normal prey)	possessive	Ag-Ca + Af-Pos
	fall ill (did you catch a cold?)	possessive	Ag-Ca + Af-Pos
catch (up with)	reach (Simon tried to catch up with others)	two role action	Ag + Ra

Table 4.8 An example of records in PTDB

parsing purposes in its original form[1]. The work on normalising and cleaning up the PTDB is described in Section 9.4.

4.3 Summary

This chapter has described the grammatical units and the two system networks adopted in this work. They constitute a selection from the Sydney and Cardiff grammars that are implemented in the Parsimonious Vole parser.

Because of its bottom up approach to unit structure, rank scale relaxation and accommodation of embedding as a general principle, Cardiff systemic functional theory is more suitable for parsing than the Sydney one. Yet when it comes to grammar, Sydney variant is more preferable as the unit definitions in the Cardiff grammar are deeply semantic in nature. Parsing with such units requires most of the time lexical-semantically informed decisions beyond merely syntactic variations. This is one of the reasons why the parsing attempts by O'Donoghue (1991b) and others in the COMMUNAL project were all based on a corpus (which is not available to the current work).

In the present thesis the syntagmatic structures are built based on transformations from the Stanford Dependency grammar motivated in the first chapter. Stanford dependency relations are closely related to traditional grammar just like the Penn part-of-speech tag set, which is integrated into the dependency graphs produced by the Stanford parser. This is the reason to adapt in this thesis Sydney unit structures as they are closer to traditional grammar syntax (Quirk et al. 1985), which makes the parsing task easier.

The next chapter lays the theoretical foundations of Dependency Grammar and introduces the Stanford dependency parser, which is used as a departing point in the

[1] see Neale's page http://www.itri.brighton.ac.uk/~Amy.Neale

current parsing pipeline (see Section 1.7.4). Because there is a transformation step from dependency to systemic functional consistency structure, the next chapter also covers a theoretical compatibility analysis and how such a transformation should in principle look.

Chapter 5

Dependency grammar (DG)

The Stanford dependency analysis of a given text constitutes the input for the algorithm developed in the current work. It provides the foundation to build the syntactic backbone adopted here. The choice of Dependency Grammar was motivated in Chapter 1. This chapter offers an overview of the grammar at large and the parser developed at Stanford University. In the last part of the chapter I discuss the cross theoretical connection between dependency and systemic functional grammars.

5.1 Origins of dependency theory

A complete linguistic theory based on the dependency concept was first elaborated by the French linguist Lucien Tesniere in his seminal work *"Elements de syntaxe structurale"*, published in 1959 after his death. He devoted much effort to argue for the adequacy of *dependency* as the organisational principle underlying numerous phenomena and in fact attempted to demonstrate the universality of his syntactic analysis method for human languages. In doing so he introduced a series of concepts and ideas, among which *verb centrality*, *stratification*, *language typology*, *nuclei*, *valency*, *metataxis*, *junction* and *transfer* are the most important ones, which I introduce following the connections. Tesniere writes:

> The sentence is an *organised set*, the constituent elements of which are the words. Each word in a sentence is not isolated as it is in the dictionary. The mind perceives *connections* between a word and its neighbours. The totality of these connections forms the scaffold of the sentence. These connections are not indicated by anything. But it is absolutely crucial that

> they be perceived by the mind; without them the sentence would not be intelligible (Tesniere 2015: 3).

Tesniere holds the view that the connection, what is know today as *dependencies*, are the foundations of the *structural syntax* known as *dependency grammar* today. According to him "to construct a sentence is to breathe life into an amorphous mass of words, establishing a set of connections between them. Conversely, understanding a sentence involves seizing upon the set of connections that unite the various words" (Tesniere 2015: 4). He introduces the hierarchy of connections as follows:

> Structural connections establish *dependency* relations between words. In principle, each connection unites a superior term and an inferior term. The superior term is called the *governor*, and the inferior term the *subordinate*. We say that the subordinate depends on the governor and that the governor governs the subordinate. [...] A word can be both subordinate to a superior word and governor of an inferior word. [...] The set of words of a sentence constitutes a veritable *hierarchy* (Tesniere 2015: 5–6).

Introduction of hierarchy and governor-subordinate dependencies defines what is a *node* and the *stemma* resembling what is now known as a *dependency tree*, the only difference being that the stemmas do not include labels on the tree edges.

> [...] In principle, a subordinate can only depend on a sole governor. A governor, in contrast, can govern multiple subordinates [...] Every governor that governs one or more subordinates forms what we call a node. [...] it follows that *each subordinate shares the fate of its governor* (Tesniere 2015: 6).

Fig. 5.1 Stemma for "Alfred speaks"

This asymmetry of connection permits construction of a tree-like structure. The diagram of the two word sentence "Alfred speaks" is provided in the Figure 5.1. The word "speaks" is the governor of the word "Alfred". The connection is depicted by the vertical line connecting the two. But to make it complete, it is important to decide on the root node.

> The node formed by the governor that governs all the subordinates of a sentence is the *node of nodes*, or the central node. It is at the centre of the sentence and ensures its structural unity by tying the diverse elements into a single bundle. It can be identified with a sentence. *The node of nodes is generally verbal* [...] (Tesniere 2015: 7)

The fundamental insight presented above about the nature of the syntactic structure concerns the grouping of words at the clause level. Tesniere rejects the subject-predicate formation that was the de facto syntactic understanding of his time. He argued that this division belongs to Aristotelian logic and is not associated with linguistics. Instead of the subject-predicate division Tesniere positions the verb at the root of the clause structure making the subject and the object subordinated seedlings. Figure 5.2 depicts the clause structure "Alfred speaks slowly", where both the subject and the object are subordinated to the central verb "speaks".

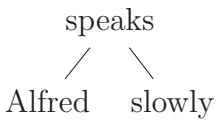


Fig. 5.2 Stemma for "Alfred speaks slowly"

Tesniere is among pioneer linguists recognising that language is organised at different levels and thus advocating a *stratified model of language*. He recognises two dimensional syntactic representation and one dimensional chain of spoken language.

> *speaking* a language involves transforming structural order to linear order, and conversely, *understanding* a language involves transforming linear order to structural order. The fundamental principle of transforming structural order to linear order involves changing the connections of structural order into the sequences of linear order. This transformation occurs in such a manner that the elements connected in structural order become immediate neighbours in the spoken chain (Tesniere 2015: 12).

In the structural realm Tesniere goes even deeper and describes the separation between syntax and semantics. To argue for that, he uses an example similar to the famous Chomskian *colourless green ideas sleep furiously* (Chomsky 1957) (that appeared three years after Tesniere's death). He employed the sentence *the vertebral silence antagonises the lawful sail*.

> Syntax is distinct from morphology, and it is no less distinct from semantics. The structure of a sentence is one thing, and the idea that it expresses and that constitutes its meaning is another. It is therefore necessary to distinguish between the structural plane and the semantic plane. [...] The structural plane and the semantic plane are therefore entirely independent of each other from a theoretic point of view. The best proof is that a sentence can be semantically absurd and at the same time syntactically perfectly correct (Tesniere 2015: 33).

Tesniere distinguishes between *nodes* and *nuclei*. Initially he defines the node in a way that resembles the phrase or a constituent but after that he changes his mind.

> we define a *node* as a set consisting of a governor and all of the subordinates that are directly or indirectly dependent on the governor and that the governor in a sense links together into a bundle (Tesniere 2015: 6).

Later in the book, he uses the term node to mean merely a vertex and even redefines it saying that "The node is nothing more than a geometric point whereas the nucleus is a collection of multiple points ..." (Tesniere 2015: 39). It is perhaps the inconsistent use of the terminology that has led to the assumption that dependency grammar does not recognises phrases but the complete sub-tree of a vertex. In fact he defines the nucleus as playing the role of both a semantic and syntactic unit:

> We define the nucleus as the set which joins together, in addition to the structural node itself, all the other elements for which the node is the structural support, starting with the semantic elements (Tesniere 2015: 38).

A notable contribution to the field of syntax is the concept of *valency* used to express combinatorial properties of verbs and other lexical items. Inspired from natural sciences, Tesniere compares the relationship between verbs and the so-called *actants* (a.k.a. *arguments*) to an atom's bonds. He writes:

> The verb may therefore be compared to a sort of atom, susceptible to attracting a greater or lesser number of actants, according to the number of bonds the verb has available to keep them as dependents. The number of bonds a verb has constitutes what we call the verb's *valency* (Tesniere 2015: 241).

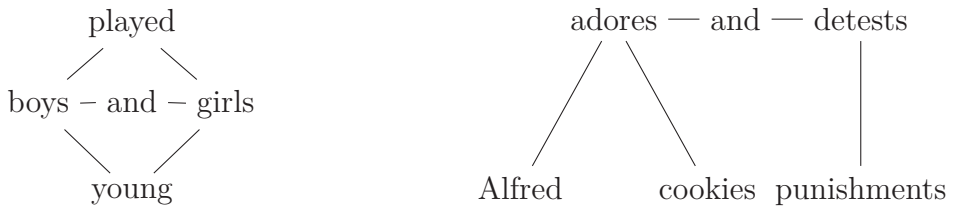
Atoms are not the only metaphor he uses and next I present another regarding the *verbal node* that is especially important for showing the syntax-semantics interplay.

> The verbal node, found at the centre of the majority of European languages, is a theatrical performance. Like a drama, it obligatorily involves a *process* and most often *actors* and *circumstances*. [...] Transferred from the theatre to structural syntax, the process, the actors, and the circumstances become respectively the *verb*, the *actants*, and the *circumstants* (Tesniere 2015: 97).

Comparison of the verb to an atom seems to emphasise connection to the syntactic aspect of valency while comparing it to a theatrical performance seems to emphasise the semantic properties of valency. Therefore his theory of valency has semantic and syntactic properties. He believed that the first actant is the agent of the action, identified as the subject in traditional grammar, and the second actant is the one that bears the action, identified as the syntactic object. Tesniere regards both of them as complements to complete the governor verb making, in this respect, the subject indistinguishable from other complements.

There are some phenomena that are deemed quite problematic for dependency grammar, namely *coordination* or *apposition*, requiring extension of the theory of grammar with a new concept. They constitute a challenge because they are not governor-subordinate relations but are rather orthogonal relations among siblings. Tesniere analyses coordination, or as he calls it *junction*, as a phenomena used in language to express (semantic) content efficiently.

He viewed junction as fundamentally different from subordination and represented it with horizontal lines. Subordination is a principle of organisation on the vertical axis whereas coordination (i.e. junction) is on the horizontal axis. Figure 5.3 depicts two example representations for the sentence "Young boys and girls played" and "Alfred adores cookies and detests punishments".



(a) Young boys and girls played (b) Alfred adores cookies and detests punishments

Fig. 5.3 Sample stemmas with *junction* representation

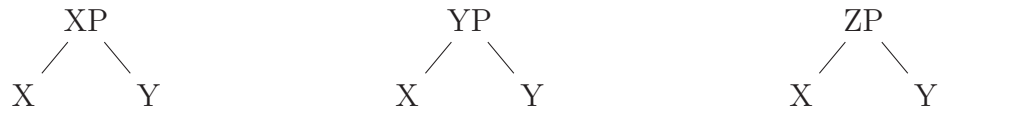
A big part of Tesniere's *Elements* (Tesniere 1959) is dedicated to the theory of *transfer*. It describes the phenomena when one class of a syntactic unit, called source

unit, takes the function usually devoted to another one, called target unit. One says that the source category is (functionally) transferred into the target category. In SFL this is called grammatical metaphor as defined in Definition 3.2.9. For example, the noun can be transferred to an adjective by preposition "of" and modify another noun, which is normally a function fulfilled by an adjective. For example in *a linguist of France* the proper noun *France* is transferred by preposition "of" into *of France* which modifies the noun *linguist* (typically an adjectival function). Transfer is a tool that explains how for example a clause can be embedded into another one or how a verb can be subordinate to another verb.

Tesniere divides words into *function words* or *translatives* (i.e. prepositions, conjunctions, auxiliary verbs and articles) and four basic categories of *content words* (i.e. verbs (I), nouns (O), adverbs (E) and adjectives (A)). The former are empty of content and primarily mark the transfer of content words from one syntactic category to another one. That is, allowing one word to take a function that is generally associated with a word of another category.

One distinguishing trait of the transfer is that the words transferred from source to target category continue to behave as the source category with respect to their dependants and as source category to its governor.

The transfer theory was controversial for the translators of the Elements. They write (Tesniere 2015: liv-lx) that while the transfer schema can not be interpreted in terms of pure dependency, it is debatable whether it can be interpreted in terms of constituency. The main distinction is in the number of nodes that one assumes to be in the syntactic structure, i.e. whether there are intermediary "virtual" nodes.



(a) Headed endocentric (b) Headed endocentric (c) Non-headed exocentric

Fig. 5.4 Constituency structure

Figure 5.4 shows how a sequence of two elements of classes X and Y can be represented in terms of constituency forming a "virtual" phrase node P. Here Figures 5.4a and 5.4b represent that one element governs the other. Such structures are called *endocentric* because the phrase class information is provided from within. In Figure 5.4c is represented a non-headed structure called *exocentric* because the class information is decided based on criteria independent of X and Y.

(a) Headed endocentric (b) Headed endocentric (c) Non-headed exocentric

Fig. 5.5 Dependency structure

The same situation for the elements X and Y can be expressed in terms of dependency structures. One consequence is that only headed structures can be represented. Figure 5.5 shows that non-headed structures cannot be represented. Hence there is no correspondent dependency representation to Figure 5.4c in Figure 5.5c. Another consequence is that there is no need for "virtual" phrase nodes and the concept of exocentricity vanishes completely.

Bringing back the discussion on the number of nodes, the constituency structure requires three nodes each time whereas dependency structure requires only two. In this sense the transfer schemes provided by Tesniere in his Elements (Tesniere 1959) resemble constituency structure more than dependency structure simply because it assumes more nodes than words.

5.2 Evolution into modern dependency theory

Nowadays dependency theory has evolved and differs from the original one presented by Tesniere. At the time the original text was written there was no such distinction as dependency and constituency structures and Tesniere's Elements (Tesniere 1959) in fact contains descriptions of and references to what may nowadays be considered constituency. Next I present which of the initial ideas did not take hold, were not addressed or merely assumed and instead have evolved into the modern dependency theory of grammar.

5.2.1 Definition of dependency

Tesniere's definition of dependency is not falsifiable. His mentalist approach that "the mind perceives connections between the word and its neighbours" (Tesniere 2015: 3) makes it impossible to falsify his choices hence leaving no means to validate one choice over the other ones. One may argue that such a mentalist approach may not be unrealistic provided the existence of a considerable volume of data from psychological experiments. So far, however, there are no known datasets reflecting a mentalist

grounding of the dependency relations and so I resort to other definitions provided below.

One way to define dependency relations and structure is by employing the constituency concept. There are efforts by Bloomfield (1933), Hockett (1958) and Harris (1951) in constituency grammar to identify constituents using tests that shed light on which segments should hold together as phrases or whether they should be considered constituents at all. One needs to decide within a constituent which word heads which other words. This means deciding which word controls the distribution of elements in that constituent (Bloomfield 1933; Zwicky 1985). A word Y depends on a word X if and only if Y heads a phrase which is an immediate constituent of the phrase headed by X (Lecerf 1961).

Another way to define dependencies, avoiding constituency, is by using combinations of two words as proposed by Garde (1977) and Mel'čuk (1988). To discern which word governs the other, one must describe which word determined the distribution of the two words taken together. This way the governor is the word that determines the environment in which the two together can appear (Tesniere 2015: lxi). In fact, the word notion is not necessary to define dependency, it can be abstracted away to the notion of syntactic units. As soon as two units combine one can posit dependency between them whereby the dependency structure is the set of dependencies between the most granular syntactic units (Gerdes & Kahane 2013). This approach is the modern widely adopted way of defining dependencies.

In addition Tesniere did not make distinctions between the dependency types. As discussed in the previous section, he had noticed that there is a difference between syntactic and semantic dependencies and that the former generally correspond to the latter but not as a strict rule and even some other times the correspondence is in the opposite direction, e.g. "the stone freezes" vs. "the frozen stone". Dependency based semantic representations have been around since the 1960s in the form of *semantic networks* (Mel'čuk 1988; Žolkovskij & Mel'čuk 1967) and *conceptual graphs* (Schank 1969; Sowa 1976).

5.2.2 Grammatical function

In modern linguistics the notion of grammatical functions (e.g. subject, object, determiner etc.) are attached to the notion of syntactic dependency. They are in fact an essential account in modern dependency-based approaches because they are the only way to distinguish between various roles the dependents play in relation to their governors. The grammatical functions attached to the dependency relations are primitives

of these dependency grammars. This is not the case for Chomskian phrase structure constituency where the functions are derived from the structural configurations. Nevertheless in constituency models such as *Lexical Functional Grammars* (Bresnan et al. 2015) and *Head-Driven Phrase Structure* (Pollard & Sag 1994) grammatical functions have been introduced as grammatical primitives.

Grammatical functions were not important in Tesniere's theory. He mentioned only, in the context of valency theory, three *actant functions* called *first*, *second* and *third*, the other verb dependants being *circumstantial*. Most dependency grammars assume dozens of functions to offer a fine-grained syntactic characterisation of language based on distinguishable syntactic properties. This way two elements have the same grammatical function if and only if they have the same *markers, order* (linear position), *agreement properties* and *distribution*. Several grammatical function sets have been developed in the fields of formal dependency grammars, parsers and tree-banks. The most important ones for English are the ones of Mel'čuk & Pertsov (1986), of Johnson & Fillmore (2000) and of Marneffe & Manning (2008a,b). In this thesis the latter is employed as it is part of the Stanford dependency parser described later in this chapter.

5.2.3 Projectivity

Central to how word order is accounted for in dependency grammar is *projectivity*. It is not present in the Elements but it is the basis for identifying *long-distance dependencies*, also known as *discontinuities* or *gapping*. The concept is introduced by Lecerf (1961) following publication of the Elements (Tesniere 1959). It is defined in terms of crossing lines when drawing dependency trees. The trees that do not contain crossing lines are called *projective* and the trees with crossing lines are called *non-projective*, i.e. violating the projection principle.

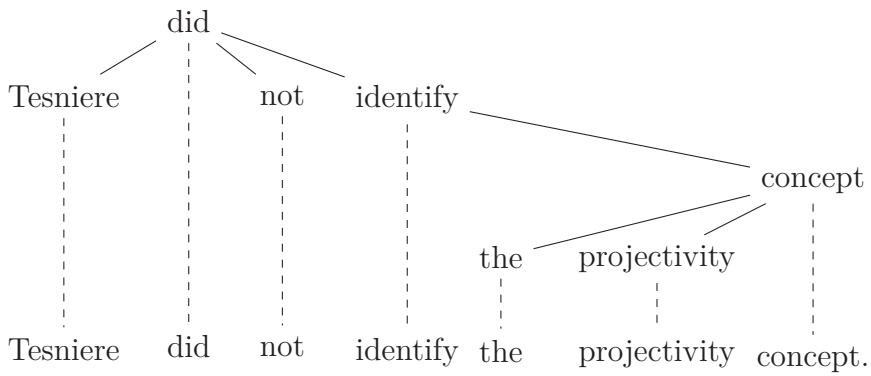


Fig. 5.6 Projective tree

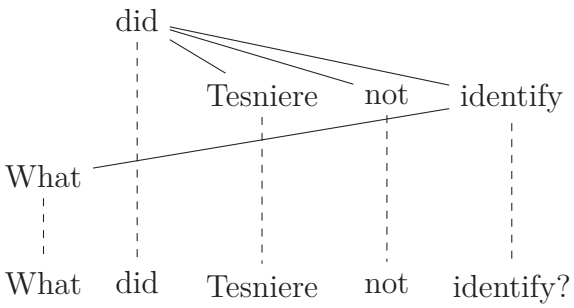


Fig. 5.7 Non-projective tree

To illustrate this principle consider Figure 5.6, where there are no crossing lines, and Figure 5.7 contains a projectivity violation because the word "what" is connected to its governor "identify" crossing three dashed projection lines. Linguistic phenomena involving non-projecting trees are: wh-fronting, topicalisation, scrambling, and extrapolation.

5.2.4 Function words

Tesniere's transfer theory, despite it's insightfulness, has little if any application in modern dependency grammar. The main reason is the implications it has for hierarchical structures. Transfer theory deprives the *translatives* (prepositions, auxiliary verbs, sub-ordinators and conjunctions) of their autonomy in the dependency tree, giving them a secondary status. As a consequence, they cannot be constitutive elements of a nucleus. The issue is reduced to the hierarchical status of such translatives as to whether they gain node status or not. I exemplify this below.

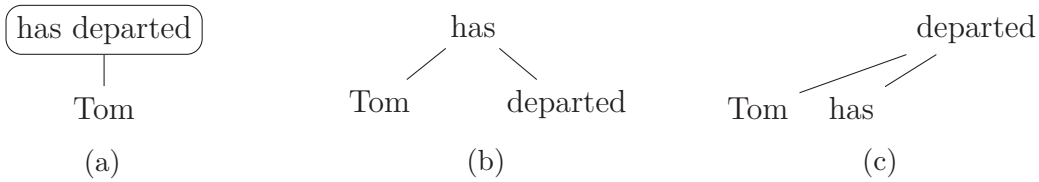


Fig. 5.8 Possible analysis representation for "Tom has departed"

Figure 5.8 represents three possible ways to analyse the word "has" in "Tom has departed". In Figure 5.8a the original approach Tesniere proposed is represented using transfer schema where the word "has" is enclosed within the full verb node "departed". The two together are granted the status of a dissociated nucleus, which means that neither alone can form a nucleus. In contrast, in Figure 5.8b and 5.8c the auxiliary "has" is granted autonomy and corresponds to what many modern grammars assume insofar.

The important thing to acknowledge here is that syntactic autonomy is conferred on the translatives contrary to what Tesniere originally proposed.

As we will see in the next section, the Stanford dependency schema (Marneffe & Manning 2008a,b) adopts content words as governors for the function words. This corresponds to the representation in Figure 5.8c. As a consequence the path between content words is shorter and uninterrupted yielding benefits in many applications.

Moreover, as we will see in Section 5.4, the Stanford dependency grammar develops further this concept and provides an additional "collapsed" schema where the function words are suffixed to the grammatical functions. For example, in "Bob and Jacob" there is a "conj" dependency relation between Jacob and Bob and a "cc" relation between "and" and "Bob". In the collapsed form the relation becomes "conj:and" between Jacob and Bob integrating the conjunction into the relation name. This is the case for prepositions and conjunctives whereas auxiliary verbs remain nodes in the collapsed form.

5.3 Dependency grammar in automated text processing

Tesniere had no intention of providing a computational theory of grammar and he was not aware that ideas he was proposing have such potential. Shortly after his death, inspired by Chomsky's Syntactic Structure (Chomsky 1957), Hays (1960, 1964) made the first attempts to formalise dependency grammar with the intention to apply it to automated text processing. A year later his colleague Gaifman (1965) showed that the *dependency grammar* formalism proposed by Hays is equivalent to Chomsky's *context free grammar* and to *categorial grammars* proposed by Bar-Hillel (1953).

Outshone by Chomskyan grammars, serious developments in parsing with dependency grammars did not come into being until the mid 1990s. A first efficient parser with a dependency-based model, called *Link Grammar*, was created by Sleator & Temperley (1995) and ten years later dependency parsing gained in popularity further yielding remarkable results such as the MaltParser (Nivre 2006; Nivre et al. 2007b), MATE parser (Bohnet 2010) and the early Stanford parser (Marneffe et al. 2006) that was generating dependency trees from phrase structure trees. A summary of dependency parsing techniques is provided by Kübler et al. (2009).

In parallel to parsers, large annotated corpora and treebanks have been developed for parser training and testing and are suitable as well for theoretical applications. A *treebank* is a collection of records consisting of natural language sentences associated

with corresponding syntax trees (using a specific grammatical model) and optionally additional annotations such as part of speech tags, named entities, and other annotations. The first treebank was the Penn Treebank (Marcus et al. 1993; Santorini 1990), which is a constituency-base treebank. A well known dependency treebank is the Prague Dependency Treebank (Böhmová et al. 2003; Hajic et al. 2001), originally created for Czech but now including English as well.

Recently an initiative to create a Universal Dependency model (Nivre 2015) started. The aim is to create uniform language independent dependency grammar. This initiative is extended by efforts to create multilingual treebanks using the the universal dependency scheme (Nivre et al. 2016). Version 2.3 of the Universal dependencies grammar model has been released[1] in association with 129 treebanks in 79 languages. These efforts continue today.

Before arriving at the now broadly accepted Universal Dependency framework, early dependency grammars were quite diverse. The schemes more often were developed in the context of corpus annotation. An early work (Carroll et al. 1998) towards unification was conducted within the Grammar Evaluation Interest Group (Harrison et al. 1991), also known as the *PARSEVAL* initiative, originally aimed at constituency parsers. Carroll et al. (1999) proposed an application-independent corpus annotation scheme (see Figure 5.9) specifying the syntactic dependency holding between each head and its dependent(s) that took into account language phenomena in English, Italian, French and German.

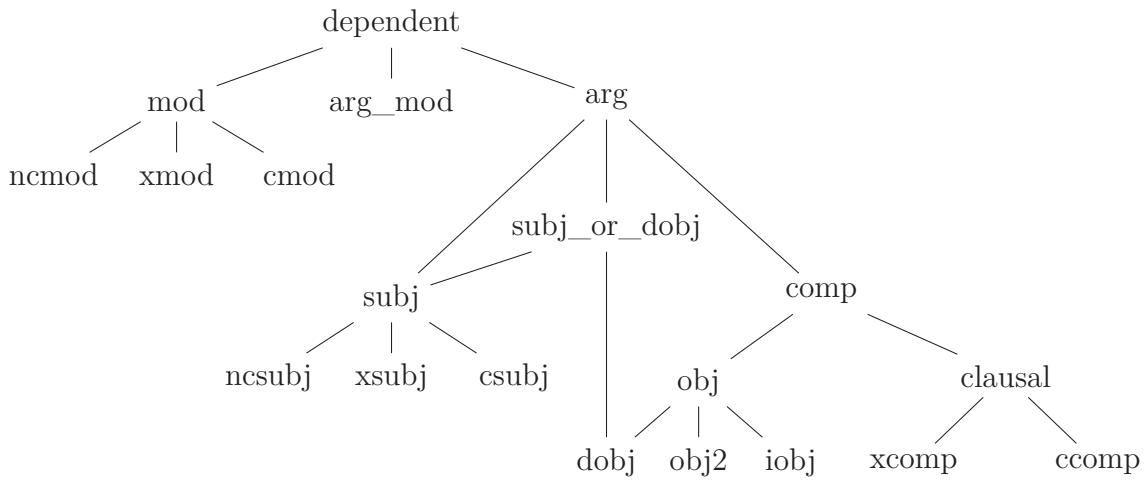


Fig. 5.9 The grammatical relations (GR) hierarchy from Carroll et al. (1999)

[1] see https://universaldependencies.org/

In the early 2000s the existing treebanks were still inadequate for evaluating the predicate-argument structure of English clauses. To address this problem, the PARC 700 treebank (King & Crouch 2003) was created by randomly extracting 700 sentences from the Penn treebank, parsing with a Lexical Functional Grammar (LFG), and converting into dependency relations manually corrected by human validators. This scheme has played a role in the creation of the Stanford dependency model that I detail below.

One convenient feature of dependency representations is that they can be encoded in a tabular format such as CoNLL (Nivre et al. 2007a), which is now adopted as a standard representation. It is employed in a recurring open competition called the "CoNLL shared task" launched for improving and innovating dependency parsing methods. The most notable are the ones from 2006 on dependency parsing (Buchholz & Marsi 2006) followed in 2007 with a track for multilingual and one for domain specific dependency parsing. By 2017 (Zeman et al. 2017) the task was parsing from raw text (as previous ones were lemmatised and annotated with part of speech information) into universal dependency representation.

5.4 Stanford dependency model

Dependency descriptions are functional in nature and this is precisely the aspect which makes possible the beneficial link between the Stanford Dependency Grammar and the Systemic Functional structures targeted in the current thesis.

The Stanford parser is one of the leaders in the domain of dependency parsing. Between 2006 and 2015 Stanford parser (Marneffe et al. 2006) implemented the Stanford dependency model for English (and a few other languages). Then in 2016 Nivre et al. (2016) proposed the language independent Universal Dependency scheme which was afterwards integrated into the Stanford Parser. Around 2015-2016 the Parsimonious Vole parser was developed based on the Stanford dependency model. No transition to universal dependency was considered at that time because neither the scheme was not mature and stable enough. For this reason, the current thesis employs the legacy Stanford grammar, which I present in this section. A transition to universal dependency model is considered for future work.

The design of the Stanford dependency set (Marneffe et al. 2014, 2006; Marneffe & Manning 2008a; Silveira et al. 2014) bears a strong intellectual debt to the framework of Lexical Functional Grammars (Bresnan et al. 2015) from which many relations were adopted. Marneffe et al. (2006) departs from the relation typology described

in Carroll et al. (1999) which was employed in the PARSEVAL initiative (Harrison et al. 1991) and from the grammatical relations of the PARC 700 (King & Crouch 2003) scheme following a style of Lexical Functional Grammar. Marneffe arranges the grammatical relations into a hierarchy rooted in a generic relation *dependent*. This is then classified into a more fine-grained set of relations that may hold between a head and its dependent following the set of principles (Marneffe & Manning 2008b) stipulated in Generalisation 5.4.1.

Generalisation 5.4.1 (Design principles for the Stanford dependency set)**.**

1. Everything is represented uniformly as binary relations over pairs of words.
2. Relations should be semantically contentful and useful to NLP applications.
3. Where possible, relations should use the notions of traditional grammar (Quirk et al. 1985) for easier comprehension by users.
4. To deal with text complexities, underspecified relations should be available.
5. When possible, content words shall be connected directly, not indirectly mediated by function words (prepositions, conjunctions, auxiliaries, etc.).

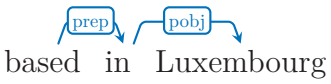
When motivating this approach to schema development, Marneffe et al. (2006) insist on practical rather than theoretical concerns, proposing that structural configurations be defined as grammatical roles (to be read as grammatical functions) (Marneffe et al. 2006). In the Chomskian tradition (Chomsky 1957) the grammatical relations are defined structurally as configurations of phrase structure. Other theories, such as Lexical-Functional Grammar, reject the adequacy of such an approach (Bresnan et al. 2015) and advocate a functional representation for syntax. Following the latter approach, Marneffe insists that information about functional dependencies between words is very important and should be explicitly available in the dependency tree.

The advantage of explicit relations is that the predicate-argument relations are readily available as edge labels in the dependency structure and can be used off the shelf for real world applications, which was an important goal in the schema design. The grammar had to be suitable for parsing within the context of syntactic pattern learning (Snow et al. 2005), relation extraction, machine translation, question answering and inference rule discovering (Lin & Pantel 2001), domain specific parsing (Clegg & Shepherd 2007), and others. The complete set of dependency relations adopted is given in Appendix B.

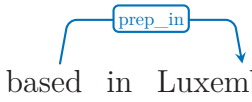
5.5 Stanford dependency representation

The Stanford Dependency Parser generates four types of dependency representations. It produces parse trees with *basic dependencies*, *collapsed dependencies* and *collapsed dependencies with propagation of conjunct* that are not necessarily a tree structure, and finally the *collapsed dependencies that preserve a tree structure*. The variant employed in the current work is the collapsed dependencies with propagation of conjunct. This structure concerns preposition, conjunction and relative clause referent nodes, and is generated by a series of transformations after the initial basic dependency parse is ready.

For example, consider the fragment "based in Luxembourg". In basic dependency representation, such as is shown in Figure 5.10a, the function words govern the content words and thus there is a preposition (prep) edge from "based" to a dependent preposition "in" from which continues a preposition object edge (pobj) to "Luxembourg". In the collapsed dependency representation the relation sequences of the type "prep-pobj" are replaced by a direct edge between the two content words labelled with the "prep" function concatenated with the intermediary preposition as can be seen in Figure 5.10b. There is a single relation between "based" and "Luxembourg" labelled "prep_in". Similar transformations are done for conjunctions.



(a) Basic (uncollapsed) preposition dependency



(b) Collapsed preposition dependency

Fig. 5.10 Function words in the Stanford dependency model

Besides collapsing prepositions and conjunctions, the dependency structure is further processed to introduce more relations even if they break the tree structure. Relative clauses are such a case where the tree structure is broken. Consider Figure 5.11a where the relative clause is introduced by a relative clause modifier relation (rcmod) from the noun "Nina" to the main verb of the relative clause "coming". The clause contains an interrogative pronoun "who" functioning as nominal subject (nsubj) and which anaphorically resolves to the clause governor "Nina". This sort of information about the antecedent of the relative clause is also introduced in the collapsed dependency representation. And thus, as depicted in Figure 5.11b, a new referent relation is added connecting "Nina" to the subordinate subject "who" of the relative clause.

(a) Basic (uncollapsed) relative clause (b) Collapsed relative clause

Fig. 5.11 Relative clause in Stanford dependency model

There are other language phenomena similar to relative clauses that break the tree structure in the collapsed dependency representation by introducing either cycles or nodes with multiple governors. This is the reason why often in this thesis the references are to dependency graphs and not trees. In fact the fundamental assumption here is that the dependency structures are graphs with a root node. I further develop this assumption in Chapter 7. Nevertheless additional or direct relations between content words (moving accounts of the function words into the graph edges) increase the usability of the dependency graphs for various purposes, including the present parse method which is detailed in Chapter 8.

5.6 Cross theoretical bridge from DG to SFG

This section aims at establishing cross-theoretical links between the Dependency theory of grammar and the Systemic Functional theory of grammar. This cross-theoretical bridge is necessary as a fundamental principle for further deriving transformation rules from a dependency representation into a systemic functional one. Such rules are then enacted in the parsing pipeline for creating the systemic constituency structure which is the aim of this thesis and is detailed in Chapter 8.

Let's recap what dependency relations are in Dependency theory and in Systemic Functional theory of grammar. In the Dependency theory of grammar, as we saw in Section 5.1, the dependency relations are conceptualised as connections between neighbouring words that stand in governor (superior) and subordinate (inferior) relations to each other, also referred here as *parent-child* relations.

In SFL the concept of dependency is less salient than the foundational role it plays in Dependency theory. Dependency relations are regarded as orthogonal relations between sibling elements of a unit (Figure 5.13b) and link *heads* to their *modifiers* in Hallidayan *logical structure* (Halliday & Matthiessen 2013b: 388), which was discussed in Section 3.4.1. The reason why the elements are siblings and *not* subordinated is due

to a *componence*-based conceptualisation of the unit structure (see Section 3.3.4) as a part-whole linearly ordered set of elements. In SFL, componence, together with filling, embedding and expounding are constituency relations. In this view subordination is replaced by the componence relation between the element and the unit it is part of and hence makes the elements siblings of equal status. Yet one element, the head, plays a special pivotal role for the unit (defined in Section 3.3.2 and discussed in Section 3.4.5) that, in the Sydney grammar, is the Head/Thing, or Head, Apex, Main Verb, etc. in the Cardiff grammar.

(48) The witness seemed quite convincing.

Consider Example 48 whose representation as a dependency structure is depicted in Figure 5.12 and as a Systemic Functional constituency structure in Table 5.1. In Figure 5.12 the structure starts with a root node "seemed" from which two relations emerge: subject (nsubj) to "witness" and an open clausal complement (xcomp) to "convincing".

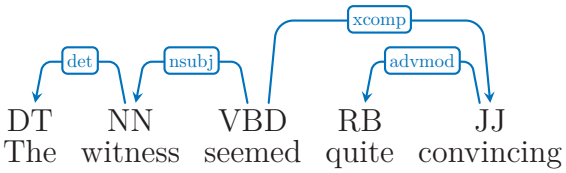


Fig. 5.12 Dependency representation

The	*witness*	*seemed*	*quite*	*convincing*
clause				
Subject		Main Verb	Complement	
nominal group		verb	adjectival group	
Deictic	Head		Temperer	Apex
determiner	noun		adverb	adjective

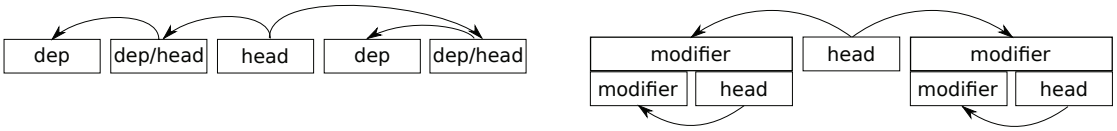
Table 5.1 Example of head-modifier sibling dependency

In Table 5.1, the corresponding structure is a root clause unit composed of three elements: a Subject, a Main Verb and a Complement. The Main Verb is the pivotal element heading the clause unit, which means that inconspicuous dependency relations hold from the Main Verb to the Subject and to the Complement. The Subject and Complement are filled by a nominal and, correspondingly, an adjectival group, whereas the Main Verb Element is expounded with a verb item "seemed". This observation is expressed in generic terms by Generalisation 5.6.1.

Next, in Figure 5.12, the determiner relation (det) between "witness" and "the" is similar to the "subj" holding between a governor and a subordinate. The corresponding constituency structure is that of a nominal group unit with a Head and a Deictic element. One exception, though, is that the governor also functions as subordinate in another relation and thus has an incoming edge. This dual role of a node has far reaching consequences in the constituency structure. Having an incoming dependency relation corresponds, in constituency structure, to the filling relation between an element of a unit and the unit of the rank next below. Here, the node "witness", acting as a subordinate to the "seemed" node, fills the Subject element of the clause. In fact, the dependency node "seemed" projects into constituency structure the expounding relation between the lexical item and the element of the clause.

In a nutshell, what we see is that the parent-child dependency relations in Dependency structure unpacks into multiple relations in the Systemic Functional structure: the componence relation between unit and element, the filling relation between elements and units of the lower rank, the identification of the head of a unit element (a.k.a. the pivotal element) and, the (indirect) sibling head-modifier relation.

On the other hand, if we focus on the underlying plain dependency relations between head and dependent we can notice a perfect isomorphism between the two structures. To illustrate this lets reduce the node labels to "head" and "dep" which will correspond, in the dependency representation, to parent (governor) and daughter (subordinate), and in constituency representation, to head and modifier siblings.



(a) Parent-child relations

(b) Sibling head-modifier relations

Fig. 5.13 Plain dependency relations in Dependency and Systemic Functional representation

Figure 5.13 illustrates side by side the parent-child and sibling dependency relations in a simplified form. In Figure 5.13a, dependencies are the only relations between the units of structure, whereas in Figure 5.13b, there are two levels (ranks) of units where the dependency relations are relevant only between sibling elements at the same level within the structure of a unit. As we have seen in Chapter 3, knowing only the unit elements is not enough to construct the constituency structure, but it is informative enough for deducing the missing parts. What Figure 5.13 illustrates is that the two structures resemble each other in a suggestive fashion that will be used below to construct a bridge between descriptions.

The intuitions from the above examples can be laid out by and large in Generalisations 5.6.1 – 5.6.3. Here I use the term *projection* to refer specifically to the correspondences between theoretical primitives of the two grammars. We say that a primitive in theory A is projected as another primitive in theory B. In this case the considered projections are from the Dependency theory of grammar into the Systemic Functional theory of grammar. The first generalisation is on maximally accounting for the dependency nodes in constituency structure.

Generalisation 5.6.1 (Structural Completeness)**.** Each node of the dependency representation is projected, in the constituency representation, into one or more units and one or more elements at different rank scales.

When translated to a constituency unit, the dependency node stands for a unit as a whole, the head element of that unit and the word expounding that element. For example, the root verb "seemed" in a dependency graph corresponds to the clause node and, the Main Verb element and the lexical item which fills the Main Verb of the clause. By analogy, the node "witness" stands for the nominal group, the head noun of a Nominal Group and fills the head element of the group. Even functional words such as prepositions that in collapsed dependency representation remain orphaned (see Figure 5.10b) have to be accounted for in the constituency structure.

Generalisation 5.6.2 (Functional Projection)**.** Each dependency relation (alone or contextualised by the word classes of the related nodes) is projected into the element of the unit corresponding to the subordinate node.

Generalisation 5.6.2 means that a dependency relation, in a dependency graph, is primarily responsible for determining the choice of a unit in the systemic functional constituency structure. For example the "nsubj" dependency relation will be projected into a Subject element of a clause unit. Sometimes however, as stated in Generalisation 5.6.2, the dependency relation alone is not enough and the context given by the governor and subordinate nodes is needed to choose the element. For example the adverbial modifier (advmod) relation alone is not enough to determine into which element to project the subordinate. If the word class context is considered then, in Figure 5.14, the verb-to-adverb "advmod" relation (VB-advmod-RB) is projected into an Adjunct while the adjective-to-adverb "advmod" relation (JJ-advmod-RB) is projected into Temperer.

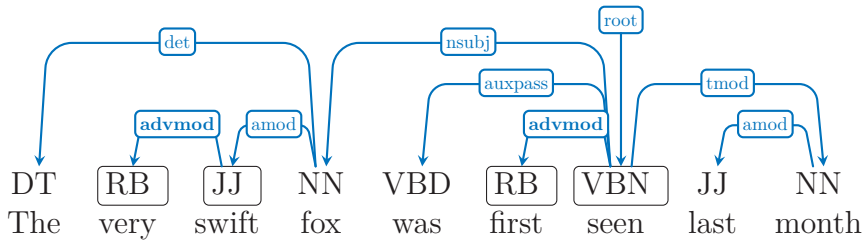


Fig. 5.14 The "advmod" relation in different word class contexts

Generalisation 5.6.3 (Substantial Projection)**.** Each dependency node projects either the filling or expounding of an element, by a unit of the rank below or by the lexical item of the node.

Generalisation 5.6.3 provides the link between the projected unit and the element of the rank above. For example, let's return to analysis from Figure 5.12 and Table 5.1. There the node "witness" subordinate to the node "seemed" by the "nsubj" relation (nominal subject) is responsible for projecting the class of the unit filling Subject element of the clause. The projected class into the Subject element is that of nominal group headed by the "witness" node because it is the governor (of the node "the"). The governor "seemed", as the root of the tree, is projected into a lexical item which expounds the Main Verb - the pivotal element of the clause. In a similar manner, the determiner (det) relation from the governor "witness" to the subordinate "the" is projected into a lexical item expounding the Head element (of the nominal group).

some	*very*	*small*	*wooden*	*ones*
nominal group				
Quantifying Determiner	Epithet		Classifier	Head
	quality group			
	Temperer	Apex		

Table 5.2 SF analysis of Example 22 (reproduced from Table 3.5)

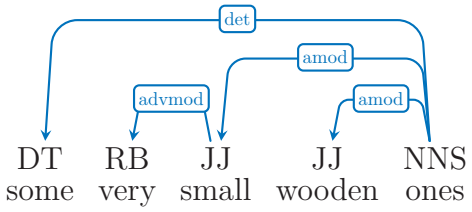


Fig. 5.15 Dependency analysis for Table 5.2

Figure 5.15 and Table 5.2 represent the analysis of a nominal group from Example 22 ("some very small wooden ones") in SFG and the Stanford dependency grammar, and serve as a second example for Generalisation 5.6.3. Consider the dependency relation "det" acting as a link between the noun "ones" and the determiner "some". When translated into the SF variant the dependency relation stands within the nominal group between the Head element (filled by word "ones") and the Quantifying Determiner element (filled by the word "some"). As mentioned earlier, all the elements in a unit are equal in the structure so the Head and Quantifying Determiner are siblings. So the items (words) filling those elements are also siblings. How then is the dependency relation established?

Lets look at a another example of two consecutive relations, the "advmod" from "small" to "very" and "amod" from "ones" to "small" in Figure 5.15. The interesting case here is the item "small" which is the head (Apex) of the quality group. It anchors the meaning of the whole group and the quality group fills the Modifier/Epithet element within the nominal group. What is not covered in the previous example is that the Apex "small" not only is a representative of the entire group but it is also suitable filler on its own for the Epithet (Modifier) element within the nominal group. Using a similar translation mechanism as above, this means that, the incoming dependency needs to be unpacked into three levels: the Epithet (Modifier) element within the current group, the unit class that element is filling (quality group) and finally the pivotal element, i.e. Apex (Head), of the filler group. In fact, to be absolutely correct there is one more level: the elements of a unit are expounded by lexical items, so a fourth relation to unpack is the expounding of the Apex by the word "small".

I have just described how the dependency relation in dependency structure (Figure 5.13a) can be unpacked into compounding elements of a unit (Figure 5.13b) corresponding to the sibling dependency considered as an indirect relation between the Head and the Modifier (in the Logical metafunction); and then from that, using Generalisations 5.6.1 – 5.6.3, deduce the rest of the constituency structure such as the componence relation between unit head and the compounding elements and the filling/expounding relation between the element and the unit below.

The projection from dependency grammar into systemic functional grammar is implemented as a traversal of the dependency graphs and creation in parallel of a systemic functional constituency structure. To achieve in practice the above mentioned level of unpacking (of the dependency relations and their context) two traversals are needed: a bottom-up and a top-down one. This is because the traversal sequence also creates a context that deals with either instantiation of a new unit and establishing

its elements or with filling an element of a unit above. More on how to enact the cross-theoretical links described this chapter will be provided in Section 8.3.

As motivated elsewhere, I will present an account for the unrealised, covert (Null) elements in syntactic structure, using the Government and Binding Theory. This will also be subjected to a similar cross-theoretical projection discussion giving formalisation and implementation descriptions.

Chapter 6

Government and Binding Theory (GBT)

Transitivity analysis in SFL is similar to what *semantic role labelling*, *thematic* or θ *role analysis* means in several other theories. This thesis provides, in Chapter 9, an account of how to perform SF Transitivity parsing resulting in a configuration of a process, participants and circumstances. For an illustration take Example 49 whose Transitivity analysis is given in Table 6.1. Here the entire clause is analysed as a Possessive configuration governed by the verb "receive" where "Albert" plays the *role* of the Affected-Carrier and "a phone call" is the thing being Possessed. Note that, for brevity, in this section, the box analysis such as that from Table 6.1 is simplified omitting the unit classes and providing the functional elements only.

(49) Albert received a phone call.

(50) He asked to go home immediately.

Albert	*received*	*a*	*phone*	*call*
Possessive configuration				
Affected Carrier	Process	Possessed		

Table 6.1 Transitivity analysis with Cardiff grammar of Example 49

Example 50 is slightly more complex and illustrates the main motivation behind the current chapter. It is analysed in Table 6.2, according to the Cardiff grammar, as a Three Role Cognition configuration with "ask" being the process, "he" the Agent and "to go home immediately" the cognised Phenomenon. The Phenomenon is filled by a non-finite clause "to go home immediately" which is, in the Transitivity account,

a Directional configuration governed by the verb "go" and has as participants the Destination "home" and the Agent Carrier in an empty Subject position that is said to be *non-realised*, *empty*, or *covert*. This is a case when the empty constituent is recoverable from the clause above and corresponds to the Subject "He". This way, the constituent "He" plays two roles: first as Agent in the Cognition process of the top clause and second as Agent Carrier in the Directional process of the embedded clause. In this work, the way to assign a second role coming from the lower clause is by detecting and making explicit the empty constituents and resolving them locally with a link to the corresponding antecedent constituent.

<table>
<tr><td>He</td><td>asked</td><td>[empty subject]</td><td>to</td><td>go</td><td>home</td><td>immediately</td></tr>
<tr><td colspan="7">Three Role Cognition configuration</td></tr>
<tr><td>Agent</td><td>Process</td><td colspan="5">Phenomena</td></tr>
<tr><td colspan="2"></td><td colspan="5">Directional Configuration</td></tr>
<tr><td colspan="2"></td><td>Agent-Carrier</td><td></td><td>Process</td><td>Destination</td><td></td></tr>
</table>

Table 6.2 Transitivity analysis with Cardiff grammar of Example 50

In language there are various cases where constituents are empty but recoverable from the immediate vicinity relying in most cases on syntactic means although in a few cases additional lexical-semantic resources are required. The mechanisms of detecting and resolving the empty constituents are captured in Government and Binding Theory (GBT) developed in Chomsky (1981, 1982, 1986) and are based on phrase structure grammar. GBT explains how some constituents can *move* from one place to another, where the places of *non-overt constituents* are and what constituents they refer to i.e. what are their *antecedents*.

The GBT approach explains grammatical phenomena using *phrase structures* (PS). This is more distant from SFG than the approach taken by the dependency grammar. Section 6.2 briefly introduces the theoretical context of GBT and then formulates the principles and generalisations relevant for the current work. Then Section 6.3 translates the introduced principles and generalisations into Dependency Grammar rules and patterns. To lay the ground for these two sections, I first place GBT into the context of transformational grammar and introduce the basic concepts.

6.1 Introduction to GBT

This section is set as as introduction to the fundamental concepts from Government and Binding Theory. GBT belongs to the family of Transformational grammars

(TG) or transformational-generative grammars (TGG). It is part of the theory of generative grammar that considers grammar to be a system of rules that generate exactly those combinations of words which form grammatical sentences in a given language (Chomsky 1965). TG involves the use of defined operations called transformations to produce new sentences from existing ones.

Chomsky developed a formal theory of grammar (Chomsky 1956) where transformations manipulated not just the surface strings, but the parse tree associated with them, making transformational grammar a system of tree automata (Stockwell et al. 1973).

A transformational-generative (or simply transformational) grammar thus involved two types of production rules: *phrase structure rules*, such as "S -> NP VP" (meaning that a sentence may consist of a noun phrase followed by a verb phrase) etc., which could be used to generate grammatical sentences with associated parse trees (phrase markers, or P markers); and *transformational rules*, such as rules for converting statements to questions or active to passive voice, which acted on the phrase markers to produce further grammatically correct sentences (Bach 1966: 59-66). This notion of transformation proved adequate for subsequent versions including the "extended", "revised extended" and Government-Binding (GB) versions of generative grammar, but is no longer compatible with the latest "minimalist" grammar (Chomsky 1993a), which for example disposes of the concept of government. The minimalist programme introduces a set of formal definitions that go beyond tree manipulation. For the purpose of the current work, however, GBT employing the idea of transformations is perfectly suitable. I selected it because of clear and extensive descriptions of the mechanisms for identification of *null elements* (also known as *empty categories*) and how to provide them with an interpretation.

6.1.1 Phrase structure

The notion of structure in a generative grammar refers to the way words are combined together to form phrases and sentences. *Merging* is the technical term used in GBT for the operation of bringing two words together into a phrase. In this operation one word will always be more prominent and is therefore called the *head* of the phrase. The resulting combination is a new constituent and is called a *projection* of the head. This is known as *X-bar theory* (Jackendoff 1977), often denoted as X' or $\bar{X}$, and embodies two primary claims: (a) that phrases may contain intermediary constituents projected from a head X and (b) that this system of projected constituency may be common to more than one category (such as N, V, A, P etc.).

These combinations of words and projections can be represented using *labelled bracketing notation* where the labels denote constituent categories. The bracketed notation is a representation equivalent to a hierarchical tree of constituent parts or *parse tree* (also known as *syntactic tree*, *phrase structure*, *derivation tree*). The parse tree represents the syntactic structure of a string according to some grammar. The equivalence between a bracketed notation and parse tree is exemplified in the following two representations of example 51 from (Haegeman 1991b: 83).

(51) Poirot will abandon the investigation.

(52) $\Big[_{S}\Big[_{NP}\Big[_{N}Poirot\Big]\Big]\Big[_{AUX}will\Big]\Big[_{VP}\Big[_{V}abandon\Big]\Big[_{NP}\Big[_{Det}the\Big]\Big[_{N}investigation\Big]\Big]\Big]\Big]$

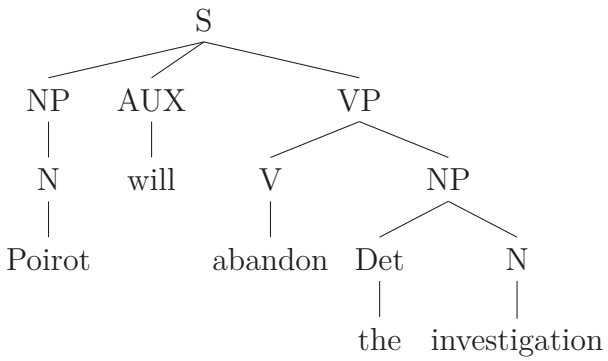


Fig. 6.1 The parse tree of Example 51 from Haegeman (1991b: 83)

A node is said to be *non-branching* if there is a single line starting below and it is called *branching* if there is more than one line going downwards. The children of a branching node are said to be bound by a *sisterhood* relation and in relation to a *parent* or *mother* node. In a phrase structure the vertical relations are referred to *dominance* relations defined below.

Definition 6.1.1 (Dominance)**.** Node A dominates node B if and only if A is higher up in the tree than B and if you can trace a line from A to B going only downwards (Haegeman 1991b: 85).

Looking at the tree diagram along the horizontal axis, GBT describes left-to-right ordering of constituents using the linear *precedence* relation.

Definition 6.1.2 (Precedence)**.** Node A precedes node B if and only if A is to the left of B and neither A dominates B nor B dominates A (Haegeman 1991b: 85).

In Figure 6.1 NP, AUX and VP nodes are sisters, they precede one another and are dominated by the S parent node. A more specific type of dominance, that will be employed later in this chapter, is *immediate dominance*, which is when there is no intermediary node between A and B. In this case, the node "Poirot" is also dominated by S but only the grandparent NP is immediately dominated by S. The same holds for precedence: the *immediate precedence* is when a node A precedes a node B and there is no intervening node in between. Node NP precedes VP but only AUX is immediately preceded.

Generalisation 6.1.1 (Projection principle)**.** Lexical information is syntactically represented.

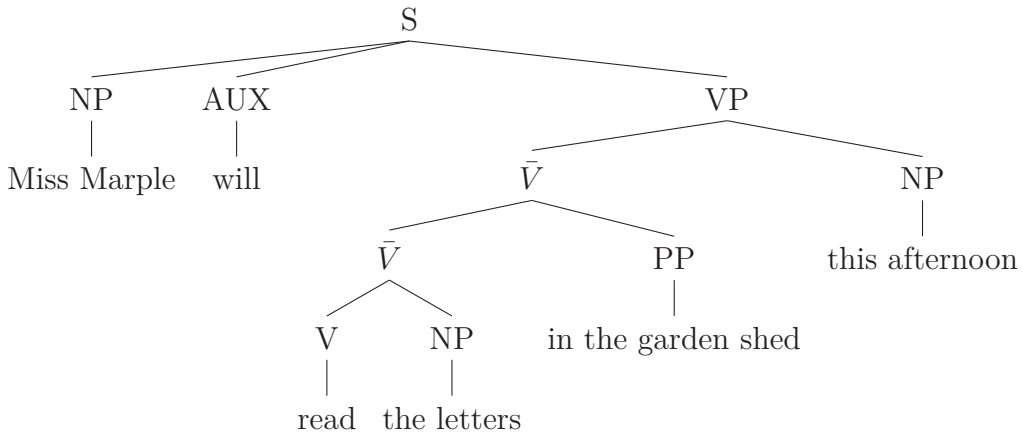


Fig. 6.2 Example of projections from Haegeman (1991b: 90)

An important principle in GBT is that of *projection* formulated in Generalisation 6.1.1. For example in Figure 6.2, projections of V that are dominated by more comprehensive projections of V are called *intermediate projections* while the node labelled VP is the *maximal projection* of V. Maximal projections are also barriers to government (see Definition 6.1.5 below). The role of the lexicon in syntax from GBT perspective is discussed at length in Stowell & Wehrli (1992).

6.1.2 Theta theory

This section introduces which constituents are minimally required to form a sentence and why. Traditionally three types of verbs are recognised: *transitive*, *di-transitive* and *intransitive*. This distinction is based on how many complements a verb requires to form a minimal complete sentence. If a verb is transitive then one NP direct object is

required. If the verb is di-transitive then two NP or one NP and one PP direct and indirect objects are required. Finally, if it is intransitive then no NP complement is allowed.

Logicians for a long time have been concerned with formulating representations corresponding to semantic structure of sentences or *propositions*. Like Tesniere (Tesniere 2015: 97) discussed in Section 5.1, Haegeman employs the metaphor of a theatre play when discussing the argument structure of predicates. A play not only describes the number of participants but also what corresponding roles they play. The specific semantic relations between the verb and its arguments is comparable with the identification of characters in a play script (Haegeman 1991b: 49).

In logical notation such as in Example 53 a proposition is comprised of a predicate (P) that takes a certain number of *arguments* (here a and b). By analogy to the logical tradition, in GBT, the verb is said to be like the predicate while the Subject together with complements are like the arguments that the predicate requires.

In Example 54 Maigret, taking Subject position, is the Agent in the process of killing while Poirot in the complement position is the Patient that receives the effects of the process of killing. The generic argument structure for the verb "to kill" can be expressed as in Example 55. The first argument is of NP category and takes the role of an Agent, while the second argument is also an NP but takes the Patient role. The transitivity of a verb dictates how many arguments there should be.

(53) P(a, b)

(54) Maigret killed Poirot.

(55) V kill: 1 (NP:Agent), 2 (NP:Patient)

In the literature these relations between the verb and their arguments are called *thematic roles* or theta-roles (θ-roles). It is said that the verb *theta marks* its arguments. The component of the grammar that regulates the assignment of thematic roles is called *theta theory*.

In GBT the theory of thematic roles is very sketchy and does not go beyond the distinction of several thematic roles (Agent/Actor, Patient, Theme, Experiencer, Beneficiary, Goal, Source, Location and the controversial Theme) (Haegeman 1991b: 50). Theta theory has a central criterion that is stipulated in Generalisation 6.1.2.

Generalisation 6.1.2 (The theta criterion)**.** The theta criterion requires that:

- each argument is associated with one and only one theta role
- each theta role is assigned to one and only one argument (Haegeman 1991b: 54)

In English, however, there is a special case, that of *expletives*, when the Subject argument is filled by the pronoun *it* that receives no thematic role and acts rather as a dummy slot filler without any semantic contribution to the meaning of the sentence (Haegeman 1991b: 62). An example is shown in Example 56. Worth noticing is also the fact that *auxiliary verbs* and *copula verbs* do not assign thematic roles (Pollock 1989).

(56) *It* surprised Jeeves that the pig had been stolen.

The verb that assigns a theta role does not need to specify which syntactic category it should be realised by. In more technical terms, this means that the categorial selection (*c-selection*) follows from the semantic relation (*s-selection*). When a theta role can be assigned to an argument it is said that it is saturated. In order to identify the assignment of respective roles arguments are identified by means of an index provided as subscript in the sentence.

(57) Maigret$_i$ killed the burglar$_j$.

(58) Maigret$_i$ said that he$_i$ was ill.

In Example 57 Maigret has the index i and the burglar may be j, meaning they are distinct referents. Conversely, in Example 58, "he" receives the same index as Maigret because they are interpreted as referring to the same entity. We say that the two are *coindexed*.

6.1.3 Government and Binding

Using the terminology from traditional grammar it is said that a verb governs its object. This is generalised in GBT as a rule that the head of a phrase, called *governor*, *governs* its complement, called the *governee*. This relation is loosely defined in Definition 6.1.3 below and formally in Definition 6.1.5.

Definition 6.1.3 (government i)**.** A governs B if

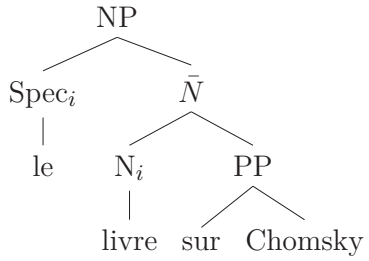
- A is a governor;
- A and B are sisters

Governors are heads (Haegeman 1991b: 86).

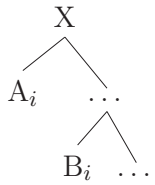
In Figure 6.1 the verb "abandon" is the head of the verb phrase (VP) and governs the direct object - nominal phrase (NP) "the investigation". V does not govern the

subject NP "Poirot". All the constituents governed by a node constitute the *governing domain* of that node. In this case VP is the governing domain of V.

Before providing the next definition of government, I first introduce the notion of C-command which provides a general pattern for how the agreeing elements relate to each other in the parse tree. C-command is formally defined in Definition 6.1.4. When considering the geometrical relation between the agreeing elements, one always is higher in the tree than the other one in the manner depicted in Figure 6.3b. In Figure 6.3a the co-subscripted nodes indicate agreement. Here the [Spec, NP] c-commands all the nodes dominated by the NP. These nodes constitute the *c-command domain* of the Spec element (Haegeman 1991b: 134).



(a) Example of agreement in French (Haegeman 1991b: 132)



(b) Schematic representation of the c-command (Haegeman 1991b: 133)

Fig. 6.3 Agreement example and schematic representation

Definition 6.1.4 (c-command)**.** A node A c-commands a node B if and only if

- A does not dominate B;
- B does not dominate A;
- the first branching node dominating A also dominates B (Haegeman 1991b: 212).

Definition 6.1.5 (Government)**.** X governs Y if and only if

- X is either of the category A, N, V, P, I;
  or
  X and Y are coindexed
- X c-commands Y;
- no barrier intervenes between X and Y;
- there is no Z such that Z satisfies the points above and X c-commands Z (Haegeman 1991b: 557).

In GBT three types of NP are distinguished: *full noun phrases* (e.g. Maigret, the doctor, etc.), *pronouns* (e.g. he, me, us, etc.), and *anaphors* comprised of reflexives (e.g. myself, herself, etc.) plus reciprocals (e.g. each other, one another). Pronouns and anaphors (reflexives and referential) lack inherent reference. Anaphors need an antecedent for their interpretations whereas pronouns do not. Pronouns indicate some inherent features of the referent so that they can be identified from contextual information. The full noun phrases called Referential expressions, or *R-expression* for short, are inherently referential and do not need an antecedent. Moreover they do not accept an antecedent (Haegeman 1991b: 226). The NP types can be defined in terms of features Anaphor and Pronominal (systematised together with the empty categories in Table 6.3 below). This way Pronouns have features [+Pronominal,-Anaphor], Anaphors [+Pronominal,-Anaphor] and the R-expressions [-Pronominal,-Anaphor]. The last combination [+Pronominal,+Anaphor] corresponds to *PRO empty category* which will be discussed in Section 6.2.1 below.

The module of the theory regulating interpretation of the noun phrase (NP) is referred to, in GBT, as *binding theory* (BT). It is formally defined in terms of c-command in Definition 6.1.6. And because BT is essentially concerned with the binding of NPs in argument positions (*A-position*), it is rather *A-binding* (see Definition 6.1.7) is of interest here. An A-position is a position in the tree to which a theta role can (but not necessarily) be assigned (Haegeman 1991b: 115).

Definition 6.1.6 (Binding)**.** A binds B if and only if

- A c-commands B;
- A and B are coindexed (Haegeman 1991b: 212).

Definition 6.1.7 (A-Binding)**.** A A-binds B if and only if

- A is in A-position;
- A c-commands B;
- A and B are coindexed (Haegeman 1991b: 240).

Each of these NP types have an associated binding principle (ways in which to interpret, if needed, the reference of the NP) provided in Generalisations 6.1.3, 6.1.4 and 6.1.5 below. These principles use the idea of *governing category* which for a node A is the minimal domain containing it, its governor and an accessible subject. A subject A is said to be accessible for B if the co-indexation of A and B does not violate any grammatical principle (Haegeman 1991b: 241).

Generalisation 6.1.3 (Principle A of binding theory)**.** An anaphor (i.e. a NP with the feature [+Anaphor] covering reflexives and reciprocals) must be bound in its governing category (Haegeman 1991b: 224).

Generalisation 6.1.4 (Principle B of binding theory)**.** The pronoun (i.e. a NP with feature [+Pronominal]) must be free in its governing category (Haegeman 1991b: 225).

Generalisation 6.1.5 (Principle C of binding theory)**.** An R-expression (i.e. a NP with independent reference) must be free everywhere (Haegeman 1991b: 227).

6.2 On Null Elements

In certain schools of linguistics, in the study of syntax, an *empty category* is a nominal element that does not have any phonological content and is therefore unpronounced. Empty categories may also be referred to as *covert nouns*, in contrast to overt nouns, which are pronounced (Chomsky 1993b). Some empty categories are governed by the *empty category principle* (see Definition 6.2.1). When representing empty categories in trees, linguists use a null symbol to depict the idea that there is a mental category at the level being represented, even if the word(s) are left out of overt speech.

GBT recognises four main types of empty categories: *NP-trace*, *WH-trace*, *PRO*, and *pro*. They are subject to Principles A, B and C of the binding theory provided above and differentiated, like other NPs, by two binding features: the anaphoric feature [a] and the pronominal feature [p]. The four possible combinations of plus (+) or minus (-) values for these features yield four types of empty categories.

[a]	[p]	Symbol	Name of the empty category	Corresponding overt NP type
-	-	t	WH-trace	R-expression
-	+	pro	little Pro	pronoun
+	-	t	NP-trace	anaphor
+	+	PRO	big Pro	none

Table 6.3 Four types of empty categories (adaptation from (Haegeman 1991b: 436))

In Table 6.3, [+a] refers to the anaphoric feature, meaning that the particular element must be bound within its governing category whereas [+p] refers to the pronominal feature which shows that the empty category is taking the place of an overt pronoun.

Definition 6.2.1 (Empty Category Principle (ECP))**.**

- Traces must be properly governed.
- A properly governs B if and only if A theta-governs B or A antecedent-governs B (Chomsky 1986: 17).
- A theta-governs B if and only if A governs B and A theta-marks B.
- A antecedent-governs B if and only if A governs B and A is coindexed with B (Haegeman 1991b: 442).

Next I describe in detail each empty category and the properties of corresponding overt noun type.

6.2.1 PRO Subjects and control theory

PRO stands for the non-overt NP that is the subject in non-finite (complement, adjunct or subject) clauses and is accounted for by *control theory* (CT).

Definition 6.2.2 (Control)**.** Control is a term used to refer to a relation of referential dependency between an unexpressed subject (the control element) and an expressed or unexpressed constituent (controller). The referential properties of the controlled element are determined by those of the controller (Bresnan 1982).

Control can be *optional* or *obligatory*. While *obligatory control* has a single interpretation, that of PRO being bound to its controller, *optional control* allows for two interpretations: *bound* or *free*. In Example 59 the PRO is controlled, thus bound, by the subject "John" of the matrix clause (i.e. higher clause) whereas in 60 it is an arbitrary interpretation where PRO refers to "oneself" or "himself". In 61 and 62 PRO must be controlled by the subject of the higher clause and does not allow for the arbitrary interpretation.

(59) John asked how [PRO to behave himself/oneself].

(60) John and Bill discussed [PRO behaving oneself/themselves in public].

(61) John tried [PRO to behave himself/*oneself].

(62) John told Mary [PRO to behave herself/*himself/*oneself].

Sometimes the controller is the subject (as in Examples 59, 60, 61) and sometimes it is the object (Example 62) of the higher clause. Haegeman (1991b: 278) proposes that there are two types of verbs, verbs of *subject* and of *object control*. The following set of generalisations from Haegeman (1991b) are instrumental in identifying places

where a PRO constituent can be said to occur and identifies its corresponding binding element.

Generalisation 6.2.1. Each clause has a subject. If a clause doesn't have an overt subject then it is covertly (non-overtly) represented as PRO (Haegeman 1991b: 263).

Generalisation 6.2.2. A PRO subject can be bound, i.e. it takes a specific referent or can be arbitrary (equivalent to pronoun "one") (Haegeman 1991b: 263). In case of obligatory control, a PRO subject is bound to a NP and must be c-commanded by its controller (Haegeman 1991b: 278).

Generalisation 6.2.3. PRO must be in ungoverned position. This means that (a) PRO does not occur in object position (b) PRO cannot be subject of a finite clause (Haegeman 1991b: 279).

Generalisation 6.2.4. PRO does not occur in the non-finite clauses introduced by *if* and *for* complementizers, but it can occur in those introduced by *whether* (Haegeman 1991b: 279).

Examples 63 and 64 illustrate Generalisation 6.2.4

(63) John doesn't know [whether PRO to leave].

(64) * John doesn't know [if PRO to leave].

Generalisation 6.2.5. PRO can be subject of complement, subject and adjunct clauses (Haegeman 1991b: 278).

Generalisation 6.2.6. When PRO is the subject of a declarative complement clause it must be controlled by an NP, i.e. arbitrary interpretation is excluded (Haegeman 1991b: 280).

Generalisation 6.2.7. The object of an active clause becomes subject when it is passivized and also controls the PRO element in complement clause (Haegeman 1991b: 281).

Generalisation 6.2.8. PRO is obligatorily controlled in adjunct clauses that are not introduced by a marker (Haegeman 1991b: 283).

Adjuncts (clauses or phrases) often are introduced via prepositions. Nonetheless there are rare cases of adjunct clauses free of preposition. Examples 65 and 66 illustrate such marker-free adjunct clauses.

(65) John hired Mary [PRO to fire Bill].

(66) John abandoned the investigation [PRO to save money].

Generalisation 6.2.9. PRO in a subject clause is optionally controlled; thus by default it takes arbitrary interpretation (Haegeman 1991b: 283).

(67) PRO_i smoking is bad for the health_j.

(68) PRO_i smoking is bad for your_i health_j.

(69) PRO_i smoking is bad for you_i.

(70) PRO_i lying to your_i friends decreases your_i trustworthiness_j.

A default assumption is to assign arbitrary "one" interpretation to each PRO subject in subject clauses. However, there are cases when it may be bound (resolved) to a pronominal NP in the complement of the higher clause. The binding element can be either the entire complement or a *pronominal* part of it like the qualifier or the possessor. Example 67 illustrates that PRO has only arbitrary interpretation since it cannot be bound to the complement "health". Moreover PRO can also be bound to (a) the possessive element of a higher clause - example 68, (b) the complement of the higher clause - example 69 and (c) either the possessives in lower or higher clause, Example 70.

6.2.2 NP-traces

In GBT, *movement* is a kind of transformation used to explain discontinuity or displacement phenomena in language. It is based on the idea that some constituents appear to have been displaced from the position where they receive important features of interpretation.

GBT distinguishes three types of movement: (a) *head-movement* - the movement of auxiliaries from I to C , *Wh-movement* - when the wh-constituent lands in Spec position of a CP (i.e. [Spec, CP]) and (c) *NP-movement* when a NP is moved into an empty subject position. NP-movement in GB theory is used to explain *passivization*, *subject movement* (in interrogatives) and *raising*. The raising phenomenon (Definition 6.2.4) is the one that is of interest for us here as it is the one involving an empty constituent.

Raising and control phenomena have been systematised by Teich (1991) in the context of systemic grammar. This work however aims at resolving the empty constituents within the syntactic structures (as GBT describes) rather than a paradigmatic

integration of the phenomena into the Transitivity system network. Thus I resort to translating the principles from GBT into the grammar of the current thesis.

When an NP moves it is said to leave *traces* (Definition 6.2.3). The moved constituent is called the *antecedent* of a trace. Both the trace(s) and the antecedent are coindexed and form what is called a *chain* (Haegeman 1991b: 309).

Definition 6.2.3 (Trace)**.** A trace is an empty category which encodes the base position of a moved constituent and is indicated as *t* (Haegeman 1991b: 309).

Consider Examples 71 to 74 where I use square brackets to indicate boundaries of an embedded clause. There are two cases of expletives (71 and 73) and their non-expletive counterparts (72 and 74), where the subject of the lower clause is moved to the subject position of the matrix clause by replacing the expletive. The movement of NPs is described in GB as leaving traces which here are marked as *t*. This phenomena is called *raising* (Definition 6.2.4) or as Postal (1974) calls this case *subject-to-subject raising*.

Definition 6.2.4 (NP-raising)**.** NP-raising is the NP-movement of a subject of a lower clause into subject position of a higher clause (Haegeman 1991b: 306).

(71) It was believed [Poirot to have destroyed the evidence].

(72) Poirot$_i$ was believed [t$_i$ to have destroyed the evidence].

(73) It seems [that Poirot has destroyed the evidence].

(74) Poirot$_i$ seems [t$_i$ to have destroyed the evidence].

The subjects “It” and “Poirot” in none of the examples 71–74 receive a semantic role from the main clause. “It” is an expletive and never receives a thematic role while “Poirot” in 72 and 74 takes an Agent role from “destroy” and is the Experiencer neither of “believe” nor of “seem”. So the verbs “believe” and “seem” do not theta mark their subjects in these examples.

Raising is very similar to obligatory subject control with a difference in thematic role distribution. In the case of subject control, both the PRO element and its binder (the subject of the higher clause) receive thematic roles in both clauses. However in the case of raising, the NP is moved and it leaves a trace which is theta marked but not to the antecedent (Haegeman 1991b: 314). This is expressed in Generalisation 6.2.10.

Generalisation 6.2.10. The landing site for a moved NP is an empty A-position. The chain formed by an NP-movement is assigned only one theta role and it is assigned on the foot of the chain, i.e. the lowest trace (Haegeman 1991b: 314).

So, in the case of raising, the landing sites for a moved NP are empty subject positions or the ones for expletives. As a result of movement, these positions are filled or expletives are replaced with the moved NP. The movement of NPs that have a *Wh-word* is described in the next section.

6.2.3 WH-traces

Wh-movement is involved in the formation of Wh-interrogatives and in the formulation of relative clauses. We are interested in both cases as both of them leave traces of empty elements that are relevant for transitivity analysis.

(75) [What] will Poirot eat?

(76) [Which detective] will Lord Emsworth invite?

(77) [Whose pigs] must Wooster feed?

(78) [When] will the detective arrive at the castle?

(79) [In which folder] does Margaret keep the letter?

(80) [How] will Jeeves feed the pigs?

(81) [How big] will the reward be?

Haegeman (1991b: 375) offers Examples 75 – 81 as examples involving *Wh-constituents*, which are any NPs or PPs that contain a *Wh-word* in their componence. A Wh-word is any of the following words or their morphological derivations (by adding suffixes *-ever*, *-soever*): *who, whom, whose, what, which, why, where, when* and *how*. Thus the wh-constituent can be a single word or a *Wh-phrase*. The Wh-phrase, in GBT, is then the NP or PP which is the maximal projection from a Wh-word. Haegeman treats each Wh-word as the head of the Wh-phrase. This is not quite the case . However, in Section 6.3.3, I , will provide a different definition of Wh-group such that it is congruent with Systemic Functional Grammars.

In GBT *case* occupies an important place in the grammar. The rules governing case are known as *case theory*. Verbs dictate the case of their arguments, a property called *case marking*. Subjects are marked with Nominative case while Complements of the verb are marked with Accusative case.

In English, however, the case system is very rudimentary as compared to many other languages. Hence, *who*, *whom* and their derivatives *whoever* and *whomever* are the only Wh-words with overt case differentiation. The other Wh-words *what, when, where* and *how* do not change their form based on case.

Example 82 shows that the Accusative (*whom*) is disallowed when its trace is in Subject position since this requires Nominative (*who*). In example 83 the reverse holds and the Nominative form is disallowed as the Wh-word moved from Complement position requires Accusative case.

(82) Who_i/*Whom_i do you think [t_i will arrive first?]

(83) Whom_i/*Who_i do you think [Lord Emsworth will invite t_i?]

Another important distinction to be made among English Wh-words is *theta-marking*, i.e. the argument and non-argument distinction. Some wh-constituents will be in A-positions (i.e. functioning as subject or complement) such as in Example 75 – 77 or in non A-position (i.e. functioning as adjunct) such as in Examples 78 and 80.

When the Wh-constituent moves, there are two places where it can land: (a) either in the subject position of the matrix clause changing its mood to interrogative (example 84) or (b) subject position of the embedded clause creating embedded questions (example 85). However regardless of the landing site, the movement principle is subject to what Haegeman describes as the *that-trace filter* expressed in Generalisation 6.2.11 and the *Subjacency condition* (Generalisation 6.2.12). Note that the matrix or embedded clauses correspond to the category of inflectional phrase (IP).

(84) Whom_i do [you believe [that Lord Emsworth will invite t_i]]?

(85) I wonder [whom_i you believe [that Lord Emsworth will invite t_i]].

Generalisation 6.2.11 (That-trace filter)**.** The sequence of an overt complementizer "that" followed by a trace is ungrammatical (Haegeman 1991b: 399).

The examples in 86 to 89 provided by Haegeman (1991b: 398) illustrate how the above generalisation applies.

(86) * Whom do you think that Lord Emsworth will invite?

(87) Whom do you think Lord Emsworth will invite?

(88) * Who do you think that will arrive first?

(89) Who do you think will arrive first?

Generalisation 6.2.12 (Subjacency condition)**.** Movement cannot cross more than one bounding node, where bounding nodes are IP and NP (Haegeman 1991b: 402).

The Subjacency condition captures the grammatically of NP-movement and exposes two properties of the movement, namely as being *successive* and *cyclic*. Consider the

chain creation resulting from Wh-movement in Examples 90 – 92 provided by Haegeman (1991b: 403–406). The Wh-movement leaves (intermediate) traces successively jumping each bounding node.

(90) Who$_i$ did [he see t$_i$ last week?]

(91) Who$_i$ did [Poirot claim [t$_i$ that he saw t$_i$ last week?]]

(92) Who$_i$ did [Poirot say [t$_i$ that he thinks [t$_i$ he saw t$_i$ last week?]]]

What Generalisation 6.2.12 states is that a Wh-constituent cannot move further than subject position of the clause forming an interrogative form. Or also it can move outside into the subject position of the clause higher above leaving a WH-trace as can be seen in the Example 91 and 92.

Now that the kinds of null elements have been described laying out the main rules governing their behaviour, I turn next to discuss how these elements can be identified in terms of Dependency grammar.

6.3 Placing Null Elements into the Stanford dependency grammar

This section provides a selective translation of principles, rules and generalisations captured in GB theory into the context of dependency grammar. The selections mainly address the identification of places where (and by which relations) the null elements should be injected into dependency structure that will later help the semantic parsing process described in Chapter 9.

In this section the grammatical accounts will often overlap. To make a clear distinction I will mark the dependency grammar relations with lower case in italic. When the syntactic functions are marked with a capital letter (e.g. Subject, Complement, Deictic) then they mean SFG functions and, if they are in lower case (e.g. direct and indirect object), then the GBT reading applies. When the (unit/word) classes are mentioned using full word lower case (nominal group, clause, etc.), then the SFL reading shall be applied and when they are all upper case acronyms (NN, PP, WH-trace, etc.) the GBT reading applies to.

6.3.1 PRO subject

Coming back to the definition of the PRO element in Section 6.2.1, it is strictly framed by the non-finite subordinate clauses. In dependency grammar the non-finite

complement clauses are typically linked to their parent via the *xcomp* relation, which is defined in Marneffe & Manning (2008a) as introducing an open clausal complement of a VP or ADJP without its own subject. Such cases can then can be resolved by introducing a PRO element as can be seen in Figure 6.4.

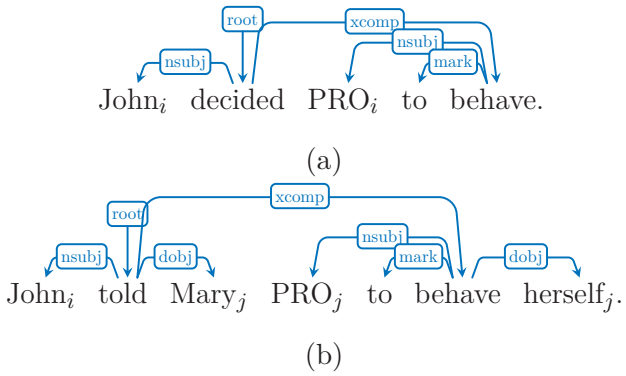


Fig. 6.4 Dependency structure with a PRO subject

These complements are always non-finite. Following the principles stated in Generalisations 6.2.1 and 6.2.3, the non-finite complement clause introduced by the *xcomp* relation would receive by default a PRO subject (controlled or arbitrary).

The markers (conjunctions, prepositions or Wh-words) at the beginning of the embedded clause are no longer connected via *xcomp* relations but instead via either *prepc*, *rcmod*, *partmod* and *infmod* together with a slight variation in clause features and constituency. Those cases are no longer treated under the PRO null element considerations and will be discussed later in this chapter since they correspond to other types of empty elements. The only exception, however, is the *prepc* relation with the preposition "whether" which also introduces a complement clause with PRO element.

I have explained earlier how to identify the place where a PRO element should be created and formulated in Generalisation 6.3.1. Before creating it we need to find out (1) whether PRO is arbitrary (equivalent to pronoun "one") or is bound to another constituent. And if it is bound then decide (2) whether it is bound to (and coindexed with) subject or object (in which case we say that PRO is subject or object controlled) as can be seen in Figure 6.4.

From the Generalisation 6.2.6 above we can derive a test checking whether the mood fo the complement clause is interrogative or declarative. Many grammars, including SFG, do not consider that the non-finite clauses can have interrogative/declarative variation (called by Halliday & Matthiessen (2004: 107-167) *mood* feature). Nonetheless, in GBT, even if a clause is non-finite such a distinction is useful. The complement clauses can have structural variation resembling a declarative or interrogative mood for

the reason that a complement clause can start with a Wh-constituent which turns it into an interrogative one. Thus the test is whether there is a Wh-marker (who, whom, why, when, how) or the preposition "whether". The presence of any marker like in example 93 at the beginning of the complement clause will change the dependency relation from *xcomp* to another one and sometimes effect the structure of the dependent clause as well. The only case when the complement clause remains subjectless and non-finite is the case introduced via a *prepc* relation and the preposition "whether". However if any such marker is missing then the clause is declarative and thus it must be controlled by a NP, so arbitrary PRO is excluded. The cases of Wh-marked non-finite clauses will be treated in Section 6.3.3 about Wh-word movement.

(93) Albert asked [whether/how/when/ PRO to go].

Based on the above I propose Generalisation 6.3.1 enforcing obligatory control for *xcomp* clauses.

Generalisation 6.3.1. If a clause is introduced by an *xcomp* relation then it must have a PRO element which is bound to either subject or object of the parent clause.

(94) Albert$_i$ asked [PRO$_i$ to go alone].

(95) Albert$_i$ was asked [PRO$_i$ to go alone].

(96) Albert$_i$ asked Wendy$_j$ [PRO$_j$ to go alone].

(97) Albert$_i$ was asked by Wendy$_j$ [PRO$_i$ to go alone].

Generalisation 6.2.7 required a test for passivisation (also known in dependency grammar and SFL as *voice*). Knowing the voice of the parent clause is necessary in order to determine which NP is controlling the PRO element in the complement clause. Consider Example 94 and its passive form 95. In both cases there is only one NP that can command PRO and it is the subject of the parent clause "Albert". So we can generalise that the voice does not play any role in controller selection in one argument clauses (i.e. clauses without a nominal complement). In Examples 96 and 97 the parent clause takes two semantic arguments. The second part of principle 6.2.2 states that in case of obligatory control PRO must be *c-commanded* by an NP. In 96 both NPs("Albert" and "Wendy") c-command the PRO element, however according to the Minimality Condition (Haegeman 1991b: 479), "Albert" is excluded as the commander of PRO because there is a closer NP that c-commands PRO. In the case of 97 the only NP that c-commands PRO is the subject "Albert" because "by Mary" is a PP (prepositional phrase) and also only NPs can control a PRO as stated in principle

6.2.6. In the process of passivisation the complement becomes subject and the subject becomes a prepositional (PP-by) complement and so the later is automatically excluded from control candidates, thus conforming to Generalisation 6.2.7 (Haegeman 1991b: 281).

The above can be synthesised into Generalisation 6.3.2 appealing to linear proximity of the words. But the linear order dimension is beyond the borders of dependency grammar in the sense that the word order is not being accounted for explicitly as a relation. Rather, the solution is technical: each word receives an index for the position it occupies within a sentence which suffices to implement Generalisation 6.3.2 applied in Chapter 9.

Generalisation 6.3.2. The controller of PRO element in a lower clause is the closest nominal constituent of the higher clause.

The adjunct non-finite clauses such as the ones in Example 65 ("John hired Mary [PRO to fire Bill]") and 66 ("John abandoned the investigation [PRO to save money]") shall be treated exactly as the non-finite complement clauses are. Generalisation 6.2.8 emphasises obligatory control for them. The only difference between the adjunct and complement clauses is dictated by the verb of the higher clause and whether it theta marks or not the lower clause. In dependency grammar the adjunct clauses are also introduced via *xcomp* and *prepc* relations, so syntactically there is no distinction between the two patterns.

The *prepc* relation in dependency grammar introduces a prepositional clausal modifier for a verb (VN), noun (NN) or adjective (JJ). Adjective and noun modification are cases of copulative clauses. Such configuration are not relevant to the context of this work because, as we will see in Section 8.1, the dependency graphs are normalised. This process involves, among others, transforming the copulas into verb-predicated clauses instead of adjective or noun-predicated clauses.

The last subordinate type concerned with the PRO element is the subject clause such as the one in Example 67 ("PRO_i smoking is bad for the health$_j$"). In dependency structure, the subject non-finite clauses are introduced via *csubj* relation. They are quite different from complement and adjunct clauses because, according to Generalisation 6.2.9, the PRO is optionally controlled. Since in this case it is not possible to bind PRO solely on syntactic grounds, Generalisation 6.2.9 proposes arbitrary interpretation discussed in Section 6.2.1. Next I turn to identifying the second type of null elements (NP-traces) in the dependency structure of a sentence.

6.3.2 NP-traces

Syntactically, NP raising can occur only when there is a complement clause by moving the subject of a lower clause into a position of a higher clause. The subject of the higher clause c-commands the subject of the lower clause. This is exactly the same syntactic configuration as in the case of PRO subjects (explained in Section 6.2.1). In dependency grammar the complement clause without its own subject is called an *open clausal complement* and is introduced via the *xcomp* relation.

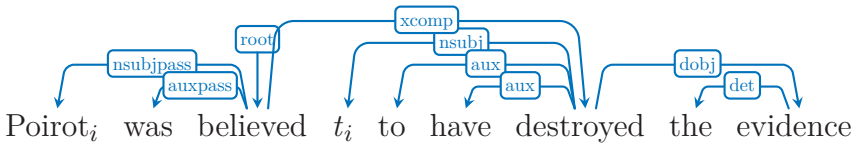


Fig. 6.5 Dependency parse for Example 72

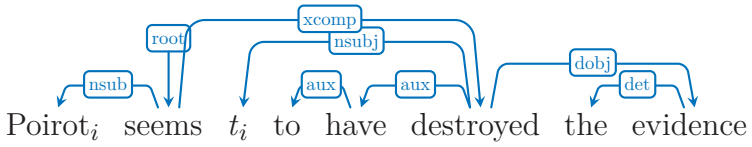


Fig. 6.6 Dependency parse for Example 74

Figures 6.5 and 6.6 represent dependency parse for Examples 72 and 74. In these examples the subject position of the embedded clause is a NP-trace that is coindexed with the subject position in the clause immediately higher. That subject can be either another NP-trace, in which case they form a chain, or an overt subject.

There are also few exceptions to the above. First, the *xcomp* complement clause, of course, should not have a subject of its own. Second, it should not be introduced with the conditional marker "if" or with preposition "for". Third, the higher clause must have no nominal complement between the subject and the embedded complement clause.

Next, if the above conditions are satisfied and the embedded clause follows the *obligatory subject control* pattern, then it is important to distinguish whether the empty subject is a PRO or a NP-trace *t*. Deciding this is not possible using only purely syntactic criteria. The distinction is dictated by the distribution of semantic (participant) roles of each verb (sense), which I discuss next.

Table 6.4 represents the semantic role distribution for the verbs "believe", "seem" and "destroy" employed in the examples above. In the second column the configuration type is provided and the last column indicates the distribution of semantic roles. The

role order is normalised such that in a declarative active voice clause the first role is given to the Subject, the second to the complement (direct object) and the last to the next complement (indirect object). The symbol "V" is there to indicate the position of the verb.

Verb	*Process type*	*canonical distribution of semantic roles*
Believe	Cognition	Cognizant + V + Phenomenon
Seem	Cognition	It + V + Cognizant + Phenomenon
Destroy	Action	Agent + V + Affected

Table 6.4 Semantic role distribution for verbs "believe" and "seem"

Figure 6.5 depicts the analysis of a passive clause with an embedded complement clause. The subjects and complements switch places in passive clauses and so do the semantic roles. In this example, the Cognizant role distributed by the verb believe to Subject position goes to the embedded/complement clause position. However Phenomenon is the only semantic role that can be filled by a clause, all other roles take nominal, prepositional or adjectival groups. This leads us to the conclusion that the passive subject Poirot does not receive the Cognizant role from the "believe" frame and in fact, as we will see later, it may receive semantic role(s) from "somewhere" else.

In Figure 6.6 the verb "seem" assigns semantic roles, according to the description in Table 6.4, only to first and second complements. The subject is left unassigned because the semantic configuration for the verb "seem" provides an expletive "it" instead of a role. The embedded clause, which is the only complement, can fill only the Phenomenon role. This means that the Cognizant role, just like in the previous example, is left unassigned and the Subject "Poirot" does not receive any semantic role from the verb "seem".

The embedded clause in both cases is governed by the verb "destroy", which assigns the Agent role to the Subject and Affected role to the complement. The Subject however has moved from the embedded clause into the Subject position of the higher clause leaving an NP-trace. The distributed semantic role moves upwards on the chain as well such that the Subject in the higher clause (the antecedent) receives the Agent role from the embedded clause.

Here the problem is to decide what type of relationship holds between the empty constituent and its antecedent (subject in the matrix clause) to which it is bound. In the case of *PRO* constituent, the thematic roles are assigned to both the empty constituent and to its antecedent locally in the clause as where they are located. So the PRO constituent receives a thematic label dictated by the verb of the embedded

clause and the antecedent by the verb of the matrix clause. In the *t*-trace case, the thematic role is assigned only to the empty constituent by the verb of the embedded clause and this role is propagated to its antecedent.

But this distinction requires analysis of the role distribution of upper and lower clause predicates and deciding the type of relationship between the empty category and its antecedent. If a semantically informed decision should be made at this stage of parsing or postponed to Transitivity analysis (i.e. semantic role labelling) is debatable because each approach introduces different problems.

Generalisation 6.3.3 presents the conditions that need to be verified in order to distinguish the t-trace from the PRO element. I employ here the traditional grammar syntactic features and categories and semantic configurations together with participant roles from the Cardiff grammar.

Generalisation 6.3.3. To identify the *t*-traces all the following conditions need hold:

- the subject control pattern respects case agreement.
- the process type of the higher clause is two or three role cognition, perception or emotion process (considering constraints on Cognizant and Phenomenon roles).
- among the configurations of higher clause there is one with:
  - an expletive subject OR
  - the Phenomenon role in subject position OR
  - Cognizant in subject position AND the clause has passive voice or interrogative mood (cases of movement).

6.3.3 Wh-traces

I now turn to how Wh-movement and relative clauses are represented and behave in dependency grammar and SF grammars. Figures 6.7 and 6.8 present dependency parses for Wh-movement from Subject and Complement positions of lower clause while 6.9 shows movement from adjunct position.

Haegeman (1991b: 374) defines phrases that contain a Wh-word as Wh-phrases. This being independent of whether the wh-word in is the head or determiner position in the phrase, as, according to Haegeman, the properties of that wh-word are projected to the level of the entire phrase. In SFG, the Wh-words function as heads but there are other cases when they act as determiners, possessors or adjectival modifiers, defined

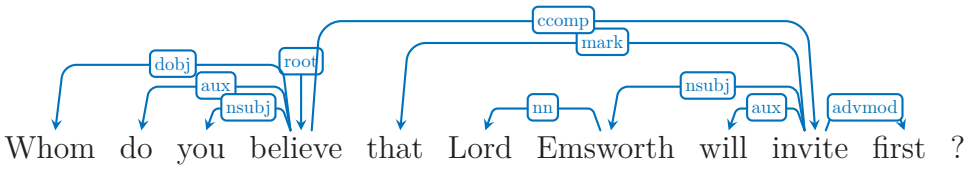


Fig. 6.7 Dependency parse for Example 83

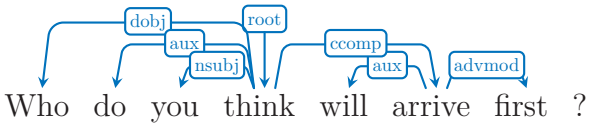


Fig. 6.8 Dependency parse for Example 82

for the purposes of this thesis in Definition 6.3.1. This issue is extensively discussed by Abney (1987), Quirk et al. (1985) and Halliday & Matthiessen (2013b). From these discussions, I have systematised the functional distribution for Wh-words and Wh-groups in Table 6.5. This systematisation follows a systemic functional approach as it is more appropriate in discussions about groups, constituents, their features and functions. Note that Wh-group is not a new unit class in the grammar but a constituent feature possibly assigned to any of the three unit classes. This systematisation is useful for scoping the Wh-movement phenomena in SFL terms and will be used below.

Definition 6.3.1 (Wh-group)**.** *Wh-group* is a nominal, prepositional or adverbial group that contains s Wh-word either as head or as modifier.

Features	**Clause functions of the Wh-group**		**Group functions of Wh-word**
	Subject	**Complement**	
person	who, whoever	whom, whomever, whomsoever	head/thing
person, possessive	whose		possessor
person/non-person	which		determiner
non-person	what, whatever		head/thing
	Adjunct		
various circumstantial features	when, where, why, how (whether, whence, whereby, wherein) (and their *-ever* derivations)		head/modifier

Table 6.5 Functions and features of Wh-words and groups

Just like in cases of NP-movement, the Wh-groups move only into two and three role cognition, perception and emotion semantic configurations. As mentioned above,

the NP-antecedents land in expletive or passive subject position, the Wh-antecedents, by contrast, land in subject or subject preceding position functioning as subject, complement or adjunct depending on the Wh-word (or Wh-group).

The essential features for capturing Wh-movement in dependency graphs are (a) the finite complement clause is identified by a *ccomp* relation between the matrix and embedded clause (b) the Wh-word/group plays a complement function in the higher clause which is identifiable by *dobj*, *prep* or *advmod* relations to the main verb (c) the function of the WH-trace in the lower clause is either Subject (e.g. Example 83), Complement (e.g. Example 82) or Adjunct. The *ccomp* relation is defined in Marneffe & Manning (2008a) to introduce complement clauses with an internal subject which are usually finite.

Regardless whether the syntactic function of the traces in the lower clause is Subject or Complement, in the higher clause the Wh-group takes the Complement function and is bound to the Main Verb via the *dobj* relation but is positioned before the main verb and the Subject (a structure corresponding to Wh-interrogatives). A wh-group can take also Subject function in the higher clause, but then it is not a case of Wh-movement and is irrelevant for us at this point because there is no empty element involved. The attribution of clause function to the WH-trace is based on either the case of the Wh-group or the missing functional constituent in the lower clause.

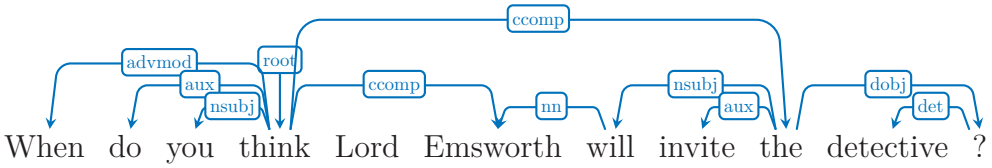


Fig. 6.9 Example dependency parse with Adjunct Wh-word

In case of WH-traces with Adjunct function in the lower clause, as shown in Figure 6.9, their antecedents also receive Adjunct functions in the higher clause. One peculiar finding about Adjunct Wh-trace is that it cannot bind, at least in English, to the clause with a (generic) simple present tense. The clause must be bound in some other tense or modality than present simple. The reader can experiment with changing tense in the above example to test this.

(98) Who$_i$ believes that Lord Emsworth will invite a detective?

(99) To whom$_i$ did Poirot say t$_i$ that Lord Emsworth will invite a detective?

Not always are the Wh-groups movements from a lower clause. It is possible that the trace of the moved element resides in the higher clause (complement) or even to

have a case of no movement when a Wh-word takes the Subject function in the higher clause. Examples 98 and 99 are good examples of a *short* (in clause) movement of this kind. These cases of Wh-movement share similarities to relative clause Wh-traces that will be described in Section 6.3.4 below. However the short movement cannot be grasped in terms of dependency grammar because order is the only factor that counts and dependency grammar is order free and does not (explicitly) account for it. The functions are already assigned accordingly so short movement is not a subject of interest for the current section.

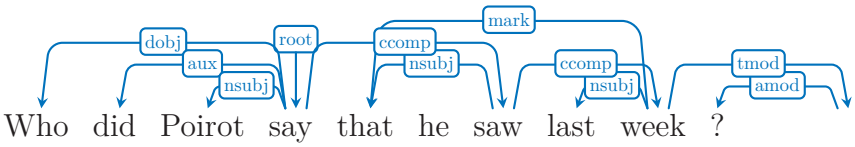


Fig. 6.10 Dependency parse for Example 92

Recall the *cyclic* and *successive* properties of Wh-movement from the previous section underlined by Example 92 and its dependency parse in Figure 6.10. GBT suggests that the Wh-movement leaves traces in all the intermediary clauses. In dependency grammar these properties are treated instrumentally for determining intermediary wh-traces in the search for the foot of the chain and none of the intermediary traces are created as null elements. There is no further purpose for them as they do not receive a thematic role in the intermediary clauses.

6.3.4 Wh-traces in relative clauses

In GB theory the Wh-words that form relative clauses (*who, whom, which, whose*) are considered moved. In dependency grammar such movement is redundant since the Wh-word and its trace are collapsed and take the same place and function. The Wh-words function either as Subject or Complement. When the relative clause is introduced by a Wh-group there is no empty element to be detected, rather there is an anaphoric indexing relation to a noun it refers to.

Focusing now on the relative clauses, there are three more possible constructions that introduce them: (a) a prepositional group that contains a Wh-word, (b) a "that" complementizer which behaves like a relative pronoun and (c) the *Zero Wh-word* which is a Wh-trace empty element which functions the same way as an overt Wh-word. Table 6.6 lists possible elements that introduce a relative clause, their features and the functions they can take. The traces of Wh-words to their antecedents are identified as follows.

Relativizing element	**Feature**	**(Clause) Function**	**Examples**
who	person	Subject	... the woman who lives next door.
whom	person	complement (non defining clause)	... the doctor whom I have seen today.
which	non-person	Subject/ complement	... the apple which is lying on the table. ... the apple which George put on the table.
whose	possessive, person	possessor in Subject	... the boy whose mother is a nurse.
(*any of the above in prepositional group*)	person/ non-person	thing/possessor in Subject	... the boy to whom I gave advice. ... the cause for which we fight.
that	person/ non-person	Subject	... the apple that lies on the table.
Zero Wh-word	person/ non-person	Subject	... the sword sent by the gods.

Table 6.6 The Wh-words introducing a relative clause.

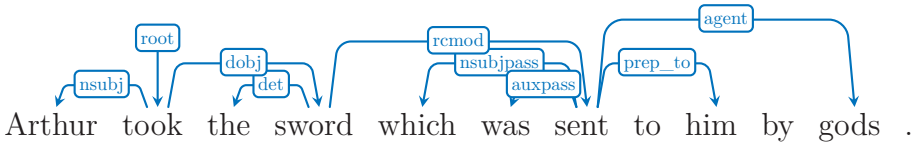


Fig. 6.11 Dependency parse for "Arthur took the sword which was sent to him by gods."

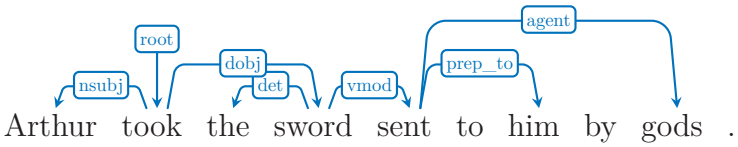


Fig. 6.12 Dependency parse for "Arthur took the sword sent to him by gods."

Relative clauses in dependency graphs are introduced by *rcmod* and *vmod* relations. The *rcmod* introduces relative clauses containing a Wh-group while the *vmod* introduce finite and non-finite relative clauses with a Zero Wh-word. So the *vmod* dependency relation suffices to signal the empty element. These two ceases are exemplified in the Figures 6.11 and 6.12.

The Zero Wh-word behaves exactly like the *PRO element* in the case of non-finite complement clauses discussed in Section 6.2.1. It receives thematic roles in both the higher clause and in the lower clause and is not a part of a chain like the cases of NP/Wh-movement.

6.4 Discussion

This chapter has treated the identification of the *null elements* in syntactic structures as this was identified as one of the major places where a mismatch between SFG and the structural requirements for Transitivity analysis obtains. Section 6.2 presented how GBT theory handles null elements and then Section 6.3 showed how the same principles translate into Stanford dependency graphs involving also, for guidance, a few references to SFL constituency structure.

This chapter also contributes to establishing cross-theoretical connections that are among the primary objectives of the current thesis. Specifically it provides translations of necessary principles and generalisations from GB theory into the context of dependency grammar. These results will be used directly in the parser implementation described in Section 9.3.

Identification of null elements will be important below for the semantic role labelling process described in Chapter 9 because, usually, the missing elements are participant roles (theta roles) shaping the semantic configuration. Therefore to increase the accuracy of semantic parsing, spotting null elements is a prerequisite. In the previous three chapters three grammatical traditions have been presented falling into the linguistics domain. Next follow three chapters explaining aspects of the Parsimonious Vole parser implementation employing a computer scientific perspective.

Chapter 7

Graphs, Feature Structures and Systemic Networks

The parsing algorithm, whose pipeline architecture we have seen in Section 1.7.4, operates mainly with operations on graphs, attribute-value matrices and ordered lists with logical operators. This chapter defines the main types of graphs, their structure and how they are used in the following chapters which detail the parsing process. This chapter also covers the operations relevant to the parsing algorithm: *conditional traversal and querying* of nodes and edges, *graph matching*, *pattern-graph matching* and *pattern-based node selection, insertion and update*.

While developing the Parsimonious Vole parser a set of representational requirements arose that can be summarised as follows:

- graph representation
- arbitrary relations (i.e. typed and untyped edges)
- description rich (i.e. features of nodes and edges)
- linear ordering and configurations (i.e. syntagmatic and compositional)
- hierarchical tree-like structure (with a root node) but also orthogonal relations among siblings and non-siblings
- statements of absence of a node or edge (i.e. negative statements in pattern graphs)
- disjunctive descriptions (handling uncertainty)

- conjunctive descriptions (handling multiple feature selections)
- (conditional) pattern specifications (i.e. define patterns of graphs)
- operational pattern specifications (i.e. a functional description to be executed in pattern graphs)

The general approach to construct an SFG parse structure revolves around the graph pattern matching and graph traversal. In the following sections I present the instruments used for building such structures, starting from a generic computer science definition of graphs and moving towards specific graph types covering also the feature structures and conditional sets.

7.1 General definitions

In the field of computational linguistics trees have been taken as the de facto standard data representation. In Section 1.7.3, I have mentioned already that I employ graph and not tree structures.

Firstly, trees are a special kind of graph. Anything expressed as a tree is as well a tree. Secondly, we gain a higher degree of expressiveness even if at the expense of computational complexity, a point to which we will come back later in Section 7.4. This expressiveness is needed when dealing with interconnection of various linguistic theories which in practice is done by mapping the nodes of one tree structure onto the nodes of another one. In addition, the structures are not always trees. There are situations when a node has more than one parent or when a node is connected to its siblings, which breaks the tree structure.

Definition 7.1.1 (Graph)**.** A *graph* $G = (V, E)$ is a data structure consisting of a non-empty set V of nodes and a set $E \subseteq V \times V$ of edges connecting nodes.

Definition 7.1.2 (Digraph)**.** A *digraph* is a graph with directed edges. A directed edge $(u, v) \in E$ is an ordered pair that has a start node u and an end node v (with $u, v \in V$)

In this thesis the graph nodes are considered to be *feature structures* forming *Feature Rich Graphs* (see Definition 7.1.10). Before formally defining these graphs, I need to address first the notion of feature structures and a few kinds of sets.

In SFL the concept of *feature* takes up an important role. Also features are said to form systems of choices that are structured in relation to one another and are suitable for describing linguistic objects and phenomena.

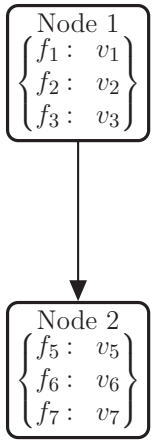
Pollard & Sag (1987) have formally described useful concepts for grammatical representations in the context of Head-Driven Phrase Structure Grammar (HPSG). They adopt the *typed feature structure theory* and extend it in innovative ways applicable in computational linguistics. Among others, they provide formal definitions for the concepts of *feature structure*, *hierarchy*, *logical evaluation*, *composition* and *unification*, the latter, key operations in parsing using feature structured grammars.

In this thesis, feature structures are important but only in a simplified version serving as graph node descriptions. The main reason is the difference in approach as the main parsing operations, here, are based on graph pattern matching (introduced in the sections below).

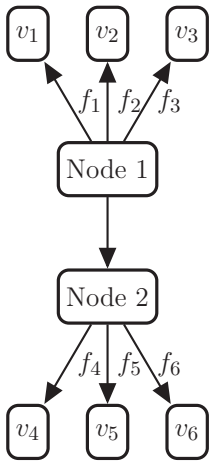
In a broad computer science sense, including Pollard and Sag definition, feature structures are equivalent to graph structures. So any feature structure can be expressed as a graph and any graph can be expressed as a feature structure. But in a narrow sense, as adopted in this thesis, it is useful to employ both concepts but each for a given purpose. The feature structure is reduced to an attribute-value matrix (see Definition 7.1.3) and the graphs to a network of feature structure nodes (see Definition 7.1.10) as depicted in Figure 7.1a, i.e. there are no nodes that carry atomic values such as strings, numbers and there are no nodes carrying an id only and no content (called here referential) as depicted in Figure 7.1b.

For example lets imagine a constituency graph fragment of two nodes *Node 1* and *Node 2* where each has three associated features as can be seen in Figure 7.1a. If we would insist to dispose of the feature structure within the node and express the features as atomic graph nodes then the result would be a graph structure such as the one in Figure 7.1b.

The main reasons in this separation are efficiency and practicality. First, it scopes the operations on atomic values as belonging to feature structures and not as graph nodes. Second, the graphs remain limited in size, close to the conceptualised linguistic structures, i.e. dependency or constituency. Otherwise, the graphs and the manner in which they are processed would rise in complexity. Firstly, the complexity would manifest through at least one more round of nodes for each dependency or constituency node (e.g. the nodes $v_1 - v_6$ in Figure 7.1b) and, secondly, through the need of distinguishing the referential (e.g. Node 1 and Node 2 in Figure 7.1b) and atomic nodes (the nodes $v_1 - v_6$).



(a) The graph with feature structure nodes



(b) The graph with atomic and referential nodes

Fig. 7.1 Graphs with feature structure nodes (adopted in this thesis) compared to graphs with atomic and referential nodes

Definition 7.1.3 (Feature Structure (FS))**.** A *feature structure* F is a finite set of attribute-value tuples $f_i \in F$. A *feature* $f = (a, v)$ is an association between an identifier a (a symbol) and a value v which is either an atomic value (symbol, number, string), a set or another feature structure.

The values of feature structures may be other feature structures allowing, if needed, hierarchical descriptions. In the current implementation, however, the values of the feature structure are restricted to atomic values or sets of values. The reason for this restriction is that the feature structures simply provide descriptions of a graph node in terms of multiple atomic values organised by the FS keys.

For convenience I define two functions to access the identifier and value in a feature structure. The function $name : F \rightarrow symbol$ returns the feature symbol (identifier) $name(f) = a$ and the function $val : F \rightarrow \{atomic, Set, FS\}$ is a function returning the ascribed value of a feature $val(f) = v$.

Definition 7.1.3 stipulates that the value of a feature may be also a set (besides an atomic value). The sets used in this thesis need to carry additional properties required for their interpretation. Specifically, the order needs to be addressed here and the capacity to specify that set elements stand in a certain logical relation to one another (e.g. conjunction, disjunction, negation, etc.). These two properties are covered in Definition 7.1.4 and 7.1.5. For convenience I will assume from now on that sets (see Definition 7.1.4) preserve order even when it is not really required.

Definition 7.1.4 (Set)**.** An (ordered) *set* $S = \{o_0, o_1, o_2, ..., o_n\}$ is a finite well defined collection of distinct objects o_i. A set is said to be ordered if the objects are arranged in a sequence such that $\forall i \in [1, n] : o_{i-1} < o_i$

Definition 7.1.5 (Conjunction Set)**.** A *conjunction set* $S_{conj} = (S, conj)$ is a set S whose interpretation is given by the logical operand *conj* (also denoting the type of the set) such that $\forall o_i, o_j \in S : conj(o_i, o_j)$ holds.

The conjunction sets used in the current work are *AND-set* (S_{AND}), *OR-set* (S_{OR}), *XOR-set* (S_{XOR}) and *NAND-set* (S_{NAND}). The assigned logical operands play a role in the functional interpretation of conjunction sets. Formally these sets are defined as follows.

Definition 7.1.6 (Conjunctive set)**.** Conjunctive set (also called *AND-set*) is a conjunction set $S_{AND} = \{a, b, c...\}$ that is interpreted as a logical conjunction of its elements $a \wedge b \wedge c \wedge ...$

Definition 7.1.7 (Negative conjunctive set)**.** Negative conjunctive set (also called NAND-set) is a conjunction set $S_{NAND} = \{a, b, c...\}$ that is interpreted as a negation of the logical conjunction of its elements $a \uparrow b \uparrow c \uparrow ...$ equivalent to $\neg(a \wedge b \wedge c \wedge ...)$

Definition 7.1.8 (Disjunctive set)**.** Disjunctive set (also called OR-set) is a conjunction set $S_{OR} = \{a, b, c...\}$ that is interpreted as a logical disjunction of its elements $a \vee b \vee c \vee ...$

Definition 7.1.9 (Exclusive disjunctive set)**.** Exclusive disjunctive set (also called XOR-set) is a conjunction set $S_{XOR} = \{a, b, c...\}$ that is interpreted as a logical exclusive disjunction of its elements $a \bigoplus b \bigoplus c \bigoplus ...$ equivalent to $(a \wedge \neg(b \wedge c \wedge ...)) \vee (b \wedge \neg(a \wedge c \wedge ...)) \vee (c \wedge \neg(a \wedge b \wedge ...))$

When conjunction sets are used as values in FSs then the logical operand dictates the interpretation of the FS. When the set type is S_{AND} then all the set elements hold simultaneously as feature values. If it is a S_{OR} then one or more of the set elements hold as values. If it is S_{XOR} then one and only one of set elements holds and finally if it is a S_{NAND} set then none of the elements hold as feature values.

The function $\tau(S)$, defined $\tau : S \rightarrow \{S_{AND}, S_{OR}, S_{XOR}, S_{NAND}\}$, returns the type of the conjunction set and the function $size(S)$, defined $size : S \rightarrow \mathbb{N}$, returns the number of elements in the set. The size function is also denoted as $|S|$.

Now that all the necessary basic notions nave been formally defined I define the feature rich graph and provide a couple of examples afterwards.

Definition 7.1.10 (Feature Rich Graph (FRG))**.** A *feature rich graph* is a digraph whose nodes V are feature structures and whose edges $(u, v, f) \in E$ are three valued tuples with $u, v \in V$ and $f \in F$ an arbitrary feature structure.

Further on, for convenience, when I refer to a graph I will refer to a feature rich digraph unless otherwise stated. The parsing algorithm operates with such graph and they are further distinguished, based on purpose as: *Dependency Graphs* (DG) (example figure 7.2), *Constituency Graphs* (CG) (Figure 7.3) and Pattern Graphs (PG) also referred to as *Query Graphs* (QG).

Edges are in general defined to carry feature structures but this capacity is not employed, for example, in the case of constituency graphs; only minimally employed in the case of dependency graphs, where the dependency relation is specified; and fully employed in pattern graphs. Nonetheless, treating all of them as feature rich graphs simplifies the implementation.

Definition 7.1.11 (Dependency Graph)**.** A *dependency graph* is a feature rich digraph whose nodes V correspond to words, morphemes or punctuation marks in the text and carry at least the following features: *word*, *lemma*, part of speech (*pos*) and, when appropriate, the named entity type (*net*); the edges E describe the dependency relations (*rel*).

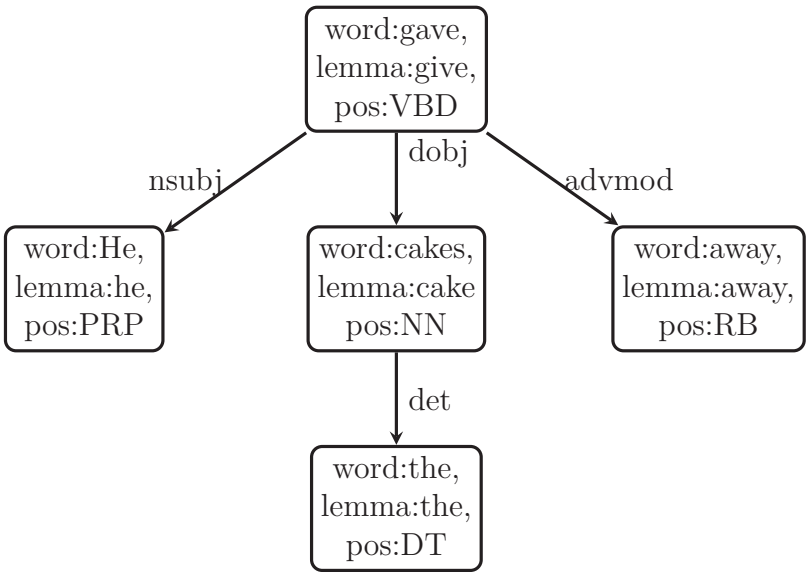


Fig. 7.2 Dependency graph example with FS nodes and edges for sentence "He gave the cake away"

Definition 7.1.12 (Constituency Graph)**.** A *constituency graph* is a feature rich digraph whose nodes V correspond to SFL *units* and carry the *unit class* and the element function within the parent unit (except for the root node); while the edges E represent constituency relations between constituents.

The basic features of a constituent node are the *unit class* and the function(s) it takes, which is to say the *element(s)* it fills in the parent unit (as described in the discussion of theoretical aspects of SFL in Chapter 3). The root node (usually a clause) is an exception and it does not act as a functional element because it does not have a parent unit. The leaf nodes carry the same features as the DG nodes plus the word class feature, which corresponds to the traditional part of speech tags.

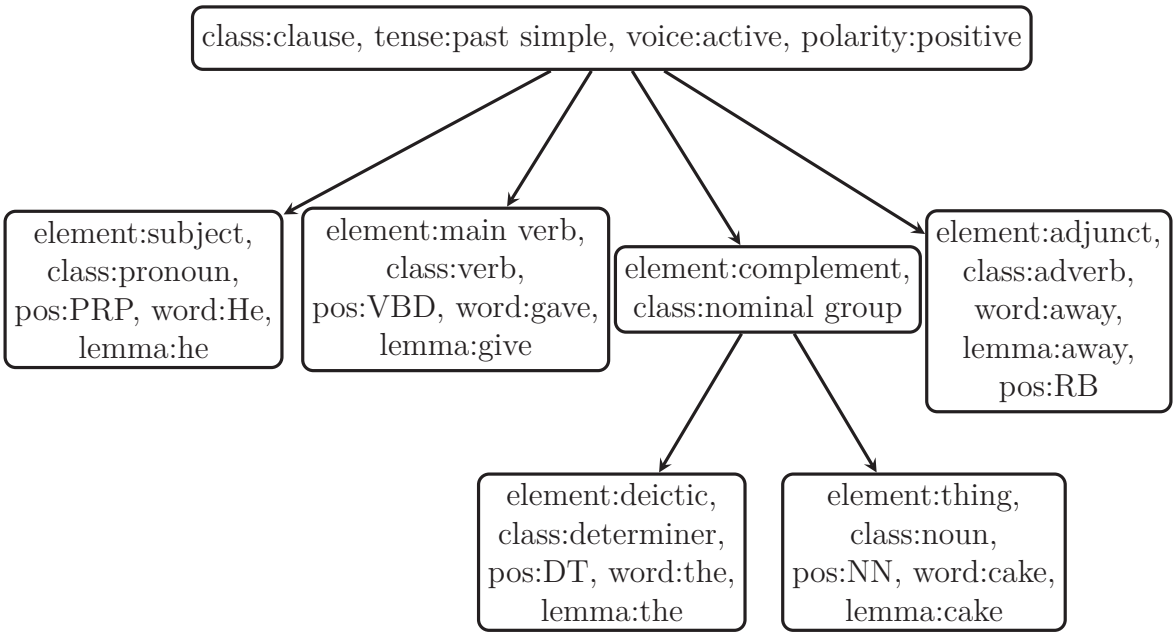


Fig. 7.3 Constituency graph example

Apart from the essential features of class and function, the CG nodes carry additional class specific features selected from the relevant system network. The features considered in this thesis were described in Chapter 4. In addition, the leaf CG nodes contain the features of dependency graph nodes enumerated in Definition 7.1.11. The way CG is enriched with features is described in the next chapter. In Figure 7.3, an example CG is shown that carries tense, modality and polarity features on the clause node in addition to class and element functions. The next section describes the graph traversal in general and two special variants needed later in the chapter.

7.2 Graph traversal

From the general set of operations on graphs defined in graph theory (Bondy et al. 1976; West et al. 2001) graph traversal in particular is of importance for the current work. It is used for the constituency graph creation step presented in the parsing pipeline from Figure 1.8 (in Section 1.7.4). The constituency graph is created by the traversal of a dependency graph. Traversal is used in this thesis for dependency graphs only. Next I address these operations in detail.

The *graph traversal* defined in Definition 7.2.1 and especially its conditional and generative extensions defined in Definition 7.2.2 and 7.2.3 are important operations in this work. They are employed in the first phase of the algorithm, for copying the dependency graph as a constituency graph as will be described in Chapter 8.

Definition 7.2.1 (Traversal)**.** Traversal $t(V_S, G)$ of a graph G starting from node V_S is a recursive operation that returns a set of sequentially visited nodes neighbouring each other in either *breadth first* (t_{BF}) or *depth first* (t_{DF}) orders.

The graph traversal is employed either for searching for a node or an edge or finding a sub-graph that fulfils certain conditions on its nodes and edges if it is a conditional traversal. For example in the semantic enrichment phase (that will be described in Section 9.2), to ensure that the semantic patterns are applied iteratively to each clause, all clause sub-graphs without including the embedded (dependent) clauses are selected from multi-clause CG graphs.

Definition 7.2.2 (Conditional Traversal)**.** Conditional traversal $t(F_V, F_E, V_S, G)$ of the graph G starting from node V_S under node conditions F_V and edge conditions F_E is a traversal operation where a node is visited if and only if its feature structure conditionally fulfils the F_V and the edge that leads to this node conditionally fulfils the F_E.

One of the potential complete traversals for the graph from Figure 7.4 starting from node 1 is {1, 2, 3, 4, 5, 6, 7, 8} using breadth first strategy or {1, 2, 5, 6, 3, 4, 7, 8} for depth first strategy. On the other hand, a conditional traversal of non-dashed nodes staring from the node 1 results in {1, 2, 4, 6}, {1, 4, 2, 6} or {1, 2, 6, 4}. The first two traversals corresponding to the breadth first strategy and the third one to the depth first strategy.

I also use the graph traversal to execute generative operations on a parallel graph, which is a special case of *graph rewriting*. For example DG traversal is employed for

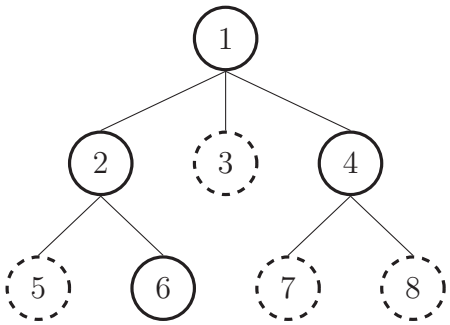
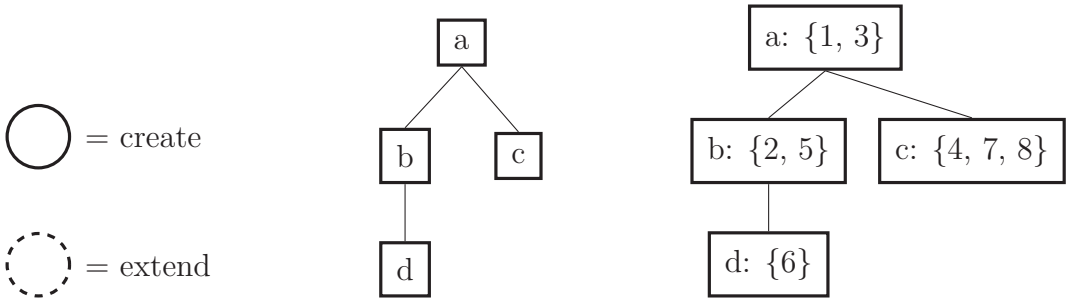


Fig. 7.4 Sample graph with numbered node of two types

bootstrapping (i.e. creating in parallel) the CG as was previously motivated in Section 1.7.4.

Definition 7.2.3 (Generative Traversal)**.** Generative traversal $g(M,G) : H$ of a source graph G via an operation matrix M is an operation resulting in the creation of the target graph H by contextually applying generative operations to bring the latter into existence. The operation matrix M is a set of tuples (ctx, o, p) that link the visited source node context ctx (as features of the node, the edge and previously visited neighbour) to a certain operation o that is executed on the target graph H with parameters p.



(a) The rule set (b) The target (c) The explained target

Fig. 7.5 The generative traversal result for Figure 7.4 using create and extend operations

Next I provide a rough description of what happens when a generative traversal is executed; the exact algorithm will be described in detail in Section 8.3. For example lets assume that only two types of operation are needed for our task at hand. The first is to create a new node on the target graph once a non-dashed node is visited on the source graph. And, second, is to pass the dashed nodes without doing anything. This is schematically represented in Figure 7.5a. Lets now apply these operations on traversing the example graph using the breadth first strategy following the order

provided above: 1, 2, 3, 4, 5, 6, 7, 8. The traversal graph is considered source graph and the target graph is empty at the beginning of the process. Upon visiting node 1 a first node is created on the target graph which is labelled *a*. When traversing nodes 2 and 4 then each of them signal creation of the nodes *b* and *c* as children of *a* in the target graph and correspondingly node 6 signals creation of node *d*. The final target graph is depicted in Figure 7.5b and in Figure 7.5c the source nodes are embedded into the target node to make explicit that the non-dashed nodes (i.e. 3, 5, 7, 8) are simply passed over without any generative operation.

Note that, in the future work, other operations can be explored if needed. Now that generative traversal is defined, by analogy, *update*, *insert* and *delete* traversals can be defined on the source or target graph by using the same mechanism of *operation matrices* mapping contexts of visited nodes and edges to update, insert and delete operations. In this work, however, these operations are not used.

In Section 7.1 the last two definitions were for the constituency and dependency graphs. They are used in this thesis to represent grammatical analysis of a sentence. Next we will look at a special type of graph which represents fragments of structure repeatable across multiple analyses. They represent generalisations or patterns that usually are associated with grammatical features or a set of features which I explain in Chapter 8. These graphs are called *pattern graphs* and the next section is dedicated to them.

7.3 Pattern graphs

Regardless of the type, constituency or dependency, the parsing process (which will be described in Chapter 8) relies on identifying patterns in graphs. The patterning is described as both graph structure and feature presence (or absence) in the nodes or edges. The *pattern graphs* (defined in 7.3.1) are special kinds of graphs meant to represent small (repeatable) parts of parse graphs that, in the context of the current work, are used to identify grammatical features.

The pattern graphs contrast with the *parse* (or *instance*) graphs which are either constituency or dependency graphs. The parse graphs express what is an actual analysis of a text, i.e. representing what is the case, whereas the pattern graph expresses a potential that could be the case in the instance graph. This way the pattern graphs have a prescriptive interpretation whereas the instance ones take a factual interpretation.

Definition 7.3.1 (Pattern Graph)**.** A *pattern graph* (PG) is a feature rich graph for expressing regularities in the node and edge structure.

I discuss two example of pattern graphs. One example shows a pattern graph encoding the present perfect continuous tense, which traditional grammar defines as in Table 7.1. Afterwards, the second example will show how the notion of linear succession among nodes is accounted for in the pattern graphs for declarative and interrogative mood.

has/have	+	*been*	+	*Vb-ing*
to have, present simple		to be, past participle		verb, present participle

Table 7.1 Present perfect continuous tense

Examples 100–102 show variations of present perfect continuous tense in a simple clause according to declarative and interrogative mood and "has" contraction. Of course there are more variations possible, for example, according to voice (active and passive), but they are omitted here because they add combinatorially to the number of examples and the ones provided already serve their purpose here. Figures 7.6-7.8 represent corresponding dependency parses for these examples (generated with the Stanford dependency parser).

(100) He has been reading a text.

(101) He's been reading a text.

(102) Has he been reading a text?

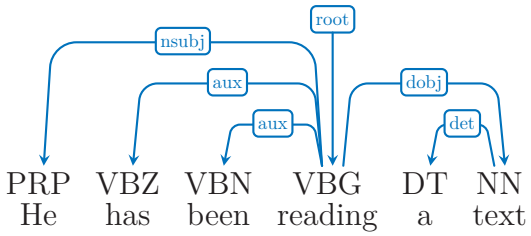


Fig. 7.6 Present perfect continuous: indicative mood, un-contracted "has"

The present perfect continuous tense can be formulated as a pattern graph (including voice) over the dependency structure as illustrated in Figure 7.9. In this pattern the main lexical verb is *present participle* indicated via the *VBG* part of speech. It is accompanied by two auxiliary verbs: *to be* in *past participle* (*VBN*) form and *to have* in *present simple* form specified by either *VBZ* for 3rd person or *VBP* for non-3rd person. Also the *to be* can be either connected by the *aux* relation or in case of passive form by the *auxpass* relation. Note that the pattern in Figure 7.9 constrains the edge

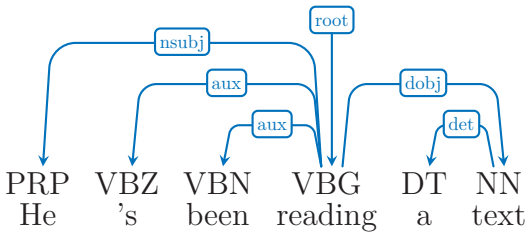


Fig. 7.7 Present perfect continuous: indicative mood, contracted "has"

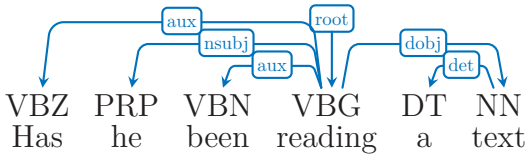


Fig. 7.8 Present perfect continuous: interrogative mood, un-contracted "has"

type (using an OR-set) to the verb *to be* which can be either *aux* or *auxpass* and the part of speech of the verb *to have* which can be *VBZ* or *VBP*.

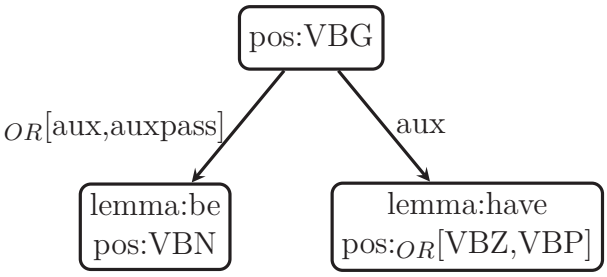


Fig. 7.9 The graph pattern capturing features of the present perfect continuous tense

One of the fundamental features of language is its *sequentiality* and *directionality*. This aspect is not inherent in graphs. In the simplest form, they just describe connections between nodes and are agnostic to any meaning or interpretation. Next, I introduce the way I deal with linear order in the pattern graphs.

Lets consider the clause mood and encode the distinction between *declarative* and *Yes/No interrogative* moods. In SFG these features are described in terms of the relative order of clause elements. If the finite is before the subject then the mood is Yes/No-interrogative, whereas when the finite succeeds subject then the mood is declarative. Example 102 contrasts in mood with Examples 100 and 101.

Order can be specified in absolute or relative terms and partially or exhaustively. In order to cover these three kinds of constraints, I introduce three special features: the node *id*, *precede* and *position*. Node id takes a token to uniquely identify a node in the graph, the precede feature takes an ordered set to indicate the (partial) linear

precedence to other node ids, and the position feature indicates the absolute position of a node.

One way to introduce order among nodes is then by marking them with an absolute position. This is a good method applicable to parse graphs. The DGs and CGs, are automatically assigned at creation time with the absolute position of the node in the sentence text via the feature *position*. This feature is present in the leaf nodes only and corresponds to the order number in which they occur in the sentence text while the non-leaf node's position is considered to be the lowest position of its constituent nodes. The absolute position description is rarely used in the PGs. The only cases are to state that the constituent is in first or last position in a sentence.

Another way to specify node order is through relative precedence, for which the node id and the precedence features are introduced above. This is the preferred method to provide the linear precedence dimension in pattern graphs. It is also relative so the specification can be partial. With this method a node specifies that it precedes a set of other nodes.

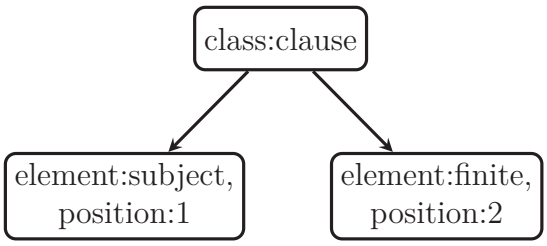


Fig. 7.10 Declarative mood pattern graph with absolute element order

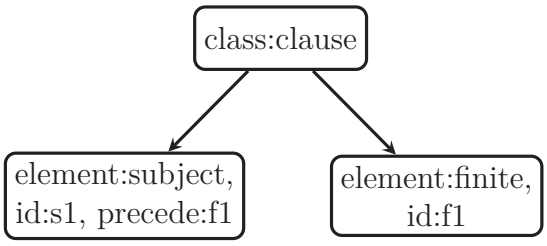


Fig. 7.11 Declarative mood pattern graph with relative element order

To continue the example of mood features, I illustrate in Figures 7.10 and 7.11 the use of relative and absolute node ordering constraints for declarative mood; and in Figure 7.12, I depict the PG for the Yes/No interrogative mood. In both the latter cases I use relative node ordering.

Patterns like the ones explained above can be created for a wide range of grammatical features. Once the grammatical feature is encoded as a pattern graph it can be identified

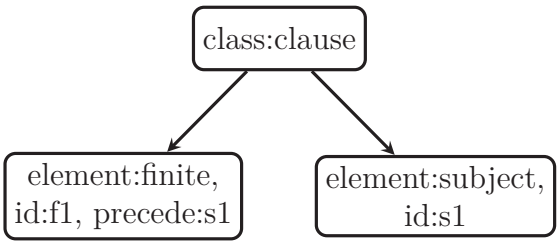


Fig. 7.12 Pattern graph for Yes/No interrogative mood

in parse graphs (DG or CG) via the *graph pattern matching* operation described in Section 7.4. Moreover, once the pattern is identified it can act as a triggering condition for the node update operation. When the pattern is matched then additional features can be added to the nodes of the parse graph and is the mechanism of enriching the parse graph. Coming back to our tense example above, once the pattern 7.9 is identified then the clause can be marked with the tense feature. In the next section I address the graph matching operation and then show how it works using pattern graphs.

7.4 Graph matching

So far we have discussed about constituency and dependency graphs and, in the last section, I introduced pattern graphs. The intuition behind pattern graphs is that they are meant to be matched against or found in other graphs. The pattern graphs can be viewed as small reusable modules and as generalisations consisting of structural patterns. I will address next what it means for two graphs to be the same, i.e. *isomorphic* and how this sameness checking is used in the current work.

In *mathematics* structure-preserving mappings $f : X \to Y$ (from one object X to the other Y) of the same type are called *morphisms*. The morphism $f : X \to Y$ is called an *isomorphism* if there exists an inverse morphism $g : Y \to X$ such that $f \circ g = id_X$ and $g \circ f = id_X$.

In computer science, the *graph matching* operation is known as a (sub-)graph isomorphism. Two graphs $G = (V_G, E_G)$ and $H = (V_H, E_H)$ are isomorphic if there exists a mapping from the nodes of graph G to the nodes of graph H, such that the edge neighbourhood is preserved. In such a context the nodes are unique atomic symbols functioning as node identifiers.

Graphs do not always have the same number of nodes (or edges). We say that a graph is smaller than another one, denoted $G \leq H$, when its number of nodes is less than that of the other graph. In such cases, for two graphs G and H where $G < H$,

the (sub-)graph matching task is redefined to establishing isomorphism(s) from G to a sub-graph of H.

Definition 7.4.1 (Graph matching)**.** For two graphs G and H, where $G \leq H$, *graph matching* is the operation of finding an isomorphism between G and H.

Definition 7.4.2 (Graph isomorphism)**.** An isomorphism of graph $G = (V_G, E_G)$ and $H = (V_H, E_H)$ is a bijective function $f : V_G \to V_H$ such that if any two nodes $u, v \in V_G$ from G are adjacent $(u, v) \in E_G$ then $f(u), f(v)$ are adjacent in H $(f(u), f(v)) \in E_H$.

Definition 7.4.3 (Sub-graph isomorphism)**.** Given two feature rich graphs $G = (V_G, E_G)$ and $H = (V_H, E_H)$, G is sub-graph isomorphic to G (denoted $G \subseteq H$) if there is an injective function $f : V_G \to V_H$ such that

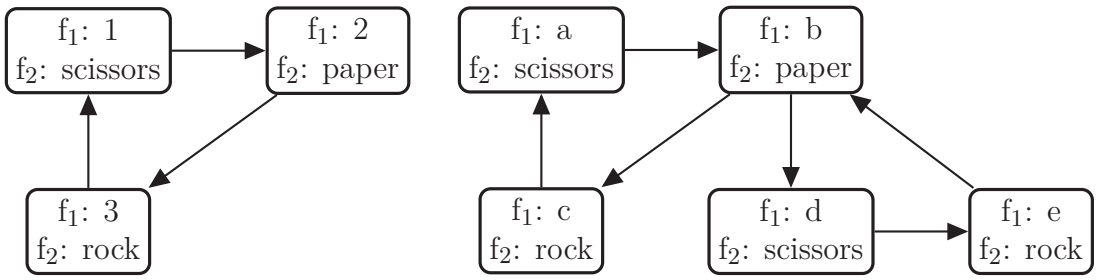
- $\forall v \in V_G, f(v) \in V_H$ and
- any two nodes adjacent in G, $(u, v) \in E_G$, are also adjacent in H, $(f(u), f(v)) \in E_H$

(a) The pattern graph (b) The target graph

Fig. 7.13 Sub-graph isomorphism {1=a, 2=b, 3=c}

Figure 7.13a depicts a labelled graph that is isomorphic to a sub-graph in Figure 7.13b. The example graphs presented in Figure 7.13 have atomic labels as nodes and the isomorphism is established as a mapping between labels. Section 7.1 above mentioned that the graphs considered in this thesis have feature structures as their nodes and no atomic nodes. But in case of feature rich graphs additional rules to establish the isomorphism need to be provided because there are multiple ways of approaching it.

Lets look at Figure 7.14 where the graph nodes are feature structures using features: f_1 and f_2. One way to approach isomorphism in this scenario is by the value of one feature, for example f_1. Then we can identify two sub-graph isomorphisms: {1=a, 2=b, 3=c} and {1=b, 2=d, 3=e}. This approach, besides additional specification what values to compare, i.e. $f_1 s$, is the same as providing a sub-graph isomorphism on the labelled graphs from Figure 7.13.



(a) The pattern graph (b) The target graph

Fig. 7.14 An example of rich sub-graph isomorphism

In addition to the rule above, lets add a constraint that the isomorphism is not only a mapping between the feature values (numbers to letters) but also that the mapped values are identical (strict value equality). If we consider the strict equality rule applied on f_1 feature, there is no isomorphism between the two graphs because first one uses numbers {1, 2, 3} and the second uses letters{a, b, c, d}. Now if we turn to the values of f_2 and apply the same rule then there is one isomorphism possible {paper=paper, rock=rock, scissors=scissors}. The second one, even if it is a cycle, {paper=paper, rock=scissors, scissors=rock} is no longer acceptable because the "scissors" and "rock" switched places in the target graph; it would have been acceptable as a mapping, but not as strict value equality. Formally, the additional equality constraint can be expressed on the graph isomorphism f as $u = f(u)$.

This brings us to the idea that, in the feature rich (sub-)graph isomorphism, we need to introduce a *matching* operator (denoted $\succcurlyeq$) for nodes. This means that we no longer can use atomic symbol mapping but have to employ the matching operator. The node matching operation is defined on feature structures. We say that a feature structure may match another feature structure once, several times or not at all, $FS_1 \succcurlyeq FS_2$. This intuition is expressed in Definition 7.4.6. The sub-graph isomorphism over the feature rich graphs is captured in Definition 7.4.4 below.

Definition 7.4.4 (Rich sub-graph isomorphism)**.** Given two feature rich graphs $G = (V_G, E_G)$ and $H = (V_H, E_H)$ and a matching relation $\succcurlyeq$, G is a sub-graph isomorphic to H if there is an injective mapping $f : V_G \to V_H$ such that

- each node in V is mapped to exactly one node in H, $\forall v \in V_G, f(v) \in V_H$ and
- each node in G matches with its correspondent in H, $\forall v \in V_G, v \succcurlyeq f(v)$ and
- any two nodes which are adjacent in G, are also adjacent in H, $\forall (u, v) \in E_G, \exists \Big(f(u), f(v)\Big) \in E_H$

We already mentioned in the introduction of this section that pattern graphs are considered as generalisations over parse graphs (constituency or dependency). The pattern graphs are smaller and their nodes have fewer features specified. The parse graphs have more nodes and features. We say that a parse graph *instantiates* a pattern graph if there exists a rich sub-graph isomorphism. This operation is called *pattern graph matching* and is defined in Definition 7.4.5 below.

Definition 7.4.5 (Pattern graph matching)**.** Given a pattern graph G and an instance (parse) graph H (either dependency or constituency), *pattern graph matching* is the operation of finding a rich sub-graph isomorphism from G to H such that each pattern node matches its corresponding instance node for each H, $\forall v \in V_G, v \succcurlyeq f(v)$.

As mentioned before, nodes of the parse and the pattern graphs are feature structures. I approach the matching between them in two steps: first, matching the feature names in Definition 7.4.6, and second, matching the feature values in Table 7.2. In order to simplify and make explanations clear, I will further refer to the feature structures that constitute nodes in the pattern graphs as *pattern feature structures* and the feature structures that constitute nodes in the instance graphs as *instance feature structures*.

Definition 7.4.6 (Feature structure matching)**.** A pattern feature structure V matches an instance feature structure U if and only if every feature in V has a corresponding feature U and their values match; that is $\forall f_V \in V, \exists f_U$ such that $name(f_V) = name(f_U)$ and $val(f_V) \succcurlyeq val(f_U)$.

According to Definition 7.1.3, the values of feature structures can be either atomic (numbers, strings, symbols, etc.), denoted *atomic*, or one of the conjunction sets: S_{AND}, S_{OR}, S_{XOR} and S_{NAND}. For simplicity, the option of nested feature structures is excluded in the current work even though it is perfectly viable configuration. Consequently, the matching relation takes into consideration the *type* of the compared elements in addition to how they relate to each other, including comparisons between set and atomic values. Note that this relation is *not symmetric*, i.e. *not commutative* because the subsequent relations used in the definition, i.e. set inclusion and set subsumption, are not symmetric. This means that $A \succcurlyeq B \neq B \succcurlyeq A$.

I will also remind here that the function $\tau(S)$, defined in Section 7.1, returns the *type* of the feature value. I extend its definition here to handle also atomic data types as follows: $\tau : x \rightarrow \{atomic, S_{AND}, S_{OR}, S_{XOR}, S_{NAND}\}$. The matching rules have to be defined for each possible pair of types returned by the function τ yielding 25 possibilities. Table 7.2 provides matching relations for each pair of types where the

rows represent value types of the pattern features, denoted $\tau(v)$, and the columns represent value types of the instance features, denoted $\tau(u)$. Each table cell contains a comparison expression returning a truth value. Cells with a bottom sign $\perp$ mean that there can be no match between these types no matter the values.

$\tau(v) \backslash \tau(u)$	*atomic*	S_{AND}	S_{OR}	S_{XOR}	S_{NAND}
atomic	$v = u$	$v \in u$	$\perp$	$\perp$	$v \notin u$
S_{AND}	$\perp$	$v \subseteq u$	$\perp$	$\perp$	$\perp$
S_{OR}	$v \ni u$	$v \cap u \neq \varnothing$	$v \supseteq u$	$v \supseteq u$	$\perp$
S_{XOR}	$v \ni u$	$\perp$	$\perp$	$v \supseteq u$	$\perp$
S_{NAND}	$v \not\ni u$	$v \cap u = \varnothing$	$v \cap u = \varnothing$	$v \cap u = \varnothing$	$v \subseteq u$

Table 7.2 Strict matching between pattern and instance feature values organised by value type

For example, if both values are of atomic type then in order to match they have to equal. If the $\tau(v)$ is atomic and the $\tau(u)$ is an AND set then v needs to be among the set of values constituting u; whereas if the $\tau(u)$ is an OR or XOR set then these values do not match, designated by the bottom sign $\perp$. The same reading applies to the rest of the table for each pair of value types.

A more permissive matching is defined in Table 7.3. Here, on the instance feature values, the two types of disjunction (OR and XOR) and the negated conjunction (NAND) are interpreted as possibly matching and are provided with the corresponding relation, whereas in the previous definition these cases were completely excluded. The permissive match is rarely used in this work but it is nevertheless useful for cases of instance graphs where the feature values could not be assigned with a certainty but as a disjunction of either one or the other.

$\tau(v) \backslash \tau(u)$	*atomic*	S_{AND}	S_{OR}	S_{XOR}	S_{NAND}
atomic	$v = u$	$v \in u$	$v \in u$	$v \in u$	$v \notin u$
S_{AND}	$\perp$	$v \subseteq u$	$v \subseteq u$	$v \subseteq u$	$v \cap u = \varnothing$
S_{OR}	$v \ni u$	$v \cap u \neq \varnothing$	$v \supseteq u$	$v \supseteq u$	$v \backslash u \neq \varnothing$
S_{XOR}	$v \ni u$	$\perp$	$\perp$	$v \supseteq u$	$\lvert v \backslash u \rvert = 1$
S_{NAND}	$v \not\ni u$	$v \cap u = \varnothing$	$v \cap u = \varnothing$	$v \cap u = \varnothing$	$v \subseteq u$

Table 7.3 Permissive matching between pattern and instance feature values organised by value type

The permissive FS matching has been developed together with the strict FS matching as it was not clear at the beginning of the work which one is suitable for current purposes. After conducting several tests it became clear that strict matching

is the one yielding the better results because it yields fewer matches. This is especially visible in the cases of Transitivity enrichment when too many incorrect patterns are qualified by the permissive operator. Now that pattern graph matching is explained, lets take a look next at how it is used to perform operations on instance graphs.

7.5 Pattern based operations

Patterns are searched for in a graph always for a purpose. Graph isomorphism is only a precondition for another operation, be it a simple selection (i.e. non-affecting operation) or an affecting operation such as feature structure enrichment (on either nodes or edges), inserting or deleting a node or drawing a new connection between nodes. The end goal is embedded into the pattern as operation specification: so that when the pattern is identified, also the desired operation(s) is(are) triggered. I call such graph patterns *operational pattern graphs* (Definition 7.5.1). Next I explain how to embed operations into the graph pattern and how they are used in the parsing algorithm.

Definition 7.5.1 (Operational graph pattern)**.** An *operational graph pattern* is a pattern graph that has at least one node *operation* and *arg* features.

The operational aspect of the pattern graph is specified in the node FS via three special features: *id*, *operation* and *arg*. The *id* feature (the same as for relative node ordering) is used to mark the node for further referencing as an argument of an operation, the *operation* feature names the function to be executed once the pattern is identified and the *arg* feature specifies the function arguments if any are required; they are tightly coupled with function implementation. If a node has the feature operation then it is called an *operational node*. Also, in the current implementation, the special features such as operation, arg, id, precede etc. are excluded from the pattern matching operation because they have functional roles linked to the implementation and do not describe the linguistic properties of a graph node.

So far the implemented operations are *insert*, which is used for creation of empty nodes, *delete*, which is used for corrections of predictable errors in dependency graphs and the *update* operation, which is the main mechanism behind graph enrichment. These operations are depicted in Figure 1.8 of the parser pipeline architecture from Section 1.7.4.

Operative patterns are enacted once they are matched to an instance graph. An operative pattern graph G is *enacted* on an instance graph H in two steps. First,

the pattern graph is strictly matched to an instance graph. If an isomorphism f is found then, second, for every operational node $v \in G, \exists att(v) = operation$, the specified operation $op = val(v.operation)$ and the corresponding node of the instance graph $u \in H$, the operation is executed on the node of the instance graph $op(u)$. If the arg feature is provided then the operation is executed with that additional argument.

7.5.1 Pattern based node update

As mentioned above the pattern based node update is used for adding onto the constituency graph new features. Lets consider Example 103 whose constituency graph is provided in Figure 7.15 and the task is to assign the *agent* feature to the subject node and *affected-possessed* feature to the complement. This can be done using the pattern graph matching with a feature update operation indicated on subject and complement nodes. The PG depicted in Figure 7.16 fulfils this purpose because it matches the constituency graph from Figure 7.15 and has the corresponding update operations indicated.

(103) He gave the cake away.

(104) He gave her the cake.

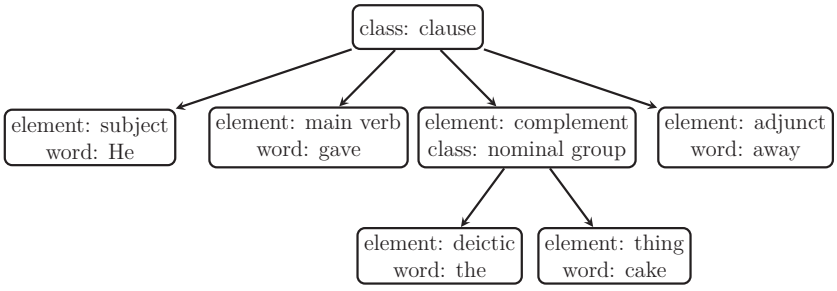


Fig. 7.15 Constituency graph corresponding to Example 103

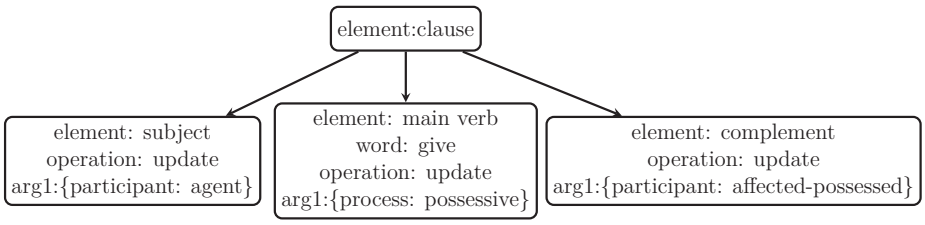


Fig. 7.16 A graph pattern for inserting agent and affected-possessed participant roles

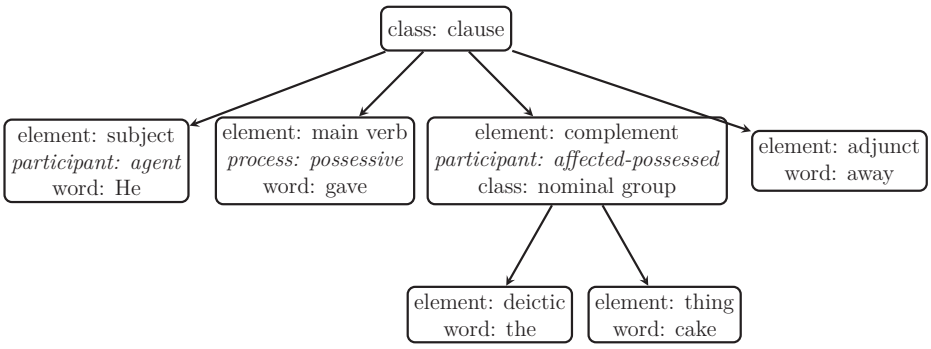


Fig. 7.17 The resulting constituency graph enriched with participant roles

Consider the same pattern, but applied to a sentence in Table 7.4. This clause has two complements and they are by no means distinguished in the pattern graph. When such cases are encountered the PG yields two matches (each with another complement) and the update operation is executed on both of the complements. To overcome such cases the PG allow defining *negative nodes*, meaning that those are nodes that shall be missing in the target graph.

For example to solve the previous case I define the PG depicted in Figure 7.18 whose second complement is a negative node and it is marked with dashed line. This pattern is matched only against clauses with exactly one complement leaving aside the di-transitive ones because of the second complement.

class:clause				
element:subject	element: main verb	element:complement	element:complement	
He	gave	her	the	cake.

Table 7.4 CG with a di-transitive verb

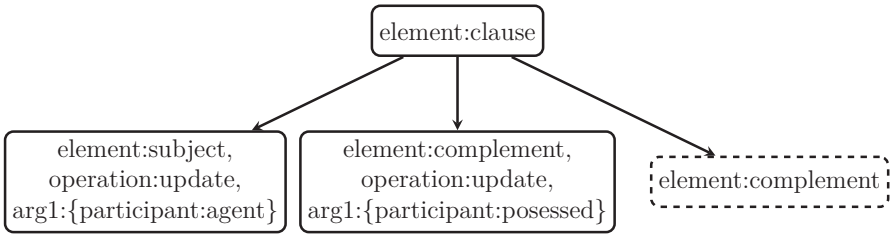


Fig. 7.18 PG for inserting agent and possessed participant roles to subject and complement nodes only if there is no second complement.

The current implementation of matching the patterns that contain negative nodes is performed in two steps. First the matching is performed with the PG without the negative nodes and in case of success another match is attempted with the negative

nodes included. If the second time the matching yields success then the whole matching process is unsuccessful, but if the second phase fails then the whole matching process is successful because no configuration with negative nodes is detected.

For the sake of explanation I call the pattern graph with all the nodes (turned positive) *big* and the pattern graph without the nodes marked negative *small*. So then, matching a pattern with negative nodes means that matching the *big* pattern (with negative nodes turned into positive) should fail while matching the *small* one (without the negative nodes) should succeed.

7.5.2 Pattern based node insertion

In English there are cases when a constituent is missing because it is implied by the (grammatical) context. These are the cases of Null Elements treated in the Chapter 6. Consider Example 105.

(105) Albert asked [∅ to go alone].

There are two clauses: first in which Albert asks something and the second where he goes alone. So it is Albert that goes alone, even though this is not made explicit through a subject constituent in the second clause. Such implied elements are called *null or empty constituents* as discussed in detail in Section 6.2. Table 7.5 provides a constituency analysis for the example and the null elements (in italic) are appended for the explicit grammatical account. In Section 6.3 I offered grammatical account of the graph patterns characterising null elements and in Section 9.3 I will describe how these patterns are used to insert null elements into the parse graphs; extensively using the pattern based node insertion treated here.

<table>
<tr><td colspan="5">class:clause</td></tr>
<tr><td rowspan="2">element: subject</td><td rowspan="2">element: main verb</td><td colspan="3">element: complement, class:clause</td></tr>
<tr><td>element: subject</td><td colspan="2">element: main verb</td><td>element: adjunct</td></tr>
<tr><td>Albert</td><td>asked</td><td>Albert</td><td>to</td><td>go</td><td>alone.</td></tr>
</table>

Table 7.5 The constituency analysis that takes null elements into consideration

To insert a new node the PG needs to specify that (1) the inserted node does not already exist, so it is marked as a negative node, (2) specify *operation:insert* in the FS of the same node and (3) provide the id of the referenced node as FS argument (arg1) if one should be taken.

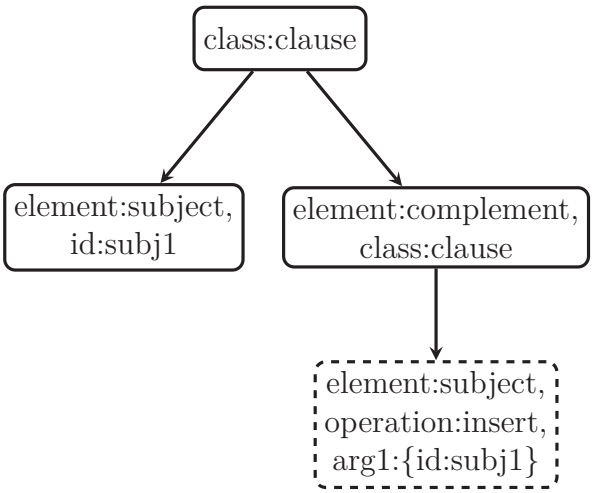


Fig. 7.19 A graph pattern to insert a reference node

In operational terms, the insertion operation means that the whole pattern will first go through a matching process. If there is a match then the new node is created. A important thing about the created node is that it may keep a reference to another node or not. In our example it does keep a reference to the subject of the dominant clause. If so, then all the features of the referee node are inherited by the new node. And if any are additionally provided then the new node overrides the inherited ones.

This section concludes our journey into the world of graph patterns, isomorphisms and graph based operations. This leaves only one more important data structure to cover: the system networks.

7.6 Systems and Systemic Networks

In Section 3.2.4 I presented the basic definition of *system* and *system network* and the notations as formulated in the SF theory of grammar. The formal definition of the system network differs from the one available in the SFL literature. Next I briefly highlight how before providing the actual definitions.

In this work the system networks are simplified to hierarchies of disjoint features maintaining the entry conditions. This corresponds to the *type logic* component of SF grammar described in O'Donnell (1993) where the syntagmatic organisation is restricted to a single functional layer. The reason behind this simplification is because the hierarchy of disjoint feature structures are perfectly suitable to correctly derive the complete set of parent features from a one or several manual selections. Moreover the systemic networks are not interconnected into a uniform grammar but separate

modules describing selected aspects of language. Once the complete set of features is derived then it is associated with a graph pattern. This pattern graph is then used in the parse graph enrichment process described in Section 1.7.4. Next I define the necessary concepts serving the current work. First I introduce the abstract concept of *hierarchy* defined in a computer science fashion by Pollard & Sag (1987: 30), which is a formal rephrasing of Definition 3.2.1 stating that the hierarchy is a logical precedence relation among the terms of a network system.

Definition 7.6.1 (Hierarchy)**.** A hierarchy is a finite bounded complete partial order $(\Delta, \prec)$.

The next concept that requires closer formalisation is that of a system first established in Definition 3.2.10. For precision purposes, this has a narrower scope without considering the system networks or precondition constraints; these are introduced shortly afterwards building upon the current one.

Definition 7.6.2 (System)**.** A *system* $\Sigma = (l, P, C)$ labelled l is defined by a finite disjoint set of distinct and mutually defining terms called a *choice set* C (of type S_{XOR}) and an *entry condition set* P of type S_{XOR} establishing the delicacy relations within a system network.

There is a set of functions defined that apply to systems: $label(\Sigma) = l$ is a function returning the system name, $choices(\Sigma) = C$ is a function returning the choice set, $precondition(\Sigma) = P$ is a function returning the set of entry condition features, and the $size(\Sigma)$ return the number of elements in the system choice set.

Definition 7.6.3 (Systemic delicacy)**.** We say that a system S_1 is more delicate than S_2, denoted as $S_1 \prec S_2$, if

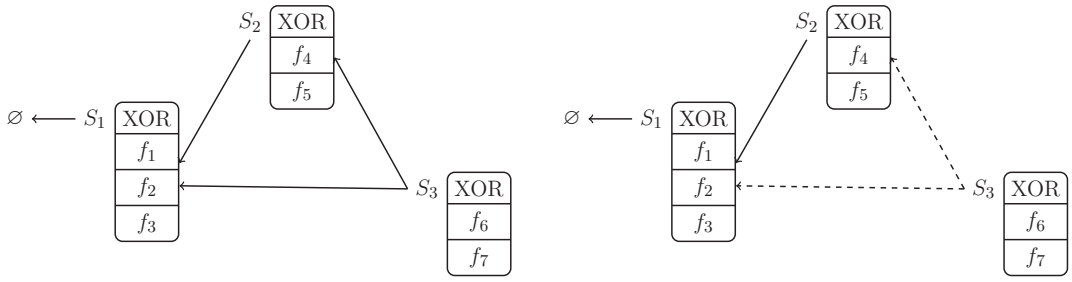
1. both system belong to the same system network: $S_1, S_2 \in SN$
2. there is at least a feature but not all of S_1 which belongs to the entry condition of S_2 i.e. $choices(S_1) \in precondition(S_2)$ or
3. there is another system S_3 that has among its entry conditions a feature of S_1 and whose features are among the entry conditions of S_2, i.e. $\exists S_1' \in SN$ such that $choices(S_1) \in precondition(S_3) \wedge choices(S_1') \in precondition(S_2)$

Systems are never used in isolation. SF grammars usually are extensive networks of interconnected systems defined as follows.

Definition 7.6.4 (System Network)**.** A *system network* $SN = (r, \Gamma)$ is defined as a hierarchy over a set of systems Γ where the order is that of systemic delicacy starting from a root feature r such that for any system in the network either there is another less delicate system or its entry condition is the root feature i.e. $\forall S_i \in \Gamma, \exists S_j \in \Gamma | S_j \prec S_i \vee precondition(S_i) = r$.

In a systemic network SN where a system S_l depends on the choices in another system S_e (i.e. the preconditions of S_l are features of S_e) we call the S_e an *early(older) system* and the S_l a *late(younger) system*. This is just another way to refer to ordering systems according to their delicacy but applying this ordering to execution of systemic selection.

The graphical notation of system networks was introduced in Section 3.2.4. Considering the above definitions, the system network can be represented as a graph where each node is a system feature and edges represent precondition dependencies. Figure 7.20 depicts examples of a system network with three systems. In Figure 7.20a the entry conditions are S_{AND} sets only, and in Figure 7.20b the entry condition for S_3 is $OR(f_2, f_4)$ depicted with dashed lines. In such a graph, all system features must be unique i.e. $\forall S_1, S_2 \in SN : choices(S_1) \cap choices(S_2) = \varnothing$ and there may be no dependency loops.



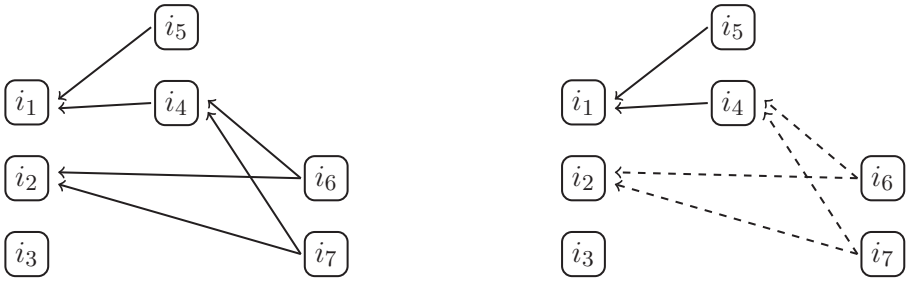
(a) System Network with conjunctive entry conditions

(b) System Network with disjunctive entry condition for S_3

Fig. 7.20 Example System Network presented as graphs

For a chosen feature in the system network it is possible to trace a path to the root feature by traversing systems through their preconditions. Generating such a path is equivalent to preselecting the features in all earlier systems. This is needed for assigning a complete set of feature selections to a pattern graph before it is used in the parse graph enrichment. Conversely, in the verification process it is necessary to check whether a set of arbitrary features belong to a *consistent* and *complete selection path*. Next I address the concepts needed for this task and how it is executed.

The system networks from Figure 7.20 can be unpacked into a *feature network* (Definition 7.6.5 which is referred to as a *maximal selection graph*) interconnected by system entry conditions. In Figure 7.21 two feature networks are depicted corresponding to the system networks above. The dashed lines mean disjunction and continuous ones mean conjunction of entry features.



(a) Feature Network graph with conjunctive entry conditions only

(b) Feature Network graph with some disjunctive entry condition

Fig. 7.21 Example Feature Network graphs

The feature network can be defined in relation to the system network as follows.

Definition 7.6.5 (Feature Network)**.** For a given system network $SN = (r, \Gamma)$, a *Feature Network* $FN(N, E)$ is a directed graph whose nodes N are the union of choice sets of the systems Γ and the edges E connect choice features with the entry condition (precondition) features of the systems Γ.

Given a feature network $FN(N, E)$ and a feature of the network $f \in N$ a *selection path* $SP(N, E)$ is a connected sub-graph of traversal paths between the root of the feature network and the feature f. A *complete selection path* is a selection path from one of the leaf nodes up to the network root.

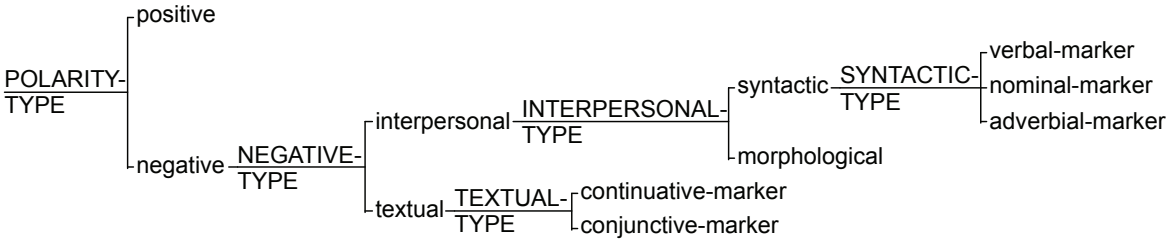


Fig. 7.22 Polarity System

The selection path is generated by traversal of the feature network from a given feature node towards the root node. If the node has no incoming edge then the result of traversal is a leaf node and the resulting selection path is complete. For example,

if *verbal-marker* feature is selected in the system network depicted in Figure 7.22 the traversal of the corresponding feature network toward the root feature yields the selection path *negative – interpersonal – syntactic – verbal-marker*. This path is also complete with respect to the network because there are no systems younger than the SYNTACTIC-TYPE system.

When the system networks define more than one feature in the precondition it leads to split paths. This means that there is more than one feature that needs to or can be preselected. If the edge is a continuous line (depicted in Figure 7.21a) the both variants are part of the same selection path. In case the edge is a dashed line (depicted in Figure 7.21b) the paths are considered alternative and a further decision making mechanism must be employed to reduce the disjunction to a single variant. In the current work no such mechanism is employed and the parse result is presented with both alternatives. In most cases the entry condition is constituted of a single feature, when there are multiple ones, usually they are conjuncted and only in a small minority of cases entry condition is a disjunction of features.

Algorithm 1: Naive backwards induction of a selection path

```
   input  : feature, system network
1  begin
2      add feature to empty selection path
3      for system in traversal path to the root of system network:
4          get entry condition features of system
5          add entry condition features to the selection path
6      return selection path
7  end
```

The pseudo code for creating a selection path as described above is outlined in Algorithm 1. Given a system network and a random non-root feature belonging to the network, it traverses the systems, one by one, towards the root and collects the entry conditions of each system into a selection path.

7.7 On realisation rules

The previous section explains that in the current work system networks are simplified to a taxonomy of features and no realisation rules are considered. This section explains how the pattern graphs are a substitute for the realisation rules and how they relate to each other.

The *realisation rule* of a systemic feature specifies how that feature is realised as a syntagmatic structure down to form using operations such as insert or expand constituent, order two constituents, preselect another feature, lexicalise etc. They are the essential ingredients binding the paradigmatic description in a syntagmatic structure. Robin Fawcett emphasises the role of realisation rules in the composition of system networks. He often stresses "no system networks without realisation rules". It is the *instantiation* process that in Halliday's words "is the relation between a semiotic system and the *observable* events or 'acts' of meaning" (Halliday 2003b: emphasis added). The realisation rules for a systemic feature are the statement of operations through which that feature contributes to the structural configuration (that is being either generated or recognised) (Fawcett 2000: p.86).

In this work the graph patterns can be considered as bundles of realisation rules and feature selections and therefore an approach to replace the realisation rules. This idea is implicitly covered in Section 7.3 and here I explicitly describe it through an example. Consider the fragment of the Mood system network from Halliday & Matthiessen (2013b: 162) depicted in Figure 7.23. This example aims at three feature selections: major, indicative and declarative. The root feature in the system network is realised through a constituent *clause*, any of the selected features is ascribed directly to it, and the selection of any subsequent features impacts the elements below through the associated realisation rules. The pattern graph that captures selection of the major feature is depicted in Figure 7.24.

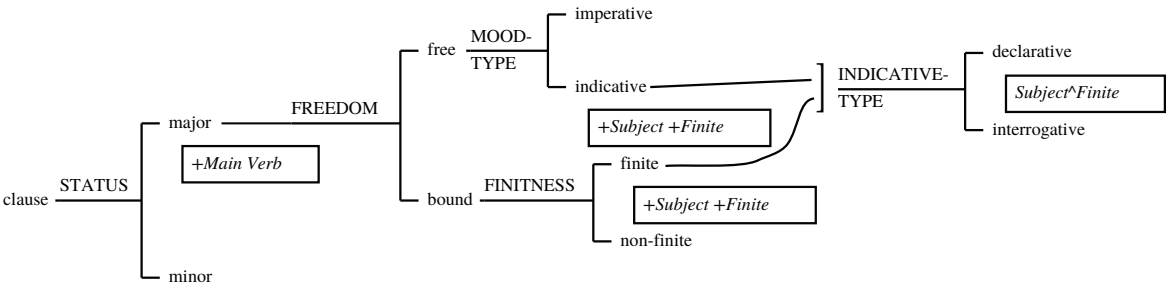


Fig. 7.23 An adapted fragment of a Mood system from (Halliday & Matthiessen 2013b: 162)

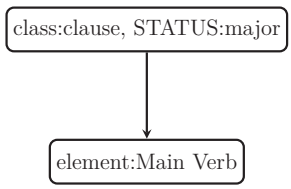


Fig. 7.24 A graph pattern for *major* feature selection in Figure 7.23

Figure 7.25 depicts the pattern graph corresponding to the selection of indicative feature. Here the clause constituent receives the whole selection path up to the root feature *clause – major – free – indicative* and in addition two more constituents are required: Subject and Finite. Almost the same pattern graph is valid in case of selecting bound feature instead of indicative.

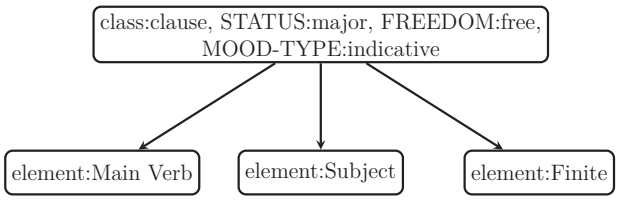


Fig. 7.25 A graph pattern for *indicative* feature selection in Figure 7.23

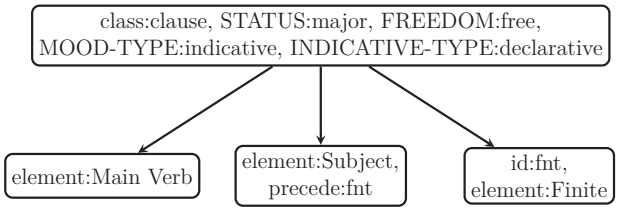


Fig. 7.26 A graph pattern for *declarative* feature selection in Figure 7.23

In Figure 7.26 the selection is taken one step further to the declarative feature. The associated realisation rule is ordering the Subject and Finite elements. This is captured via the "precede:fnt" where "fnt" is the id of the Finite constituent.

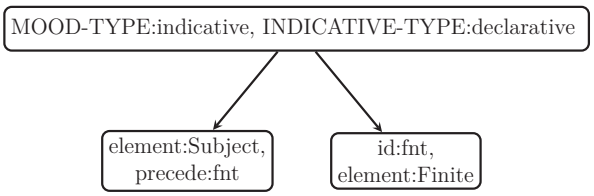


Fig. 7.27 A graph pattern for the selection if *indicative* and *declarative* features in Figure 7.23

The pattern does not need to refer to the complete selection path but can be limited to the context of a few related features. For example, Figure 7.27 represents selection of the indicative and declarative features in isolation. In this case the class of the parent constituent (that in the above cases is the clause) is no longer specified because the restricted selection path and thus the root of the network is not reached. Also none of the preselected features *major* and *free* are specified either.

One limitation, however, of the graph patterns is dealing with conflation phenomena. For example, the cases of the Main Verb conflated with Finite elements have to be accounted by with pattern graphs where one constituent has two functions instead of pattern graphs with two separate constituents each with the corresponding function. This limitation can be addressed in the future by manipulating the definition of the feature structure matcher described in Section 7.4.

7.8 Summary

This chapter described from a computer science perspective the SFL concepts introduced in Chapter 3 and prepares the ground for the following chapters that address the implementation details of the Parsimonious Vole parser.

A central theme covered here are the graphs and graph patterns. They play the key role in identifying grammatical features in dependency and constituency structures. They are also an excellent candidate for expressing *systemic realisations* which have not been considered in the current work as being associated with the systemic features.

Authoring realisation rules is a difficult task and requires proper tool support. The same is the case for graph patterns and even more so when they need to be related to systemic networks or network parts. The system network authoring tool, such as the one available in UAM Corpus Tool (O'Donnell 2008b), could provide also a graph pattern editor allowing association of graph patterns to systemic features. This would have to be embedded into a module implementing a grammar development environment. Building such an editor is an opportunity to create additional value if taken up in the future developments. Also employing a mature specialised technology for manipulating large amounts of graph data as available in the Semantic Web suite of tools is another direction for the future described in the Section 11.2.

In the next chapter I describe the parsing pipeline and how each step is implemented starting from the Stanford dependency graph all the way down to a rich constituency systemic functional parse structure.

Chapter 8

Creating the systemic functional constituency structure

The previous chapter introduced the building blocks for the parser pipeline algorithm depicted in Figure 1.8. This chapter covers the entire first phase of the algorithm called "graph building". The input for the parsing pipeline is made up of Stanford dependency parse graphs. The dependency graphs are sometimes erroneous or treat certain linguistic phenomena in a way incompatible with the current approach. Therefore a preprocessing stage is needed to correct and canonicalise the dependency graphs; this is covered in Sections 8.1 and 8.2. Then these graphs are rewritten into systemic constituency graphs. The process by which this happens is covered in Section 8.3.

8.1 Canonicalisation of dependency graphs

Beside stable errors, there are two other phenomena that are modified in the preprocessing phase: *copula* and *coordination*. They are not errors per se but represent simply an incompatibility between how the Stanford parser represents them and how they need to be represented for processing by the current algorithm and grammar.

In this section I describe a set of transformation operations on the dependency graph before it is transformed into a systemic constituency graph. The role of the preprocessing phase is to bring in line aspects of the dependency parse to a form compatible with the systemic constituency graph creation process by (a) correcting known errors in DG, (b) cutting down some DG edges to form a tree, and (c) changing the Stanford parser's standard handling of copulas, coordination and few other phenomena. This is achieved via three transformation types: (a) *relabelling of edge relations*, (b) relabelling node POS, and (c) reattachment of nodes to a different parent.

8.1.1 Loosening conjunction edges

The Stanford parser employs an extra edge for each of the conjuncts such that there is one indicating the syntactic relationship to the child or parent nodes (just like for any other nodes) and additionally one that shows the conjunction relationship to its sibling nodes. In this step, the parent or child relations except for the first conjunct are removed leaving only the sibling relations.

Some common patterns occurring between noun, verb and adjective conjuncts are depicted in Figures 8.1 - 8.4.

(a) Composite subject (b) Composite object

Fig. 8.1 Conjunction of nouns in subject and object positions

The main reason these extra edges need to be removed is to avoid traversal of the same node via different paths. This, in the current algorithm, has as consequence execution of the same operation multiple times such as for example creation of multiple constituents from the same DG node, which is of course undesirable. For example, if multiple subject relations occur in the DG then multiple subjects are going to be instantiated in CG and this is grammatically incorrect. Rather only one complex unit needs to be created with the subject role composed of two noun phrases; this was discussed in Section 3.4.6.

The way I resolve this problem is by removing functional edges to/from each conjunct except the first one. There are two generic patterns in Figures 8.5a and 8.6a correspondingly with incoming and outgoing edges that are transformed into the forms depicted in 8.5b and 8.6b.

I split the cases into two: patterns with incoming dependency edges and outgoing ones. First, see the pattern of conjuncts with *incoming dependency* relations represented

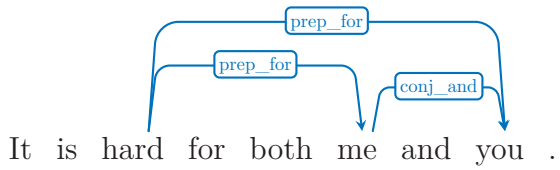


Fig. 8.2 Conjunction of prepositional phrases

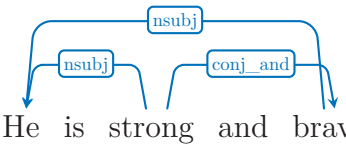


Fig. 8.3 Conjunction of copulatives sharing the subject

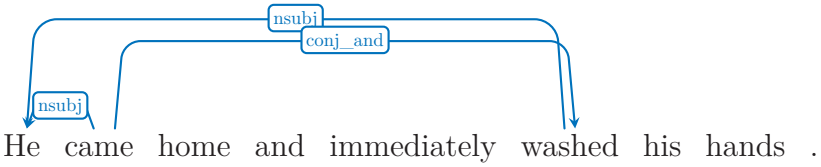
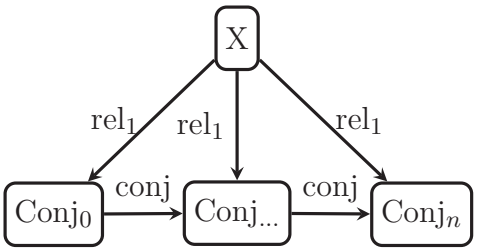
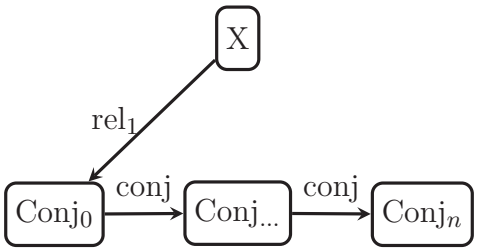


Fig. 8.4 Conjunction of verbs sharing the same subject

in Figure 8.5a and exemplified in Figures 8.1a - 8.2. In SFG terms it corresponds to cases when the functional element of a parent constituent is filled by a complex unit below.



(a) Conjuncted elements with incoming tightly connected dependencies



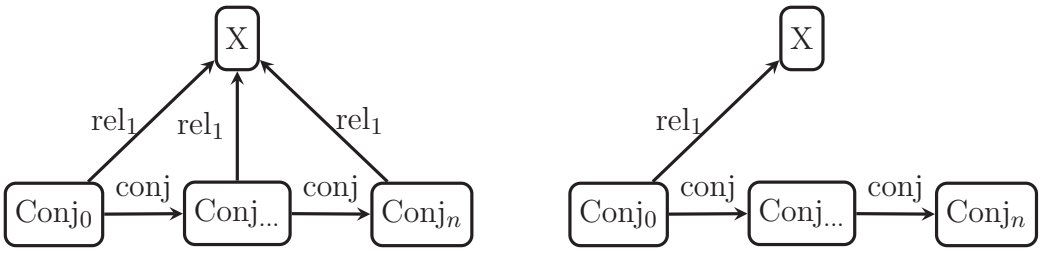
(b) Conjuncted elements with incoming loosely connected dependencies

Fig. 8.5 From tightly to loosely connected incoming conjuncted elements

The second is the pattern of conjuncts with *outgoing dependency relations* depicted in Figure 8.6a. In SFG terms it correspond to cases when a unit is sharing an element with another conjunct unit. These are mainly the cases of conjuncted verbs or copulas and are further discussed in the Chapter 6 about null elements. In GBT terms, the second to last conjuncts may omit, for example, the subject constituent if the conjuncts are verbs or copulas as in Figures 8.3 - 8.4.

8.1.2 Transforming copulas into verb centred clauses

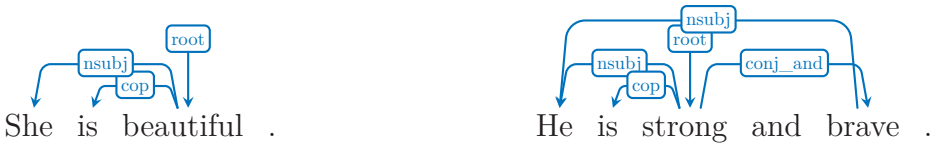
In the Stanford dependency grammar *copular verbs* are treated as dependants of their complements (see Figures 8.7a and 8.7b) because of the intention to maximise



(a) Conjuncted elements with outgoing tightly connected dependencies

(b) Conjuncted elements with outgoing loosely connected dependencies

Fig. 8.6 From tightly to loosely connected outgoing conjuncted elements



(a) Simple copulative

(b) Conjunction of copulatives sharing the subject

Fig. 8.7 Simple and conjuncted copula in dependency graphs

connections between content words. This configuration breaks the rule of the main verb being the head of clause discussed in Sections 4.1.1 and 4.1.2.

Moreover, despite that a variety of verbs are recognised as copulative e.g. *act, keep, sound*, etc. the Stanford parser provides copula configurations only for the verb *to be* leading to unequal treatment of copular verbs.

This case is sometimes accompanied by two relations that create cycles in the DG. They are the *xsubj*, the relation to a controlling subject and *ref*, the relation to a referent. The two relations are removed in this parsing phase and their resolution is transferred to the semantic analysis stage of the algorithm.

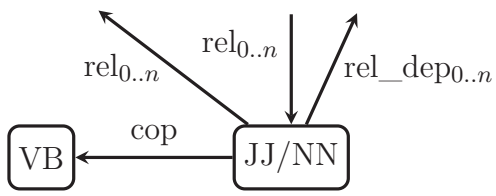
To make the copulative verb the root of its clause, the following rules are implemented. First, some relations are transferred from the copula complement (adjective JJ or noun NN) to the copulative verb. The transferred relations are listed in Table 8.1 which distinguishes them based on the part of speech of the *copula complement*.

part of speech	*dominated relation*
NN	dep, poss, possesive, amod, appos, conj, mwe, infmod, nn, num, number, partmod, preconj, predet, quantmod, rcmod,ref, det
JJ	advmod, amod, conj

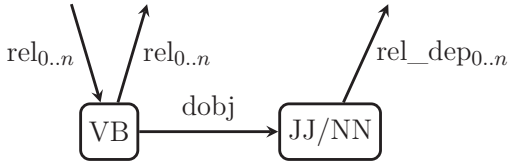
Table 8.1 Relations dependent on the POS of the dominant node

Second, all the outgoing connections from the copula complement are transferred to the verb except those listed in the second column of Table 8.1; these relations must stay linked to the NN or JJ nodes. Third the *cop* relation is deleted. Fourth, all the incoming relations to the copula complement are transferred indistinguishably to the verb because these are all clause related and should be linked to the clause dominant node. Finally the *dobj* link is created from the verb to the complement noun/adjective.

Figure 8.8a represents the generic pattern of copulas in Stanford DGs. The outgoing relations are distinguished between those in the filter as *rel_dep* and the rest simply as *rel* while the incoming relations are not discriminated. Figure 8.8b captures the final state of the transformation where the filtered outgoing relations stay attached to the complement node while the rest incoming and outgoing relations are moved to the verb.



(a) Generic pattern for copulas in Stanford parser.



(b) Generic pattern for copulas after the transformation (the same as non-copular verbs).

Fig. 8.8 Generic patterns for dealing with copulas in dependency graphs

In case of conjuncted copulas as in the example in Figure 8.7b, the approach is slightly complicated by the fact that the copula resolution algorithm should be executed for each copula conjunct, however because of the previous step which is loosening the conjunction and removing graph cycles, only the first copula conjunct is concerned.

8.1.3 Non-finite clausal complements with adjectival predicates (a pseudo-copula pattern)

Figure 8.9 represents a dependency parse exemplifying a clausal complement with an adjectival predicate. In this analysis there is a main clause governed by the verb *to paint* and a second one by the adjective *white*. In SFL a simple clause, such as the one depicted in Figure 8.9, receives a different analysis as is represented in Table 8.2.

The *xcomp* relation is defined in Marneffe & Manning (2008a) to introduce non-finite clausal complement without a subject. Stanford dependency grammar allows adjectives (JJ) and nouns (NN) to be heads of clauses, but only when they are a part

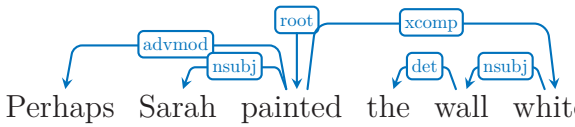


Fig. 8.9 Dependency parse for clausal complement with adjectival predicate

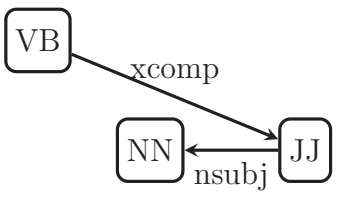
Perhaps	*Sarah*	*painted*	*the*	*wall*	*white.*
Adjunct	Subject	Finite/Main Verb	Complement		Complement
	Agent	Material Action	Affected		Attribute

Table 8.2 SFG analysis with attributive adjectival complement

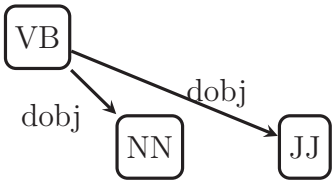
of a copulative construction. In Figure 8.9 it is not the case, there is no copulative verb *to be* and also *the wall* receives the subject role in the complement clause which should be absent. So I treat this as a misuse of the *xcomp* relation and the adjective should not be treated as governing a new clause but rather non-clausally complementing the verb *to paint*. This is in line with SF grammars where adjectival predicates are not allowed.

Certainly, depending on the linguistic school, opinions may diverge on the syntactic analysis comprising one or two clauses. But when analysed from a semantic perspective it is hard to deny that there is a Material Process with an Agent and Affected thing which is specifying also the resultant (or goal) Attribute of the Affected thing.

To accommodate such cases the dependency graph is changed from the pattern in Figure 8.10a to form Figure 8.10b. The *xcomp* relation is transformed into *dobj* and the subject of the embedded clause (if any) becomes the direct object (*dobj*) in the main clause. This is not a correct treatment from the dependency grammar point of view but it suits the purpose of the current work. As the *dobj* relation is projected later into a Complement element in the constituency structure, it fits well the case of adjectival Complements in the Cardiff grammar.



(a) Adjectival clausal complement



(b) Adjectival clausal complement as secondary direct object

Fig. 8.10 From adjectival clausal complement to two clausal complements

8.2 Correction of errors in dependency graphs

The Stanford Parser is based on results from various machine learning (ML) techniques applied to parsing. Its accuracy was increased over time to ≈ 92% for unlabelled attachments and ≈ 89% for labelled ones (in version 3.5.1). This section addresses known error classes of wrongly attached nodes or wrongly labelled edges and nodes. These errors have been discovered during the development of the Parsimonious Vole parser and are corrected to increase the result accuracy.

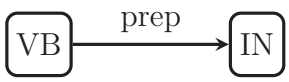
As the Stanford parser evolved, some error classes changed from one version to another (v2.0.3 – v3.2.0 – 3.5.1). Also the set of dependency labels for English initially described in Marneffe & Manning (2008a,b) changed to a cross-linguistic one (starting from v3.3.0) described in Marneffe et al. (2014).

As noted by Cer et al. (2010) the most frequent errors are related to structures that are hard to attach, i.e. prepositional phrases and relative clauses. During the implementation of the current parser a set of errors were discovered, the most frequent of which are described in this section along with how are they treated. These errors are specific to Stanford parser versions v2.0.3 – 3.2.0. This section may constitute a valuable error analysis feedback for the authors of Stanford dependency parser.

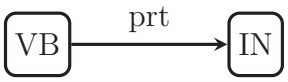
8.2.1 Free prepositions and *prep* relation

As noted before, only the collapsed version of the DGs are taken as input. This means that no pure *prep* relations should occur but their expanded version with the specific preposition appended to the relation name, i.e. *prep_xxx*, are used.

This is not always the case, especially with phrasal verbs, where the *prt* relations are mislabelled as *prep*. The correction consists in changing the *prep* (Figure 8.11a) into *prt* (Figure 8.11b) if the preposition node has no children, e.g. *pobj*.



(a) Mislabelled relation to free preposition.



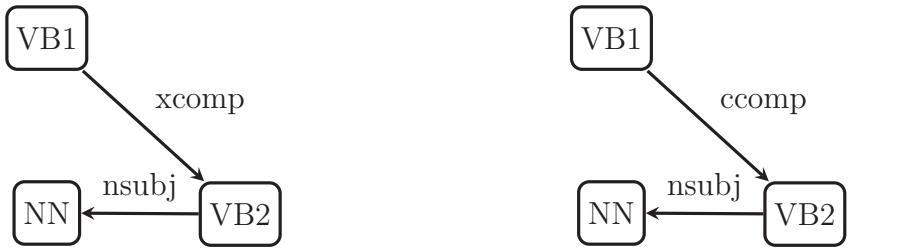
(b) Corrected relation to free preposition as verbal particle

Fig. 8.11 Treatment of free preposition connected to a verb as verbal particles

8.2.2 Non-finite clausal complements with internal subjects

The *xcomp* relation stands for open clausal complements of either a verb(VB) or adjective (JJ/ADJP). The latter is actually transformed as discussed in Section 8.1.3. The open clausal complement defined in Lexical Functional Grammar (Bresnan 2001: p270–275) is always non-finite and does not have its own subject. However sometimes the *xcomp* relation appears either (a) with finite verbs or (b) with its own local subjects; both cases correspond to the definition of the *ccomp* relation.

To address this I transform all the instances of *xcomp* relation to *ccomp* if the dependent verb has a local subject (nsubj) or a finite verb as depicted in Figures 8.12a - 8.12b.



(a) Mislabelled clausal complement (b) Corrected clausal complement

Fig. 8.12 Treatment of the non finite clausal complements with internal subjects

8.2.3 First auxiliary of non-finite POS

Sometimes the first auxiliary in a clause is mistakenly labelled as a non-finite verb. For some words the exact POS is less important as it has no large impact on the CG graph and features. But, in the case of first auxiliary verb of a clause, it makes a substantial difference. It has an impact on determining the finiteness of the clause in a later stage of the algorithm. The algorithm therefore checks the POS of the first auxiliary according to the mapping defined in Table 8.3.

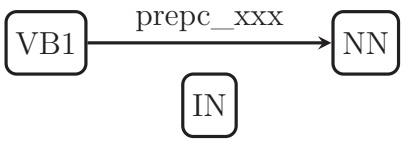
word	*POS*	*notes*
shall, should, must, may, might, can, could, will, would	MD	modals
do, have, am, are	VBP	present
has, is, does	VBZ	present 3rd person
did, had, was, were	VBD	past

Table 8.3 Mapping lexical forms of auxiliaries to their POS

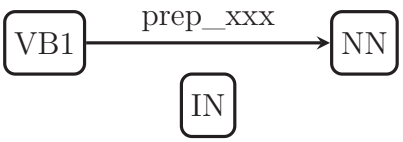
In this stage the part of speech of the first verb in a clause is checked whether it is found in the list of words mentioned in Table 8.3. If it is present then the part of speech is verified to coincide with the expected POS provided in the table. When they do not coincide the POS is replaced according to the value in the table.

8.2.4 Prepositional phrases as false prepositional clauses

prepc is a relation that introduces, via a preposition, a clausal modifier for a verb, adjective or noun. Assuming that the copulas had been changed as described in subsection 8.1.2 then the head and the tail of the relation can only be a verb. However when the relation head is not a verb (only nouns encountered so far) then the relation needs to be corrected from *prepc* to *prep* introducing a prepositional phrase rather than a subordinate clause.



(a) Mislabelled prepositional phrase as clausal modifier



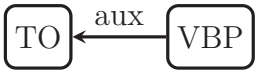
(b) Corrected prepositional phrase

Fig. 8.13 Treating prepositional phrase links

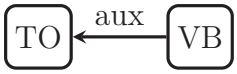
8.2.5 Mislabelled infinitives

In English, the base form of the verb often coincides with present simple form (non 3^{rd} person). Therefore the POS tagger sometimes mislabels infinitive (VB) as present simple (VBP).

The algorithm checks the presence of the preposition *to* linked via *aux* dependency relation positioned in front of the verb. If the preposition is present then the verb POS is changed to VB which is the correct POS for an infinitive form. Conversely, if the auxiliary preposition is not present the verb POS is changed into VBP, which corresponds to the present simple form of the verb.

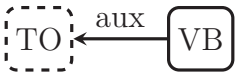


(a) Infinitive mislabelled as present simple

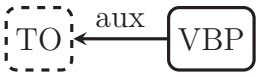


(b) Correct infinitive

Fig. 8.14 Treating infinitives



(a) Present simple mislabelled as infinitive

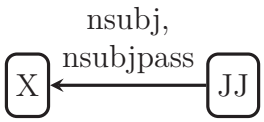


(b) Correct present simple

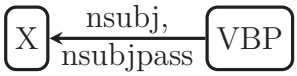
Fig. 8.15 Treating present simple

8.2.6 Attributive verbs mislabelled as adjectives

In English, *attributive verbs* often have the same lexical form as their corresponding adjectives. This is a reason for the POS being mislabelled as adjective (JJ) instead of verb (VB) leading to situations when an adjective (JJ) has an outgoing subject relation which means that its POS should actually be VB. The algorithm checks for such cases and corrects the JJ POS into VBP (non 3^{rd} person present simple).



(a) Mislabelled attributive verb



(b) Corrected attributive verb

Fig. 8.16 Treating adjectives with subject as verbs

8.2.7 Non-finite verbal modifiers with clausal complements

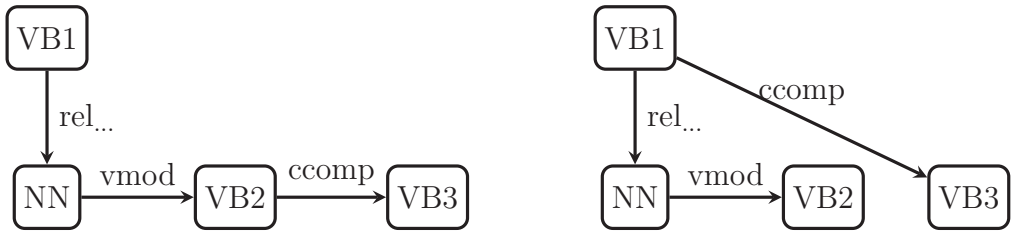
The early version of Stanford Dependencies (Marneffe & Manning 2008a) proposes two relations for non-finite verbal modifiers *partmod* for participial and *infmod* for infinitival forms exemplified in Example 106. Later in Marneffe et al. (2014) both relations are merged into *vmod*.

(106) Tell the boy playing the piano that he is good.

Clauses such as "(that) he is good" following immediately after the qualifier clause ("playing the piano" in the example 106) are problematic with respect to where they shall be attached: to the main clause or to the modifying one. This problem is similar to the prepositional phrase attachment problem.

In this case, of course, attachment would depend on whether the verb accepts a clausal complement or not. In Example 106 the verb *to play* does not take clausal complements and so the clause "that he is good" is complementing "tell the boy". The Stanford parser does not take into consideration such constraints and sometimes provides an incorrect attachment.

This type of error can be captured as the graph pattern in Figure 8.17a which is transformed by the algorithm into the form represented in Figure 8.17b.



(a) Clausal complement attached to the modifier clause

(b) Clausal complement attached to the main clause

Fig. 8.17 Treating clausal complements of the verbal modifiers

Syntactic structure is not enough to capture this error because it originates in the semantic influences on the syntax. To grasp them an extra constraint check is the possible lexico-semantic type of the verb. As only verbal and cognition process types can take clausal complements as phenomena, the verb in the higher clause VB_1 needs to be capable of accepting clausal complement VB_2 before performing the reattachment. In other words, if VB_1 is capable of accepting two complements (i.e. di-transitive) then most likely VB_2 is a complement, otherwise it is certainly not.

8.2.8 Demonstratives with a qualifier

Demonstratives (*this, that, these, those*) occur as both determiners and as pronouns. In English, when demonstratives are used as determiners, they function as a Deictic element of a nominal group, i.e. modifying the head of the nominal group. When used as pronouns, demonstratives never form phrases but occur as single words filling a clause element. Translated into dependency grammar, demonstratives may have as parent either a noun (NN) or a verb (VB*).

Examples below show uses of demonstratives in both cases. The word (thing/things) enclosed between round brackets should not be read as part of the sentence. These examples show that having those generic nouns in the sentence is grammatically correct but if they are missing the meaning does not change because they are implied by the demonstrative pronouns.

(107) Bill moved those beyond the counter.

(108) Put that in our plan.

(109) Look at those (things) beyond the counter.

(110) What is that (thing) next to the screen?

(111) I thought those (things) about him as well.

(112) He felt that (thing) as a part of him.

When a demonstrative is followed by a prepositional phrase the question arises whether the prepositional phrase shall be attached to the verb and take a role in the clause or it should be attached as post-modifier to the demonstrative. I note that demonstratives cannot take by themselves a post-modifier in either case as determiner or pronoun.

However there are cases when apparently the post-modifier (prepositional phrase) pertains to the demonstrative as in Examples 109 and 110 and in cases such as Examples 111 and 112 when the post-modifier pertains to the clause.

In fact the only acceptable analysis for apparently a demonstrative with a Qualifier (i.e. post-modifier) is as noun phrases with the Thing missing and the Deictic taking the role of the Head. The implied missing head is the generic noun "thing(s)" or any noun anaphorically binding the demonstrative.

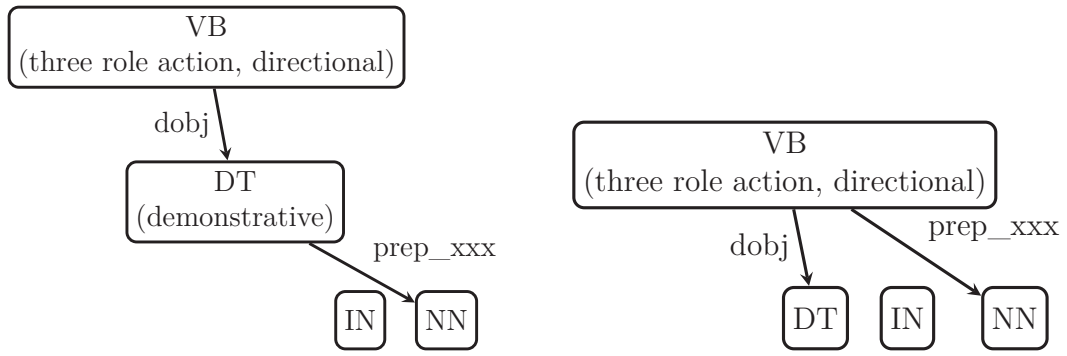
The verb argument structure and syntactic constraints on the arguments described in the Transitivity classification of process types enable precise distinctions of such cases. However at this stage the algorithm does not employ this type of information. Therefore as a rule of thumb, the prepositional phrase following the demonstrative shall be attached to the verb in the case of non-projective[1] di-transitive verbs which are *three role actions* and *directional* processes.

In Examples 107 and 108, attaching the prepositional phrase to the demonstratives (depicted in Figure 8.18a) is incorrect. It should be attached to the verb (as in Figure 8.18b) because the prepositional phrase can function as Destination or Location in each case, i.e take semantic roles.

The algorithm detects cases of demonstratives that have attached a prepositional phrase. If the parent verb is a three role action or a directional process then the prepositional phrase is reattached to the verb.

Ideally, the algorithm should also change the POS of the demonstrative into pronoun but unfortunately, the Penn tag-set only contains personal and possessive pronouns. The demonstratives are always labelled as determiners so no POS change is made to the dependency graph but it is properly represented when converted into the constituency graph.

[1]Projective verbs express cognitive and verbal processes like saying, thinking or imagining and often they verbs are di-transitive.



(a) Prepositional phrase attached to the demonstrative determiner which is the head of a nominal group

(b) Prepositional Phrase attached to the verb with a demonstrative pronoun in between

Fig. 8.18 Treating the attachment of prepositional phrases preceded by the demonstratives

8.2.9 Topicalised complements labelled as second subjects

The topicalisation (or thematic fronting) of complements is described in *Trace Theory* as *WH/NP/PP-movement*. Examples 113–117 from Quirk et al. (1985: pp. 412-413) present this phenomen. It is used in informal speech where it is quite common for an element to be fronted with nuclear stress thus being informationally and thematically stressed. Alternatively this phenomena is used as a rhetorical style to point at parallelism between two units and occurs in adjacent clauses as in Examples 116–117.

(113) Joe(,) his name is.

(114) Relaxation(,) you call it.

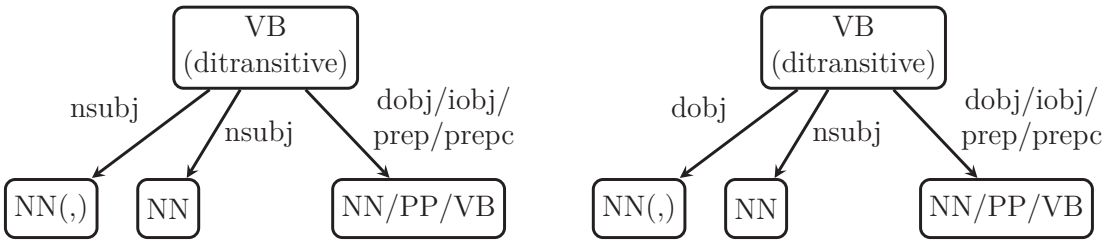
(115) Any vitamins(,) I could be lacking?

(116) His face(,) I'm not found of but his character I despise.

(117) Rich(,) I may be (but that does not mean I'm happy).

These are difficult cases for the Stanford parser (tested with versions up to 3.5.1). None of the above examples are parsed correctly. However, if the comma is present between topicalised complement and the subject, then it produces parses that are closest to the correct one where the topicalised complement is labelled as second subject but still not a complement. So having a comma present helps.

The algorithm is looking for the cases of multiple subjects (represented in figure 8.19a) and gives priority to the one that is closest to the verb. The other one is relabelled as a complement (Figure 8.19b). The rule is generalised in the algorithm for multiple subjects even if so far only cases of two subjects have been observed.



(a) Two consecutive nominal groups before the verb labelled as subjects

(b) Topicalised Direct Object – moved to pre-subject position

Fig. 8.19 Treating consecutive nominal groups before the verb as topicalised Complement and Subject

8.2.10 Misinterpreted clausal complement of the auxiliary verb in interrogative clauses

Sometimes the auxiliary verb in the interrogative clauses (Examples 118 and 119) is mistakenly used as a clause main verb. Instead of an *aux* relation from the main verb to the auxiliary there is a clausal complement relation from the auxiliary to the main verb.

(118) Do you walk alone?

(119) Has Jane fed the cat?

The algorithm searches for the pattern depicted in Figure 8.20a and transforms it into the form Figure 8.20b.

(a) Mislabelled clausal complement

(b) Corrected clausal complement

Fig. 8.20 Treating clausal complements in interrogative clauses

8.3 Creation of systemic constituency graphs from dependency graphs

This section describes how the systemic constituency structure is generated from the dependency graph. This is treated in computer science as *graph/tree rewriting*. This

is treated by Barendregt et al. (1987), Courcelle (1990), Plasmeijer et al. (1993) and Grzegorz (1999), to name just a few.

The Parsimonious Vole parser prototype is not using any of the above mentioned graph rewriting methods. It was important, at the time, to explore the exact set of operations and mechanisms necessary to fulfil this parsing approach. So I have implemented my own method of graph rewriting.

Because in the prototype implementation no pre-existing algorithm has been used, future work could integrate the state of the art methods in graph rewriting. This section explains the algorithms employed for rewriting dependency graphs into systemic functional constituency graphs. The focus here is directed towards understanding what is needed for transforming from dependency into systemic constituency graphs.

The currently implemented process consists of DG traversal and execution of generative operations on a parallel structure, progressively building the CG. The choice of the generative operation is based on a rule tables described in Section 8.3.3. The DGs and CGs resemble each other but they are not isomorphic. The CG is created in two phases are presented in Algorithm 2. The first phase, through a top-down breadth-first traversal of a DG, generates, using a rule-set, an incomplete CG that omits the heads and a few other elements for each CG unit. Also, no unit classes are specified, except if that unit is a clause. The second phase, through a bottom-up DG traversal, complements the first one ensuring creation of all CG constituents corresponding to missing unit elements and assigns the unit class.

Algorithm 2: Creation of the constituency graph

input : dg (the dependency graph), rule table
output : cg (the constituency graph)

```
1 begin
2 |   create the partial cg by top-down traversal
3 |   complete the cg by bottom-up traversal
4 end
```

Before presenting the two stages of graph creation, I will first reiterate over the difference in the dependency nature in the constituency and dependency graphs. Then I will also talk about the tight coupling of the two graphs and the rule tables used in traversal.

8.3.1 Dependency nature and implication on head creation

Section 3.4 explained the different dependency relation nature in dependency graphs and in systemic functional constituency graphs. The DG uses a *parent-child dependency* while in Constituency Graphs there is a *sibling dependency*. This difference implies that, when mapped into CG, a DG node stands for both a unit and that unit's head. In other words a DG node corresponds to two functions and unit classes at different rank scales. For example, the root verb in DG corresponds to the clause node and the lexical item which fills the Main Verb of the clause.

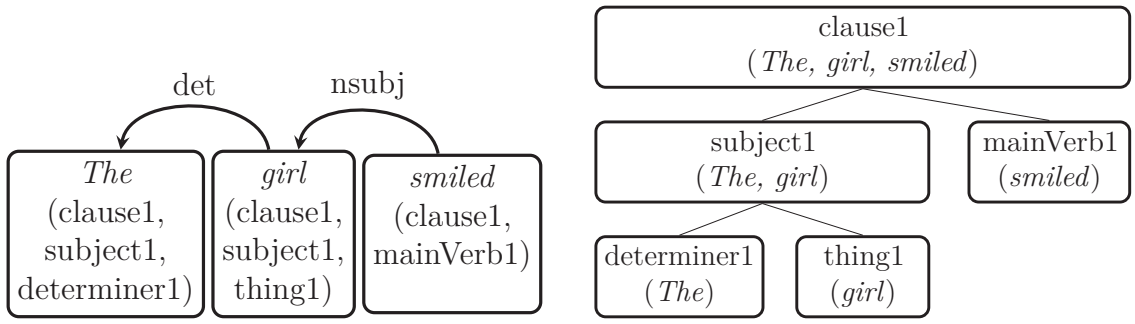
The two functions at different rank scales are the main reason why the creation algorithm is separated into two phases with a traversal top-down and another bottom-up. In the current approach, the top-down perspective considers the DG node functioning in the upper rank. The result of the top-down phase is a constituency graph without head (and sometimes a few other) elements/nodes.

The bottom-up perspective considers the DG nodes functioning in the lower rank and aims at creating the remaining nodes, mainly heads. The bottom-up phase is performed by traversing the constituency graph and not the dependency graph. As the dependency nature in CG is among siblings, the traversal task seeks to spot and locally resolve the missing elements. The local resolution is performed based on the syntagmatic unit structure with the aid of the tight coupling between the dependency and constituency graphs that is explained in the section below.

8.3.2 Tight coupling of dependency and constituency graphs

At the creation stage, the CG is tightly coupled with the original DG. This means that each CG node has associated a corresponding DG node in the DG together with the set of immediate child nodes. This coupling allows navigating easily from one graph to the other via stored references. We say that a graph node is *aware* of its ascription in another graph if it carries information to which nodes it is linked within the second graph.

Through a stack of CG nodes, the DG nodes are made aware of which CG nodes they correspond to and in which order they subsume them. An example of tight coupling is depicted in Figure 8.21a. On the other hand, the CG nodes are also made aware through a list of DG nodes, over which DG nodes they span, which is in Figure 8.21b. This way the positioning information is available bidirectionally about CG an DG structures.



(a) Constituency aware DG nodes (b) Dependency aware CG nodes

Fig. 8.21 Graph nodes aware of their correspondents in another graph

Figure 8.21a depicts a dependency graph. Each node has a stack of ids corresponding to constituents in the CG (Figure 8.21b). Conversely, Figure 8.21b, depicts a constituency graph where the constituent nodes carry a set of tokens corresponding to DG nodes. This way the nodes of DG in Figure 8.21a and the nodes of CG in 8.21b are aware of each other's correspondents.

This node awareness has two interesting properties worth exploring. First, the DG nodes receive a vertical constituency strip. Each strip is a direct path from the root to the bottom of the constituency graph where the word of the DG is found. These strips are the very same ones explored in the parsing method explored by Day (2007). Second, the CG nodes receive a horizontal span over DG nodes enabling exploration of elements in linear order. These two properties could eventually be explored in future work to inform or verify the correctness of the constituency graph. In the present work the application of node awareness is limited to the complete construction of the CG.

8.3.3 Rule tables

Constituency Graphs are created through a top-down breadth-first walk of the dependency graph. During the top-down breadth-first walk of the DG each visited node triggers execution of a *generative operation* on the growing CG. To know what operation to execute a rule table is used where the edge, head and tail nodes are mapped to a generative operation and possibly a parameter (specifying the element type if a constituent is to be created).

A simplified example of the rule table is presented in Table 8.4. The full table is provided in Appendix E. It can be regarded as an attribute value matrix (implemented as a Python dictionary) where the left column, the *key*, contains a unique *dependency*

graph context serving as a rule trigger; while the left side column, the *value*, contains the operation to be executed within the given context.

	Key	**Value**	
		Operation	***Parameter***
1	nsubj	new constituent	Subject
2	csubj	new constituent	Subject & clause
3	prepc	new constituent	Complement, Adjunct & clause
4	VB-prep-NN	new constituent	Complement, Adjunct
5	NN-prep-NN	new constituent	Qualifier
6	VB-advmod-WR	new constituent	Complement
7	VB-advmod-RB	new constituent	Adjunct
8	mwe	extend current	
9	nn	extend current	

Table 8.4 Example of rule table mapping specific and generic dependency context to generative operations

The current implementation uses three operation types: (a) *creating a new constituent* under a given one (b) *creating a new sibling* to the given one (c) *extending* a constituent with more dependency nodes.

The parameter is used only for operations (a) and (b) and specifies which element the new constituent is filling as described in Sections 3.2 and 3.3. Most of the time there is only one element provided but in the case of prepositional phrases and clauses it is impossible to specify purely on syntactic grounds the exact functional role and thus multiple options are provided (Adjunct or Complement) and then in later parsing phases, when the verb semantic configurations are verified, these options are reduced to one.

There are two types of keys in the rule table: the *generic* ones where the key consist of the (non-extended) dependency relation and the *specific* ones surrounded by the POS of head and tail edge nodes taking the form *Tail–relation–Head*. For example, *nsubj* relation (row 1) always leads to creation of a Subject nominal constituent regardless if it is headed by a noun, pronoun or adjective. Since all individual cases lead to the same outcome it suffices to map the dependency relation to the creation of a new constituent with Subject role ignoring the POS context of head and tail nodes. The same holds for the *prepc* relation (row 3) as it always leads to creation of a subordinate clause constituent with Complement or Adjunct roles. So the generic relations can be viewed as equal to the form *Any–relation–Any* only that the nodes are omitted due to redundancy.

In the case of *prep* relations (rows 4 and 5) the story is different. Their interpretation is highly dependent on the context given by the parent/tail and child/head nodes. If it is connecting a verb and a noun then the constituent prepositional phrase takes the role of either Complement or Adjunct in the clause. But if the prep relation is from a noun to another noun, then it is a prepositional phrase with Qualifier function in the nominal group.

Some dependency relations are not mapped to an operation of creating a new constituent but rather extend the existing constituent with all nodes succeeding the current one in the DG. This operation is used for two reasons: either (a) the constituent truly consists of more than one word, for example the cases of multi-word expressions (e.g. ice-cream) marked via an *mwe* relation (row 8) or (b) the relation (with or without its POS context) is insufficiently informative for instantiating a constituent node and is postponed for the second phase of the CG creation.

Note that the contextualised relations provided in the rule table represent "slight" generalisations over what may be found in the dependency graphs. The generalisation consists in using only the first two letters of the POS (which, in PENN tag set can be up to four letters long). For example nouns generically are marked as NN but they may be further specified as NNP, NNPS and NNS; or verbs (VB) may be marked as VBD, VBG, VBN, VBP, and VBZ depending on their form.

Now that I covered the rule table structure I briefly present the algorithm for making rule selections based on simple or contextualised keys.

Algorithm 3: Operation selection in the rule table based on the edge type

```
   input  : rule table, edge
   output : rule
 1 begin
 2     generic key ← the simplified label on the edge
 3     head POS ← the POS of the edge head node
 4     tail POS ← the POS of the edge tail node
 5     specific key ← concatenate (tail POS + generic key + head POS)
 6     if specific key index in rule table:
 7         rule ← value for specific key from rule table
 8     elif generic key index in rule table:
 9         rule ← value for generic key from rule table
10     else:
11         rule ← None
12     return rule
13 end
```

Algorithm 3 is based on two dictionary lookups: one for specific key (contextualised by the edge relation and its nodes) and another one for generic key based on the edge relation alone. The rule table is conceived as a Python dictionary with string keys and two-tuple containing the operation and the element type parameter. If the key is found (either specific or generic) in the rule table then the operation and parameter are returned, otherwise None is returned.

Next I explain the top-down traversal phase which is the cornerstone of the constituency graph creation.

8.3.4 Creating partial constituency graph through top-down traversal

The goal of this first phase is to bootstrap a partial constituency graph starting from a given dependency graph and a rule table. The CG is created as a parallel graph structure through the process of breadth-first traversal on DG edges as described in Algorithm 4. The rewriting of the DG graph into a partial CG is performed as follows. DG nodes, starting from the root, are traversed top-down breadth-first and for each visited node apply the creation or extension operation as provided in the rule table.

Algorithm 4: Partial constituency graph creation by top-down traversal

```
   input  : dg (the dependency graph), rule table
   output : cg (the constituency graph)
 1 begin
 2     create the cg with a root node
 3     make the cg root node aware of the dg root node
 4     for edge in list of dg edges in BFS order:
 5         rule ← find in rule table the rule for current edge context
 6         operation ← get operation from the rule table
 7         element type ← get the parameter from the rule table
 8         constituency stack ← get the constituency stack from the tail node of the
             current dg edge
 9         cg pointer ← get the CG node from the constituency stack
10         children ← all child nodes for the current dg edge
           // constructing or extending the cg with a new node
11         execute the operation on cg given element type, cg pointer and children
12     return cg
13 end
```

First the CG is instantiated and an empty root node is created. Also, the root node is made aware of the root node in DG as described in Section 8.3.2. Then the DG is traversed in breadth first order (BFS) starting from the root node and as each DG edge is visited an operation is chosen based on the edge type and POS of the connected nodes (Lines 7 - 10). Line 5 of the algorithm is responsible for looking up and selecting the operation from the rule table as described in Algorithm 3. Then the creative operation is executed with the established parameters: dependency successors (children), a constituent node parenting the newly created one (cg pointer), and element type which is chosen from the rule-table together with the operation.

In Python, functions are first class objects allowing objects to be called (executed) if they are of type "callable". This duality allows storing the functions directly in the rule table and then, upon lookup, they are returned as objects but because they are also callable these objects are executed with the expected set of parameters based on their function aspect. The possible operations were already explained in Section 8.3.3: *extend current* and *new (sibling) constituent*. Next I present the pseudo-code for each of the operations. Note that these operations do not return anything because their effect is on the input cg and dg.

Extend constituent. Algorithm 5 outlines the functionality for extending the current cg pointer. It does two main things. It increases the span of an already existing CG node over more DG nodes and makes them, concomitantly, aware of each other.

Algorithm 5: Extend a constituent with DG nodes

```
   input  : cg pointer, children, element type, edge, dg, cg
1  begin
       // handling special relations prep and conj
2      if prep∨conj in edge relation:
3          free nodes ← find in dg the free nodes referenced in the edge relation
4          create new node with marker function under the cg pointer with free
             nodes as children
5          children ← children & free nodes
       // making the children and cg pointer aware of each other
6      for node in children:
7          constituency stack ← the constituency stack of the node
8          push the cg pointer to the constituency stack
9          span ← constituent span of the cg pointer
10         extend the span with current node
11 end
```

If, however, the edge relation is a conjunction or a preposition then the children list is extended with the free nodes that stand for the preposition or conjunction in place and potentially neighbouring punctuation marks (line 3).

This exceptional treatment is due to the fact that *prep* and *conj* relations are always specialised by the preposition or conjunction in place. For details on this aspect of the Stanford Dependency Grammar refer to Section 5.5.

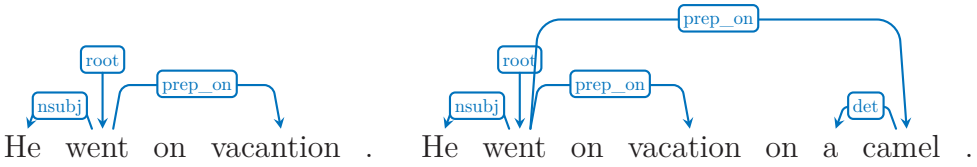


Fig. 8.22 Examples of challenging free nodes

Figure 8.22 exemplifies easy (on the left) and more difficult (on the right) cases of free node occurrence. The challenge in the second graph comes from the fact that there may be two suitable free nodes for the edge *went-prep_on-camel*. Another challenge in resolving free nodes is when the preposition is a multi-word construction.

Once all the free DG nodes are found, a new cg node is created with *Marker* element type spanning over them (line 4). Then the free nodes are included in the list of children and all together are made aware of the current cg pointer and vice versa.

Create new constituent. Algorithm 6 is an operation that inserts into CG a new node/constituent (line 4). The new constituent is created as a child of a pointed CG node with the element type extracted from the rule table together with the operation. Once the cg node is created, it is extended with the children nodes as described in Algorithm 5 above.

Note that only the functional element is assigned to the freshly created constituent. Its class is added in the second phase of the creation algorithm. This is due to the fact that a function can be filled by units of several classes. The bottom-up traversal provides a holistic view on the constituency of each unit giving the possibility to assign a class accordingly. For details see Chapter 3.

A variation of the *create new* is *create sibling* outlined in Algorithm 7. It sets the newly created constituent as a sibling of the current one and not as a child. This makes the new constituent a child of the current cg pointer's parent.

Algorithm 6: Creating new child constituent

```
input : cg pointer, children, element type, edge, dg, cg
1 begin
2     node ← new Constituent
3     type(node) ← element type
4     add to cg new edge (cg pointer, node)
      // invoking Algorithm 5
5     extend cg pointer with children of edge
6 end
```

Algorithm 7: Creating new sibling constituent

```
input : cg pointer, children, element type, edge, dg, cg
1 begin
2     cg pointer ← get the parent of cg pointer
      // invoking Algorithm 6
3     create new constituent with an updated cg pointer
4 end
```

8.3.5 Completing the constituency graph through bottom-up traversal

Chapter 3 explained that each constituent must specify the unit class and the element it is filling within its parent unit. The first phase of the algorithm achieves creating most of the constituents and assigns each unit functional elements derived from the dependency graph. The constituency graph misses, however, the unit classes and the syntactic head nodes. The second phase complements the first one by fulfilling two goals: (a) creation of constituents skipped in the first phase and (b) class assignment to the constituent units.

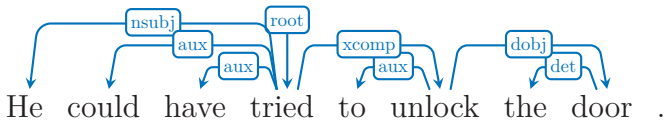


Fig. 8.23 The dependency graph before the first phase

Figure 8.24 depicts an example CG generated in the first phase with dotted lines representing places of the missing constituents.

The missing constituents are the syntactic heads for all units. The clause, besides the Main Verb element which is the syntactic head of the unit, also misses the Finite,

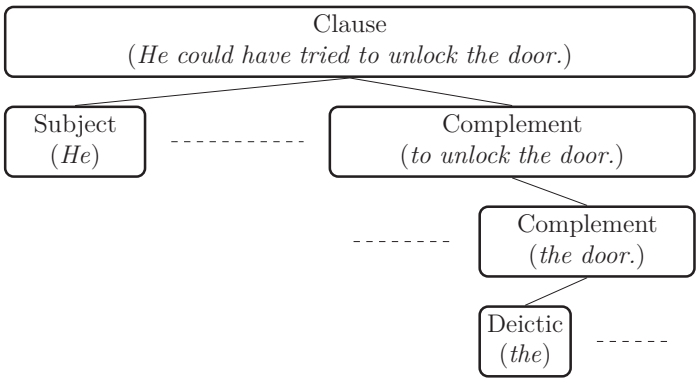


Fig. 8.24 Constituency graph after the top-down traversal missing the head nodes

Auxiliary elements. Determining these functions strongly depends on the place within a unit and syntagmatic order in which units occur.

The class membership of constituent units is decided based on three pieces of information available within each constituent: (a) part of speech of the head dependency node, (b) element type of the constituent, and (c) presence or absence of child constituents and their element types. The corresponding constraints are listed in Table 8.5. The first column shows the unit class (to be assigned), the second and third columns enumerate part of speech and element types that constituents might fill. The second and third column enumerations are exclusive disjunctive sets (S_{XOR}) because only one may be selected at a time, while the list in the last column is an open disjunction (S_{OR}) because any of child elements may be present. The last column is an enumeration of what child constituents the current one might have. The *n/a* means that information is unavailable.

Algorithm 8 traverses the CG (not the DG) bottom-up with *post-order depth-first* order (line 2). This order means that first the child nodes are visited recursively before the node is visited, as compared for example with *pre-order depth-first* order, when first the node is visited and then its child nodes. During this traversal, the algorithm assigns to every visited constituent node a unit class and creates the missing child constituents.

As mentioned above in Section 8.3.2, CG and DG are tightly coupled which means that each CG node spans over a set of DG nodes. In this stage, traversal over the CG nodes is equal to traversing groups of DG nodes at each step. This creates a focused mini-context suitable for resolving the unit class and the missing elements out of the DG chunks.

When assigning unit class, the following information is considered: (a) part of speech of the head DG node that triggered node creation in the first phase (head POS),

Class	*POS of the Head DG Node (XOR)*	*Element Type (XOR)*	*Child Constituents (OR)*
Clause	VB*	Subject, Complement, Qualifier, n/a	Subject, Complement, Adjunct, n/a
Prepositional Group	CD, NN*, PR*,WP*, DT, WD*	Complement, Qualifier, Adjunct	Marker, n/a
Nominal Group	CD, NN*, PR*,WP*, DT, WD*, JJ, JJS	Subject, Complement	Deictic, Numeral, Epithet, Classifier, Qualifier, n/a
Adjectival Group	JJ*	Complement, Epithet, Classifier	Modifier, n/a
Adverbial Group	RB*, WRB	Adjunct	Modifier, n/a

Table 8.5 Constraints for unit class assignment

Algorithm 8: Creating the head units and assigning classes

```
   input  : cg, dg
1  begin
2      for node in list of cg nodes in DFS post-order:
3          head POS ← get POS of the corresponding dg node
4          element type ← get assigned function from node
5          children ← get node children
           // assigning classes
6          class ← find class based on head POS, element type and children
7          assign node the class
           // creating the rest of the units
8          if node is not a leaf:
9              create the remaining elements under the node
10 end
```

(b) the assigned element type (element type) and (c) element type of each direct child (children of node). Lines 6 to 7 assign classes according to conditions provided in Table 8.5.

The CG nodes corresponding to non-modal verb DG nodes are assigned clause class. This rule corresponds to the one-main-verb-per-clause principle discussed in Section 4.1.1. This approach however does not take into consideration elliptic clauses and they need additional resolution that is considered for future work and can be overcome by an *ellipsis resolution mechanism*, similar to the one for *null elements* described in Chapter 6.

The second part of the algorithm creates head nodes for every non-leaf constituent and in case the node is a clause then it also creates the clause elements: Finite, Auxiliary, Main Verb, Negator and Extension.

After the second stage, all the DG nodes must be covered by CG nodes. Moreover the CG nodes build up to a constituency graph that at this stage is always a tree. If the class and element type information is available, the created nodes are then ready to be enriched with choices from systemic networks as will be described in the next chapter.

8.4 Summary

In this chapter a set of transformations of DGs from the Stanford parser has been described in detail, followed by explanation of algorithms rewriting DGs into CGs. The DG transformations are there to correct known errors in Stanford parser version 3.5.1 and to adjust treatment of certain linguistic features such as copulas, conjunction and others. The final section of the chapter described how the DG is rewritten into a CG using create and extend operations upon graph traversal and tight coupling between the CG and DG nodes.

There are state of the art algorithms for graph rewriting with proven efficiency. The current work intends to be neither generic nor an efficient rewriting algorithm but rather to explore the process by which a DG can be rewritten into a SFL CG. In the future, to increase the speed and performance, the current algorithm could be rewritten using for example a graph programming language or a graph rewriting formalism.

Now that it has been described how to construct the systemic functional constituency graph, representing the syntactic backbone for parsing, we turn our attention to fleshing out this backbone with systemic features selected from system networks. The feature enrichment is performed by employing graph matching and pattern based operations as explained in Sections 7.4 and 7.5. How this process works is explained in the next chapter.

Chapter 9

Enrichment of the constituency graph with systemic features

The previous chapter described how to create the systemic functional constituency structure which is the syntagmatic organisation aimed at in this work. This chapter presents the mechanisms by which the paradigmatic account is provided through selection of systemic features at the level of each constituent. I present how the constituency graph is enriched with features from two main system networks MOOD, introduced in Section 4.2.1, and TRANSITIVITY, introduced in Section 4.2.2.

In the parsing process pipeline depicted in Figure 1.8 there is a phase called *increasingly semantic graph enrichment*. The present chapter covers this phase entirely starting from Mood enrichment, to Null Element creation and finally Transitivity enrichment.

The main method of enrichment is by execution of update graph patterns (presented in Section 7.5) on the constituency graph. The MOOD graph patterns have been manually designed across various levels of delicacy. The patterns usually cover from one to four systemic selections from sibling or chained systems. Then the graph patterns are employed in the MOOD enrichment process provided in Section 9.2.

In SFL, Transitivity analysis roughly corresponds to what is known in mainstream computational linguistics as semantic analysis of text or *semantic role labelling* (SRL), a well established task in mainstream computational linguistics (Carreras & Màrquez 2005; Pradhan et al. 2007). In this task the clause is assigned a semantic frame in which the predicate functions as the process and the participant constituents take frame dependent roles (or functions). The nodes that do not receive any participant role are adjuncts which act as circumstances and are currently outside the scope of this thesis.

Sometimes not all constituents are realised in the clause. Usually these constituents play semantic roles in the process configuration realised by the clause. This happens for one of two reasons: the participant is implicit and resolvable from discourse structure or it is implicit and resolvable by a lookup outside the clause borders within the same sentence. The resolution from the discourse structure is outside the scope of the current work; the second resolution type, however, is implemented as it is based only on the sentence structure. In this work the account of empty constituents is a prerequisite for performing Transitivity analysis and is implemented as described in Government and Binding Theory (GBT) (Haegeman 1991b) introduced in Chapter 6.

Because the Transitivity analysis goes beyond the syntactic structure it needs to rely on additional external semantic resources. One such resource is the Process Type Database (PTDB) created by Neale (2002) introduced in Section 4.2.3. This is a table which lists possible configurations of semantic roles for each verb sense for over five thousand common verbs in English. This resource is integrated into the current parser pipeline to automatically assign semantic configurations and participant roles.

The majority of implementations for the SRL task use probabilistic models trained on an annotated corpus whose outcome is a single most probable assignment of semantic roles; the selection is based on the maximum likelihood. In the current work I mostly employ a lexical data base containing sets of configurations for each verb sense. These configurations are interpreted as what may be the case, i.e. what are the possible semantic roles, and the result is a small set of possible semantic roles rather than the best single guess. In order to reduce the number of possible assignments taking the analysis close to the goal of a single "correct" configuration, I use the preparatory step of identifying covert constituents (i.e. Null Elements).

In the following sections I explain the practical steps of enriching the CG with TRANSITIVITY features starting from how the PTDB has been normalised and made machine readable, then how the graph patterns have been generated from the PTDB and finally how the patterns are matched onto the structural backbone enriching it with systemic features.

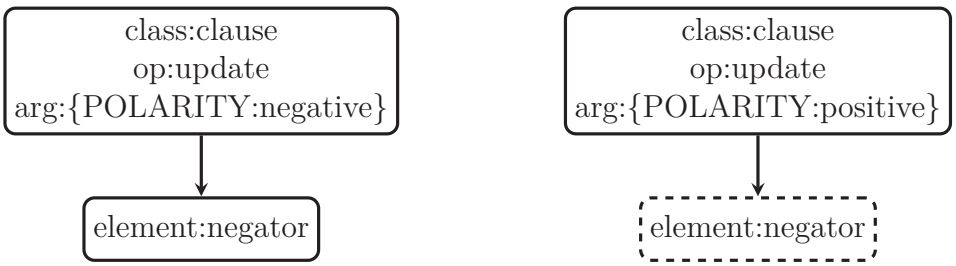
9.1 Creation of MOOD graph patterns

In this section I describe a set of graph patterns that have been manually created and included into the parsing process of the MOOD system. All of the MOOD features can be recovered from the constituency and dependency elements. Therefore the graph patterns provided below rely on constituency information, i.e. class and element and

on dependency information such as POS, lemma, incoming and outgoing relation for the anchor node, order, etc.

This section describes how the patterns look and how they were created. An extended representation of all the patterns is provided in Appendix G.

The first two patterns depicted in Figure 9.1 are used to determine POLARITY choices. The clause polarity in this work is considered to depend solely on the presence of a negation particle (this limitation is addressed in Section 4.2.1), which, in DG is represented by the *neg* edge label and in CG is signalled by the presence of a negator element. The pattern in Figure 9.1a specifies that the root node is a clause and has a negator constituent. If this pattern is identified then the negative POLARITY feature selection is added to the clause node. Conversely, if the pattern from Figure 9.1b, where the negator element is marked to be missing, is successfully matched then the clause node is updated with positive POLARITY.

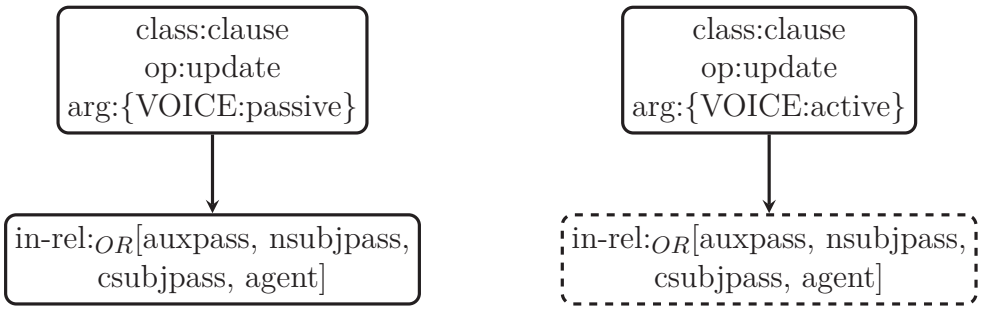


(a) Negative POLARITY (b) Positive POLARITY

Fig. 9.1 POLARITY detection graph patterns

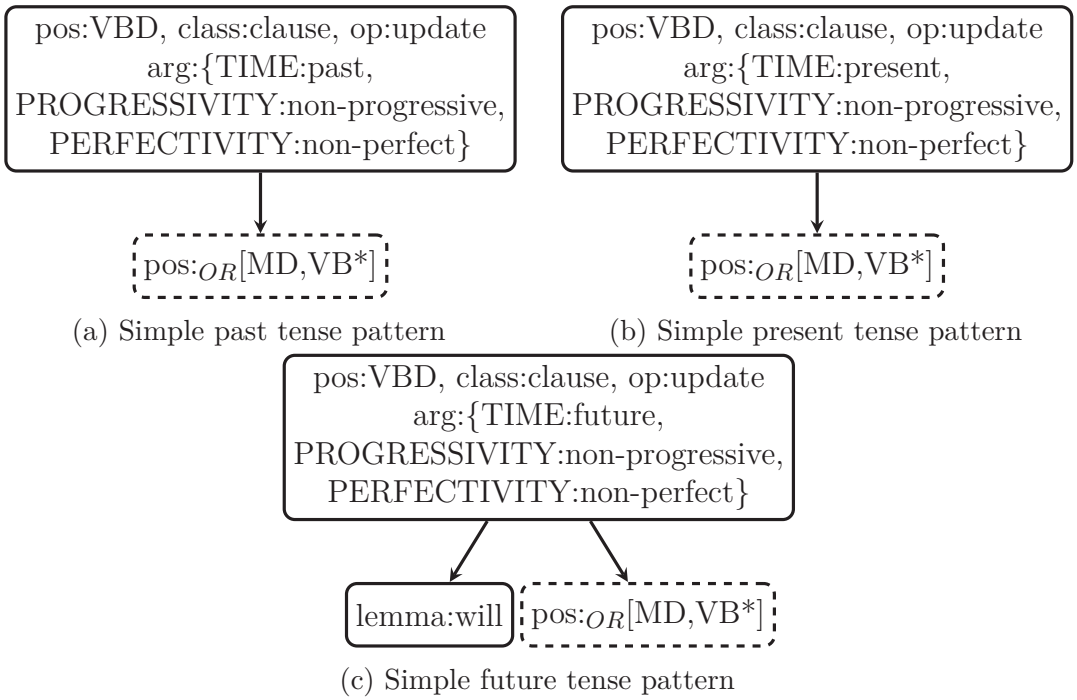
A similar case holds for VOICE. The graph pattern in Figure 9.2 corresponds to the selection of passive voice. In DG it is captured by any of the four relations outgoing from a verb to another node. The dependency relations are: *auxpass*, *nsubjpass*, *csubjpass*, *agent* introducing either a passive auxiliary verb, a nominal subject, clausal subject or the agent in complement position. If the pattern is matched in a dependency graph then it reflects passive voice, otherwise the voice selected is active. As the CG nodes have full awareness (described in Section 8.3.2) of DG nodes and edges the patterns can be written using the incoming relation (in-rel) special feature that represents all the incoming edges to the DG node corresponding to the current constituent.

The story is very similar for the rest of the patterns. There is a mixture of positive and negated nodes (in dashed boxes) described by constituency or (still) dependency special features. The reason for using dependency graph information is that they already cover rich syntactic variations that can be exploited. As we move towards patterns with more semantic information the DG features are no longer used.



(a) Passive voice (b) Active voice

Fig. 9.2 Voice detection graph patterns



(a) Simple past tense pattern (b) Simple present tense pattern

(c) Simple future tense pattern

Fig. 9.3 Simple past, present and future tense patterns

Figure 9.3 depicts a set of patterns for enriching the simple present, past and future tenses. They are presented as an additional example of graph patterns. They are mutually exclusive by design, but in principle no one can prevent a mistake in grammar so that more than one graph pattern yields a positive outcome. This is, in fact, one of the limitations of the current parsing method. So, for example, if the negated described by pos:$_{OR}$[MD,VB*] is omitted from the pattern, then it will yield matches with situations when there is an auxiliary modal verb involved, which is not correct because the intention is to capture clauses with a single verb.

9.2 Enrichment with MOOD features

In this stage the CG nodes are assigned system network features from graph patterns and a lexical-semantic dictionary. This is achieved by visiting each CG node in a bottom-up order and executing the enrichment functions.

The enrichment functions are provided via two rule tables. The first rule table (activation table) offers a pairing between element class and/or element (also called here the trigger) and an ordered set of system names. The second rule table is an association between a system name, an enrichment function (either matching or dictionary lookup) and a parameter that is either a set of graph patterns or a dictionary. Both tables have been manually created following the MOOD system network along with a few simple systems for nominal phrases created for illustration. The graph patterns and dictionaries have also been manually complied following either traditional grammar sources, mainly Quirk et al. (1985), or SFL sources, mainly IFG4 (Halliday & Matthiessen 2013b).

The systems are provided in Table 9.1 in the right column, as ordered associations with the node class or function, in the left column. The list of systems from the MOOD network is partial because, as we will see next, the set of associated patterns usually cover several systems at once, therefore the least delicate one serves as a marker for a portion of the system network.

Key	*System activation order*
clause	POLARITY, FINITENESS, MOOD TYPE, VOICE, TENSE, MODALITY TYPE
nominal	PERSON, ANIMACY, GENDER, NUMBER
deictic, pre-deictic	DETERMINATION
thing, possessor	PERSON, ANIMACY, GENDER, NUMBER

Table 9.1 System activation table by unit class or element type

Table 9.2 associates systems with the enrichment functions and a parameter. Currently there are two enrichment functions: one based on matching graph patterns (as described in Section 7.5) and the other one based on a dictionary of lexical items paired to a set of features.

Algorithm 9 presents the pseudo-code for enriching CG nodes with systemic choices using enrichment functions based on the two rule tables presented above. There is one loop nested in another. The outer one is a bottom-up iteration over the CG nodes in depth first (DFS) post-order. The inner loop iterates over the provided systems for the focus node. Then a lookup in Table 9.2 returns the enrichment function to

System Name	*Function*	*Parameter*
POLARITY	match all patterns	polarity set
VOICE	match all patterns	voice set
FINITENESS	match all patterns	finiteness set
MOOD TYPE	match all patterns	mood set
TENSE	match all patterns	tense set
MODALITY TYPE	match all patterns	modality set
DETERMINATION	dictionary lookup	determination dictionary
PERSON	dictionary lookup	person dictionary
ANIMACY	dictionary lookup	animacy dictionary
GENDER	dictionary lookup	gender dictionary
NUMBER	match all patterns	plurality set

Table 9.2 Association of systemic networks to functions

Algorithm 9: Enriching CG with systemic features

```
   input  : cg
1  begin
2      for node in list of cg nodes in DFS postorder:
3          for network in activated networks for the node class or element:
4              selector function ← get associated function and parameter
5              run selector function knowing node, cg and parameter
6  end
```

be executed for that system network. This technique of using a mapping table from system networks to functions is similar to the one employed in the CG creation phase (Algorithm 4) presented in the previous chapter.

Algorithm 10: Match-all-patterns enrichment function

```
   input  : node, cg, pattern set
1  begin
2      for pattern in pattern set:
3          execute pattern based node update in cg given node context
4  end
```

Algorithm 10 takes a focus node, the cg it belongs to, and a pattern set and executes for each pattern the pattern based node update operation as described in Section 7.5. If multiple patterns match then multiple updates are performed consecutively. The second enrichment function is based on associations between lexical items and feature selections described below.

Algorithm 11: Dictionary-lookup enrichment function

```
input  : node, cg, dictionary
begin
    lexical item ← get lexical item from the node
    find lexical item in dictionary
    systemic choices ← get the associated features + implied preselected features
    add systemic choices to the node
end
```

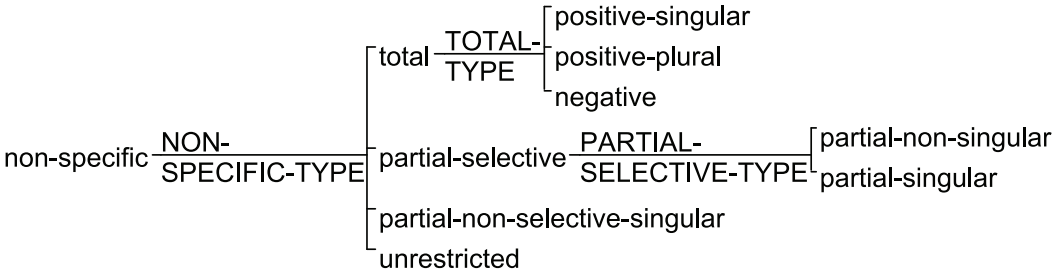


Fig. 9.4 The NON-SPECIFIC DETERMINATION system network

The dictionary lookup function outlined in Algorithm 11 checks whether the word(s) of the CG node are in a dictionary. If the word is found then the function assigns the graph node with the associated features from the table. In addition, using the naive backwards induction method described in Algorithm 1, all the preselected features from a system network are determined and assigned to the graph node. An example of the dictionary is presented in the Table 9.3 and the system network of NON-SPECIFIC determination is shown in Figure 9.4.

Lexical item	*Feature*
a	partial-non-selective-singular
all	positive-plural
either	partial-singular
that	non-plural

Table 9.3 Dictionary example for the NON-SPECIFIC DETERMINATION system network

This section completed the explanation of how the MOOD features are assigned to the constituency graph. In the remainder of this chapter is addressed the task of assigning TRANSITIVITY process types and participant roles to the constituent units introduced in Costetchi (2013).

9.3 Creation of empty elements

In the current work, when participants are missing but are syntactically recoverable in the sentence then they are inferred from the structure and reference nodes are created for the missing elements. This phenomena is described in GB theory specifically as the *Control and Binding* of empty elements (Haegeman 1991b) introduced in Section 6.2. The *reference constituents* are important for increasing the completeness and accuracy of semantic analysis by making the participants and their corresponding labels explicit.

This stage is particularly important for semantic role labelling because usually the missing elements are participant roles (theta roles) shaping the semantic configuration. The most frequent are the cases of *control* where the understood subject of a clause is in the parent clause as in Examples 120–122 where *Subj* is a generic subject placeholder introduced in Chapter 6 as *PRO*, *pro*, *t-trace* and *wh-trace*.

(120) Poirot$_i$ is considering whether [*Subj*$_i$ to abandon the investigation].

(121) Susan$_i$ promised us [*Subj*$_i$ to help].

(122) They told you$_i$ [*Subj*$_i$ to support the effort].

There are also movement cases when a clause constituent receives no thematic role in a higher clause but one in a lower clause. The other case is of the non-overt constituents that are subjects in relative clauses and refer to the head of the nominal group. This part of the algorithm is set up to detect cases of *null elements* as described in Section 6.3, which relates GBT to Dependency Grammar and creates placeholder constituents for them which are in the next step enriched with semantic roles. Currently the NP traces and PRO subjects are created with a set of graph patterns, while the Wh traces are created with an algorithm.

9.3.1 PRO and NP-trace Subjects

The *xcomp* relation in DG can be encoded as a CG pattern graph (Figure 9.5) targeting the constituents that are non-finite clauses functioning as complement that have no subject constituent of their own and no “if” and “for” markers (according to generalisation 6.2.4). They receive a PRO subject constituent (governed or not) by the parent clause subject.

The generalisation 6.3.2 reflects criteria for selecting the controller of PRO based on its proximity in the higher clause. The schematic representation of the pattern for obligatory and subject object control (treated in Section 6.3.2) is depicted in Figures 9.6 and 9.7 respectively. In the case of Figure 9.7 the prepositional complements do

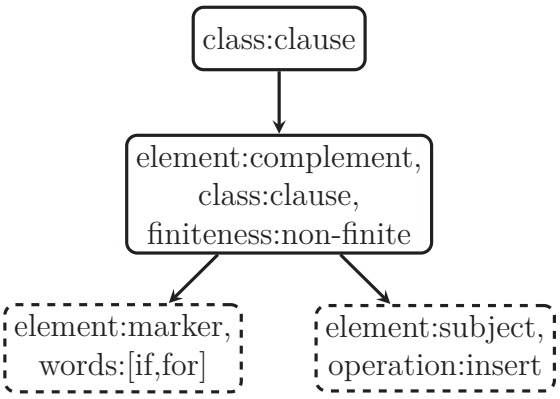


Fig. 9.5 CG pattern for detecting PRO subjects

not affect subject control treatment in any way. The reason for that is because the graph pattern specifies only the nominal complements, which is complementary to object control pattern in Figure 9.6.

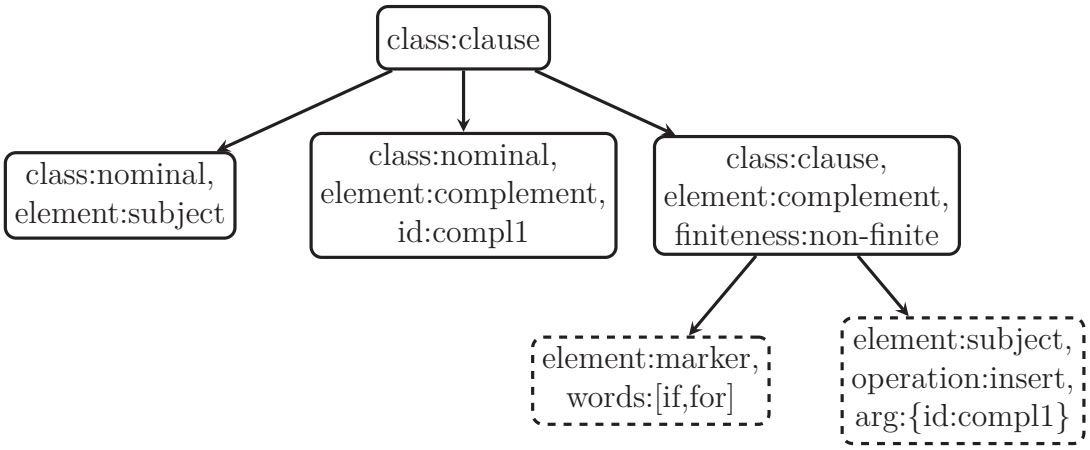


Fig. 9.6 CG pattern for obligatory object control in complement clauses

In dependency grammar the adjunct clauses are also introduced via *xcomp* and *prepc* relations, so syntactically there is no distinction between the two and patterns from Figures 9.6 and 9.7 are applicable.

Before discussing each approach I would like to state that when the empty constituent is being created two important details are required: (a) the antecedent constituent it is bound to and (b) the type of relationship to its antecedent constituent or, if none is available, the type of empty element: t-trace or PRO. Now identifying the antecedent is quite easy and can be provided at the time of CG creation, but since the empty element type may not always be available then it may have to be marked as partially defined.

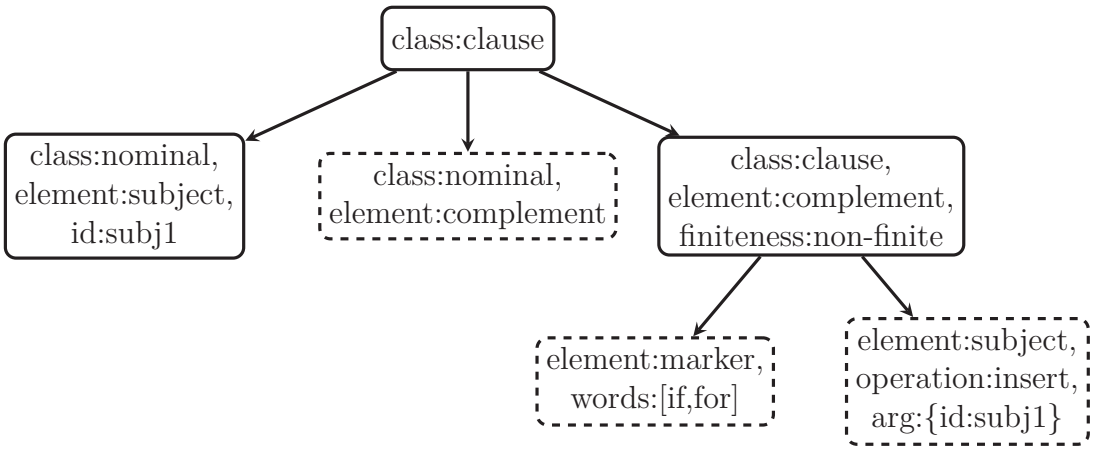


Fig. 9.7 CG pattern for obligatory subject control in complement clauses

The first solution is to create the empty subject constituents based only on syntactic criteria, ignoring element type (either PRO or *t*-trace) and hence postponing the decision to the semantic enrichment phase (addressed in this chapter). The advantage of doing this is a clear separation of syntactic and semantic analysis. The empty subject constituents are created in the places where they should be and so this leaves aside the semantic concern of how the thematic roles are distributed. The disadvantage is leaving the created constituents incomplete or under-defined. Moreover the thematic role distribution must be done within the clause limits but because of raising, this process must be broadened to a larger scope beyond clause boundaries. This of course is an unwise approach as it might lead to unbounded dependencies and so unbounded complexity that needs to be addressed.

The second solution is to decide the element type before Transitivity analysis and remove the burden of complex patterns that go beyond clause borders. Also, all syntactic decisions would be made before semantic analysis and the empty constituents would be created fully defined with the binder and their type. But this means delegating semantically related decision to syntactic level (in a way peeking ahead in the process pipeline).

In the current work, however, the semantic roles are addressed within the clause borders following the principle of one-main-verb-per-clause and thus avoiding the above mentioned risk of unbounded complexity. Also, the transitivity analysis is done based on pattern matching. This means a tremendous rise in complexity as the scope of a graph pattern is extended to two or more clauses. Instead, a desirable solution is iteration over all the clauses in the CG (a sentence) and matching semantic patterns within the clause boundaries one at a time.

The solution adopted here is a mix of the two described above and addresses the issues of: (a) increasing the complexity of patterns for transitivity analysis, (b) leaving undecided which constituents accept thematic role in the clause and which do not.

The process to distinguish the empty constituent type starts by (a) identifying the antecedent and the empty element (through matching the subject control pattern in Figure 9.7), (b) identifying the main verbs of higher and lower clauses and correspondingly the set of possible configurations for each clause (by inquiry to the process type database (PTDB) described in the transitivity analysis Section 9.6).

If conditions from Generalisation 6.3.3 (from Section 6.3.2) are met then the empty constituent is a subject controlled *t*-trace. Now we need a set of simple rules to mark which constituents receive a thematic role. These rules are presented in Generalisation 9.3.1 below.

Generalisation 9.3.1. Constituents receiving thematic roles are marked with a "thematic-role" label, those that do not receive a thematic role are marked with "non-thematic-role" and those that might receive thematic role with "unknown-thematic-role". So in each clause:

- the subject constituent is marked with thematic-role label unless (a) it is an expletive or (b) it is the antecedent of a *t*-trace; then marked non-thematic-role
- a complement constituent that is an nominal group (NP) or an embedded complement clause is marked with thematic-role label.
- a complement that is a prepositional group (PP) is marked with unknown-thematic-role.
- a complement that is a prepositional clause is marked with unknown-thematic-role label unless they are introduced via "that" and "whether" markers then it is marked with thematic-role label.
- the adjunct constituents are marked with non-thematic-role.

According to Generalisation 6.2.9 PRO is optionally controlled in subject non-finite clauses. Since it is not possible to bind PRO solely on syntactic grounds, Generalisation 6.2.9 proposed arbitrary interpretation, i.e. no binding to an antecedent; and this is the solution adopted in this work for PRO elements.

The pattern for subject control in a subject clause is represented in Figure 9.8. This of course is an oversimplification and more rigorous binding rules would need to be developed in future work to cover binding scenarios exemplified in Examples 67–70.

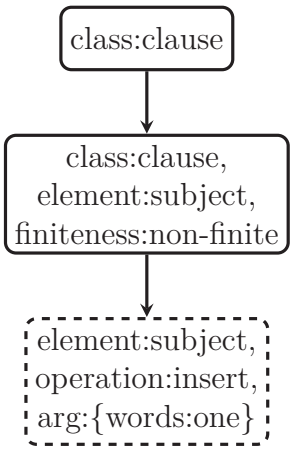


Fig. 9.8 CG pattern for arbitrary control in subject clauses

9.3.2 Wh-traces

Creating constituents for Wh-traces involved a slightly larger number of scenarios and for pragmatic reasons I implemented the following algorithm rather than create the set of corresponding graph patterns. Nevertheless in future work this should be expressed as graph patterns in order to be consistent with the general approach of the thesis. Algorithm 12 shows how it is currently done.

Algorithm 12: Creating the Wh-traces

```
   input  : cg
 1 begin
 2     if more than one clause in cg:
 3         for element in list of Wh-elements in cg:
 4             identify the Wh-groups containing the element
 5             identify the syntactic function of the Wh-element within the group
 6             identify the function of Wh-group in the clause
 7             for group in cg: low to high
 8                 if Wh-group is not Subject AND
 9                 Wh-group is not in lowest embedded clause:
10                     if Wh-group is Adjunct function:
11                         create Adjunct Wh-trace using dg and cg
12                     else:
13                         create Theta Wh-trace using dg and cg
14 end
```

The first line of the algorithm checks if there is more than one clause in the CG, otherwise it cannot continue. Then all the Wh-elements, their functions within the group and the clause are identified. Then, from the lower to higher, clauses are iterated

and the constituent corresponding to Wh-trace in the lower clause is created and linked to the trace constituent in the parent clause. The creation of the Adjunct or Theta Wh-traces involves different procedures. The corresponding algorithms have been omitted in this section but are included in Appendix H.

After the null elements are created the constituency graph is ready for the semantic enrichment stage, and semantic configurations are assigned to each clause. The next sections introduce first how the PTDB has been normalised and how the graph patterns are created from it; they then proceed with the semantic enrichment algorithm.

9.4 Cleaning up the PTDB

The original version of the PTDB available on Neale's personal page[1] is not usable for computational purposes as such. It contains records applying a couple of different notations and sometimes informal comments for human understanding, which from a machine standpoint are noise and cannot be processed. In this section I explain how the original PTDB was transformed into a machine readable form in order to be used as a lexical database.

The internal structure of the PTDB is detailed in Neale's PhD thesis (Neale 2002: 193–231). Here I focus on three columns which are of interest for the parsing process: the *verb form* (1^{st}), the Cardiff grammar *process type* (6^{th}) and the participant role *configuration* (8^{th}). Note that column numbers correspond to the original PTDB structure. After the transformation the PTDB column descriptions are as described in Table 9.4. The field names in italics are the ones of interest and have been modified.

Next I describe the transformed PTDB and how it is interpreted. For a start, the verb form column contains either the base form of the verb (e.g. draw, take), base form plus a preposition (e.g. draw into, draw away, take apart, take away from) or the base form plus a phraseological expression (e.g draw to an end, take on board, take the view that, take a shower). The prepositions are either the verbal particles or the preposition introducing the prepositional phrase complement. Prepositions often influence the process type and the participant configuration. So they are important cues to consider during semantic role assignment. The verb forms that have the same process type and configuration but different prepositions are often grouped together delimited by a slash "/" (e.g. draw into/around, take off/on) or if optional (i.e. coincide with the meaning of the verb base form without any preposition), they are placed in round brackets "()" (e.g. flow (into/out/down)).

[1] see http://www.itri.brighton.ac.uk/~Amy.Neale/

Column	Original	Modified
1/A	Form	Form
2/B	*Occurrences of form*	*Occurrences of form*
3/C	COB class (& figure where possible)	COB class (& figure where possible)
4/D	meaning description	meaning description
5/E	Occurrences in 5 million words	Occurrences in 5 million words
6/F	*Cardiff Grammar feature*	*Cardiff Grammar process type (re-indexed/renamed)*
7/G	Levin Feature	*Cardiff participant feature*
8/H	*Participant Role Configuration*	*Cardiff participant feature (extra)*
9/I	Notes	Levin feature
10/J		*Participant Role Configuration*
11/K		Notes

Table 9.4 The table structure of PTDB before and after the transformation

The process type column registers one feature from the PROCESS-TYPE systemic network depicted in Figure 4.4, which was introduced in Section 4.2.2. The participant configuration column contains a sequence of participant type abbreviations joined by a plus sign "+" (e.g. Ag + Af, Em + Ph, Ag-Cog + Ph). The order of participants corresponds to the active voice in aeclarative mood, also called the *canonical form of a configuration* described in Fawcett (forthcoming). Originally the configurations contained the "Pro" abbreviation signifying the place of the main verb/process. As all configurations are in canonical form, the Pro was redundant occurring always in the second position and so has been removed. The first participant, in canonical form, corresponds to the Subject, the second to the first complement and the third to the second complement. Some participants are optional for the meaning and are marked with round brackets "()", e.g. Ag + Af-Ca (+ Des), meaning that the participant may or may not be realised. Sometimes, for directional or locational process types, the second or third participants may function as Adjuncts, which currently complicates the matching process.

Not all the records in the original resource fulfil the description above and so needed corrections. For example when Neale had doubts during the making of PTDB, she marked uncertainties with a question mark "?". In addition, the "," (comma) and "&" (and) signs are used inconsistently with various meaning in all columns. Also,

comments such as "not in Cob" (i.e. not in Cobuild) were encountered in several columns.

Some records contain only prepositions listed in the verb form column, which actually represents omissions of the main verb that is to be found in the immediately preceding records(s); those have been fixed by pre-pending the verb form to the preposition.

Among the identified verb meanings in PTDB, there are also some that do not contain configurations. These records missing a process type and configuration have been removed.

The process type feature column contained originally a second feature which has been removed; it represented a compressed version of the participant configuration and it was redundant as the full configuration is registered in the next column.

In the PTDB Neale uses slightly different process type names than the ones used in this work. The process type features have been thus re-indexed and adapted to match exactly the feature labels in the PROCESS-TYPE systemic network (e.g. "one role action" became "one-role-action", "emotion plus xxx" became "emotive", "cognition xxx" became "two-role-cognition"). Appendix F provides the mapping across the process type versions.

The configuration column is one of the most important in the PTDB. Checking its consistency with respect to Fawcett's Transitivity system revealed the need for some corrections. For example "Af + Af", "Af-Ca + Pos + Ag", "Af-Cog + Ph + Ag" are grammatically impossible configurations and were manually corrected to the closest likely configuration "Ag + Af", "Ag + Af-Ca + Pos", "Ag + Af-Cog + Ph".

Other records, judged by the process type, were incomplete. For example instances of two role actions registered only one of the roles, e.g. Af or Ca omitting the Ag participant. These records have also been manually corrected by prepending the Ag, Ag-Af or Cog roles as appropriate.

The "Dir" participant is interpreted as direction but is not registered/defined in the Cardiff Grammar. Nevertheless there is a "Des" participant which I believe is the closest match. Therefore all "Dir" occurrences have been changed to "Des". One may argue that the two have different meanings, however grammatically they seem to behave the same (at least in the accounted configurations).

By contrast some process types have been changed from action into either locational or directional because they contained either "Loc" (location), "Des" (destination) or "So" (source) participants which are not found in action processes unless they function as adjuncts, which are out of the context of the current description.

A note worth making here is that locational process types, in particular movement sub-process types, are more difficult to assign roles correctly. Their participants are locations, directions, destinations etc. and these participants can equally serve as adjuncts of various spatial types. This aspect has not been directly addressed in present work and is reflected in the evaluation results (presented in Chapter 10) as a lower accuracy for these process types as compared to other ones.

The Cardiff features column indicates the process type selected in the TRANSITIVITY system corresponding to one of the top levels depicted in Figure 4.4 provided in Chapter 4. Next section provides a description of how the graph patterns are generated from the PTDB.

9.5 Generation of the TRANSITIVITY graph patterns

The configuration pattern graphs are used for CG enrichment executed through graph matching operation as described in Section 7.4. In the previous section we saw how the PTDB has been cleaned up and normalised to support automatic generation of the *Configuration Graph Patterns* (CGP), which afterwards are used to enrich constituency graphs with transitivity features. These graph patterns represent a constrained syntactic structure that carries semantic features that are applied if the pattern is identified.

CGPs are generated from the process type and participant configuration columns of the PTDB. Figure 9.9 depicts the prototypical template for generating a three role CGP for canonical participant order that is active VOICE and declarative MOOD. This pattern matches declarative clause with a subject and two complements and in case of success updates the constituents with process type and participant roles. When the configuration has only one or two participants the graph pattern indicates one or two negative complement nodes as depicted in Figures 9.10 and 9.11. In this section I do not aim at providing an exhaustive account of all the pattern forms but explain the principles by which they are automatically generated.

Besides the canonical CGP a set of variations are generated for each configuration corresponding to yes-no and Wh-Subj/Wh-obj/Wh-adj interrogative forms, imperative form and to passive voice form. When each of the variants are supported by the process type and participant configuration, the following CGP are generated: (1) the declarative active (2) the passive (3) the imperative and (4) Wh-interrogative (Wh-Subj/Wh-obj/Wh-adj especially important for locational and directions processes).

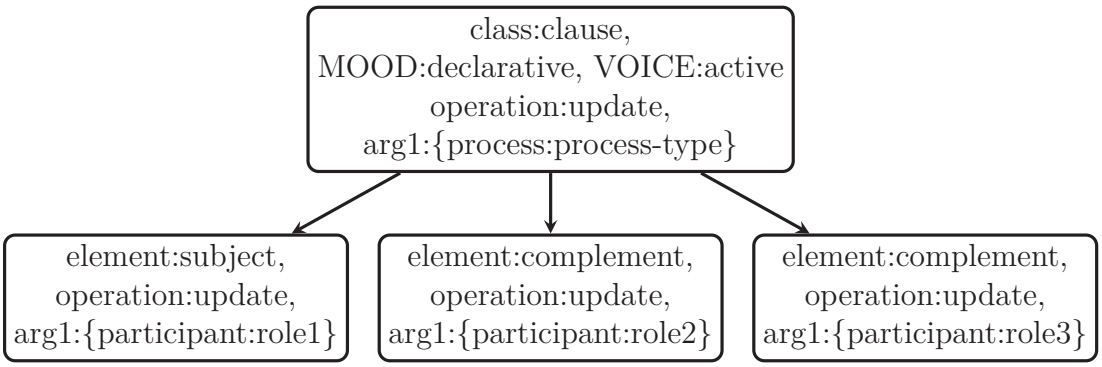


Fig. 9.9 Declarative MOOD and active VOICE graph pattern with three participant roles

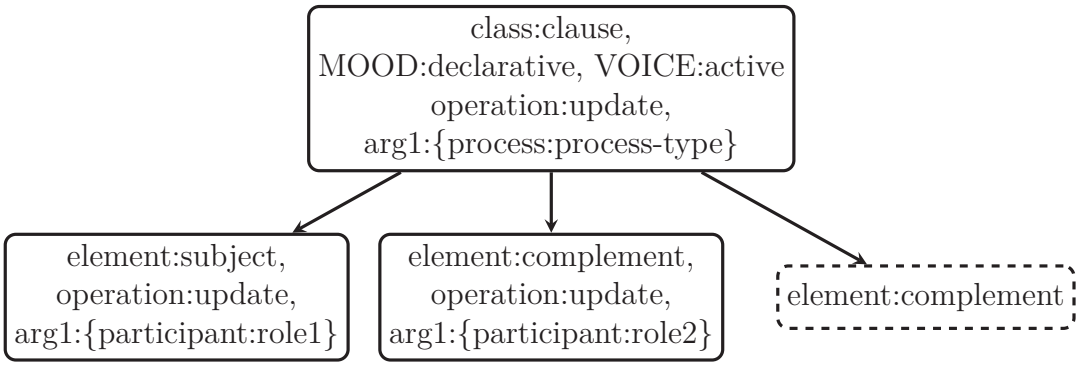


Fig. 9.10 Declarative MOOD and active VOICE graph pattern with two participant roles

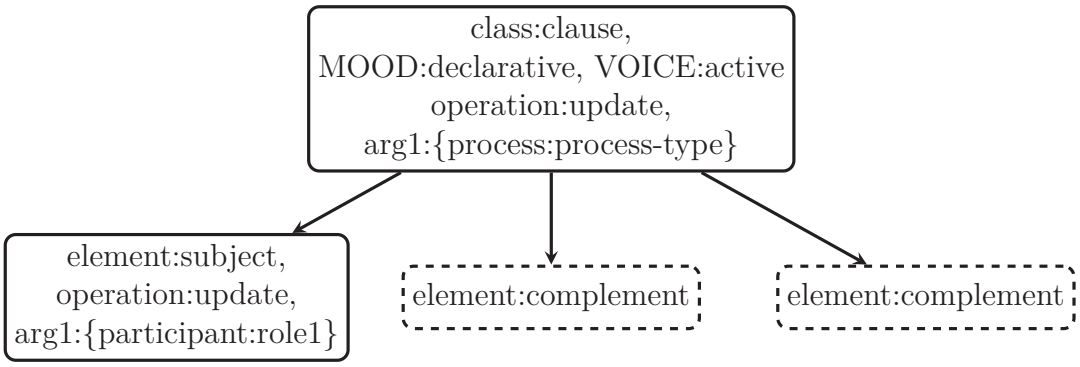


Fig. 9.11 Declarative MOOD and active VOICE graph pattern with one participant role

If the configuration accepts passive voice, i.e. the first participant in the configuration is not the expletive “there” or the pleonastic “it” and the last role is not the Agent role, then both active and passive voice CPG are generated. Otherwise the passive form is not possible.

The imperative form CGP is generated if the first role of the configuration implies an active animate entity. Thus the nominal features of the subject must already

be provided. Roles that accept imperative form are: Agent, Emoter, Cognizant, Perceiver and their compositional derivations, e.g. Agent-Carrier, Agent-Cognizant, Affected-Emoter etc. Clausal subjects are excluded.

The passive differs from the active voice pattern by switching the places of the first two roles resulting in the second role matched to the subject function and the first role to the first complement. In the case of imperative, the first role as well as the subject constituent are simply omitted.

Algorithm 13 outlines how the CPGs are generated from the PTDB. The CPGs are represented as Python structures and are stored in a Python module. This way the graph patterns are accessible as native structures making it easy to instantiate and execute the graph patterns. The process types are also grouped by the process type and number of participants which reduces the number of patterns to match per clause.

Algorithm 13: Generating the CPGs from the PTDB

```
   input  : PTDB
 1 begin
 2     generate unique set of process type + participant roles
 3     generate unique set of process types
 4     for process type in possible process type:
 5         for configuration in configuration set:
 6             generate declarative active pattern graph
 7             if no expletive in configuration:
 8                 if configuration accepts passive:
 9                     generate declarative passive pattern graph
10                 if configuration accepts imperative:
11                     generate imperative pattern graph
12                 if locational process:
13                     generate expletive there pattern graph
14                 if configuration participants may function as Adjuncts:
                       /* the Directional processes varying optional
                          Source, Path and Destination                 */
15                     generate variate role indicative active pattern graphs
16                     generate variate role indicative passive pattern graphs
17                     generate variate role imperative pattern graphs
18                     generate variate role Wh-interrogative pattern graphs
19 end
```

The first two lines of the algorithm synthesise the PTDB by grouping unique configurations for each process type. Then for each configuration of each process type

one to three pattern graphs depending on the configuration and process type specifics are generated.

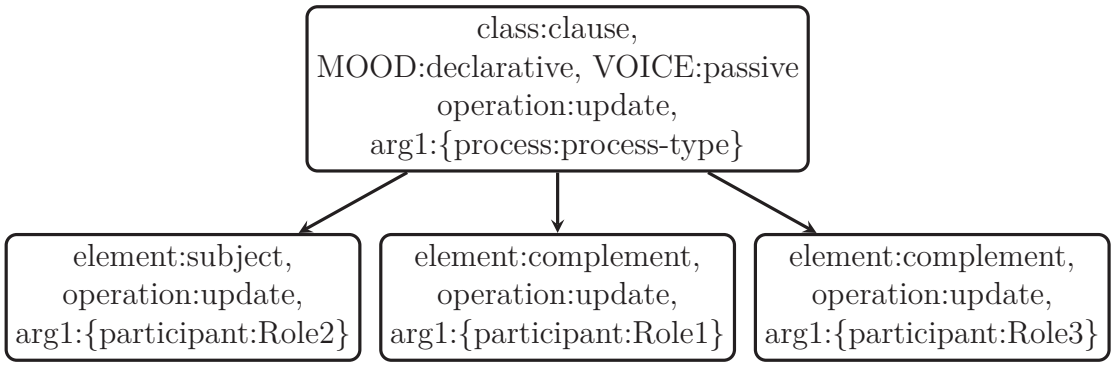


Fig. 9.12 Declarative MOOD and passive VOICE graph pattern with three participant roles

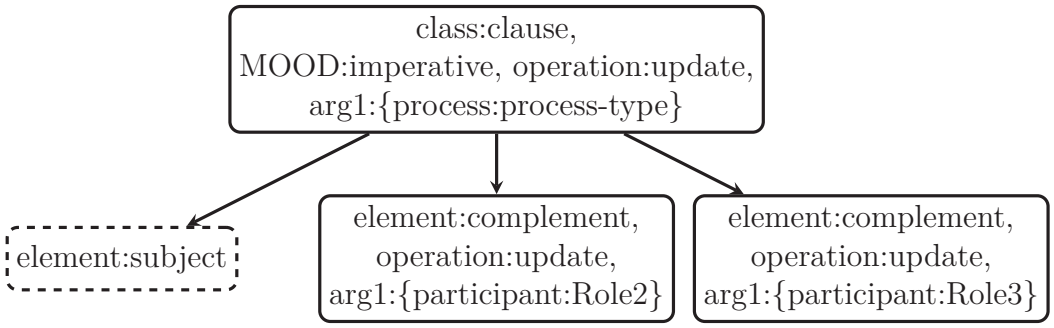


Fig. 9.13 Imperative MOOD graph pattern with three participant roles

The declarative MOOD active VOICE pattern (depicted in Figure 9.9) corresponding to the canonical form in PTDB is always generated. If the configuration does not contain an expletive and accepts passive voice then the corresponding pattern is generated with the first and second roles switched as in Figure 9.12. Note that role2 is assigned to the subject and role1 to the first complement. If the configuration accepts imperatives, then also a subject-less pattern graph is generated with the first role omitted as depicted in Figure 9.13.

Directional processes are a special case. Examples 123 to 125 are equally valid configurations. Example 126 is a generic representation highlighting the optionality of these participants.

(123) The parcel travelled from London[So].

(124) The parcel travelled via Poland[Pa].

(125) The parcel travelled to Moscow[Des].

(126) The parcel travelled (from London[So]) (via Poland[Pa]) (to Moscow[Des]).

And so in directional configurations, second, third and fourth participants are optional and may occur in any order, but at least one of them should be present. Therefore So, Pa and Des participants patterns should be generated for all combinations as presented in Table 9.5.

So	Pa	Des
+	-	-
-	+	-
-	-	+
+	+	-
+	-	+
-	+	+
+	+	+

Table 9.5 Participant arrangements for Directional processes (order independent)

Finally, the CPGs are grouped by process type. This alleviates the burden of selecting the number of patterns to test for a certain clause.

The patterns are generated in advance and so at runtime are ready for execution. This decreases execution time. Next follows the description of how the generated configuration graph patterns are used in the Transitivity enrichment phase.

9.6 Enrichment with TRANSITIVITY features

Once the constituency graph has been enriched with MOOD and nominal DEIXIS features and the null elements created, it is ready to be enriched with TRANSITIVITY features. The algorithm identifies, in each clause, the main verb and the potential participant constituents and searches in the PTDB for the lexical item matching the main verb and any of its extensions filtering (based on the clause constituency) the possible configurations for the verb (comprising all the verb configurations). Then all the graph patterns corresponding to the possible configurations are executed on the clause, which, if matched, will enrich the clause CG.

Algorithm 14 outlines the semantic parsing process implemented in the current parser which is a cascade of three loops. The first loop iterates through clauses in the mood constituency graph and for each the candidate process types are identified by considering: (a) the main verb, (b) the prepositions connected to it (either prepositional particles, or prepositions introducing a complement or adjunct prepositional phrase

Algorithm 14: Transitivity parsing

```
   input  : cg, dg
1  begin
2      for clause in clauses in mcg:
3          select from PTDB candidate process types and configurations
4          filter configurations fitting the clause
5          for config in valid possible configurations:
6              filter pre-generated pattern graphs of the config fitting the clause
7              for pattern in filtered pattern graph set:
8                  enrich clause using pattern and mcg filtered by role constraints
9  end
```

listed in Table 9.6) or (c) phrasal expressions such as "take a shower" which were explained in Section 4.2.3.

Role	**Prepositions**
Des	to,towards,at,on,in,
Ben	to,for,
Attr	as,
Ra	on,in,
So	from,
Pa	through,via,
Loc	in,at,into,behind,in front of, on
Mtch	with,to,
Ag	by,
Ph	about,
Cog	to

Table 9.6 Prepositional constraints on participant roles

The second loop iterates through the candidate configurations for each candidate process type and selects the graph patterns that should be matched to the current clause. Then iteratively, each of the retrieved graph patterns (in the third loop) are applied to the clause graph. Line 7 enriches CG nodes with new features of the pattern graph each time they are successfully matched. Before enrichment the CG nodes are checked against an additional set of conditions (captured by Algorithm 15) which were omitted in the pattern graph. These conditions may prevent enrichment even if the pattern has been identified.

Algorithm 15: Participant Role constraint check if a role is not illegal for constituent

```
   input  : node, role, dg
1  begin
       /* Cog, Em and Perc must be animates                          */
2      if role is Cog or Em or Perc:
3          check that the node has animate feature
       /* clauses can only be phenomenas                             */
4      if node is a clause:
5          check that role is Ph only
       /* prepositional phrases can only start with certain
          prepositions for a role                                    */
6      if node is a Prepositional Phrase:
7          get the list of allowed prepositions for the role
8          check if the prepositional phrase starts with any of the allowed
            prepositions
9  end
```

9.7 Summary

This chapter has described how the constituency backbone is enriched with syntactic and semantic features from the MOOD and TRANSITIVITY system networks using graph patterns. Besides the core sections describing the enrichment algorithms, this chapter has provided explanations about the graph pattern creation, CG extension with null elements and the clean-up of PTDB

First null elements are identified and filled with proxy constituents. This process ensures higher accuracy of semantic role assignments from the configuration patterns in the second step.

The configuration patterns have been generated from the PTDB - a verb database accounting for Transitivity patterns in Cardiff grammar. In order to generate these patterns the PTDB had first to be cleaned up, unified and aligned to the present Transitivity system. Then for each configuration a set of possible patterns were generated, which vary based on mood, voice, process type and participants. Finally the semantic role labelling step employs the same pattern based enrichment mechanism as used in Section 9.2.

The algorithms can be improved by externalisation of constraints and conditions. In the next iterations of Parsimonious Vole parser development should be towards higher abstraction and separation between the grammatical constraints (in SFL represented as systemic realisation rules) and the algorithm.

Chapter 10

Empirical evaluation

This chapter presents the evaluation the Parsimonious Vole parser. The aim of the evaluation is to determine how accurately the text analysis is produced; and in particular, how well the parser performs at unit boundary detection (i.e. text segmentation), unit class assignment, element assignment, and feature selections. The grammar that is employed in this evaluation was already introduced in Chapter 4, the corpus annotations will be introduced in Section 10.1, the evaluation method in Section 10.2, while the results will be covered in Sections 10.3 and 10.4.

The evaluation data was generated by comparing the labelled segments available from the corpus annotations to the labelled segments from the parser output. The parser accuracy is measured in terms of *precision*, *recall* and F_1 scores. The parser *precision* measures how many segments have been produced by the parser that are also found by manual analysis; and the parser *recall* measures how many correct segments have been produced by the parser relative to the total number of produced segments. F_1 score is a harmonic mean of the precision and recall.

Each corpus, introduced in Section 10.1, was annotated in a manner that slightly differs from the analysis structure produced by the parser, due to differences in the annotation methodology. These differences will be described in detail in Section 10.1.3. Before then, to better understand the differences consider the example segments in Listings 10.1 and 10.2. In this example, the segments differ in the way the spaces and the end of sentences punctuation are framed into the clause segments and so, in this evaluation, they are considered as partially (or closely) matching clauses. The exact matches are used to establish a base line accuracy.

Listing 10.1 Example segment from the corpus

```
0 587forced me into treatment611
```

Listing 10.2 Example segment from the parser output

```
0 583and forced me into treatment .612
```

The evaluation methodology that will be described in detail in Section 10.2, considers perfect alignment between segment boundaries and their labels. Also it considers alignment of segments with the same label and partial boundary overlap provided that the difference between them is not too large and there is no other better matching candidate at a shorter distance. This means that segment spans such as the ones in Listings 10.1 and 10.1 are given some credit in the alignment process. The main reason for taking segmentation discrepancies into consideration is to provide a wider sample for the evaluation of systemic selections available for the MOOD and TRANSITIVITY system networks. Another reason for keeping the partial matches is that discarding them completely is not entirely correct either because it narrows down the evaluation ground of the systemic features on the paradigmatic axis. The next section describes the corpora used in current evaluation, followed by the evaluation methodology, and finally the evaluation results are presented.

10.1 Evaluation corpus

This section briefly introduces the two corpora used in the evaluation of the Parsimonious Vole parser. They are the OCD corpus annotated with Mood features, and the OE corpus annotated with Transitivity features. Table 10.1 provides a summary of the corpora descriptions.

Corpus name	Meta-function	Words	Clauses	Annotator(s)
OCD	Mood	3446	529	Ela Oren & Eugeniu Costetchi
OE	Transitivity	11021	1503	Anke Schultz & Tatsiana Markovic

Table 10.1 Evaluation corpus summary

Each corpus was annotated in a manner that slightly differs from the analysis structure produced by the parser. After having presented each corpus in more detail in the next two sections, I present the main differences between them and the parser output in the last part of this section.

10.1.1 OE corpus

The OE corpus is a smaller part of the Bremen Translation Corpus (BTC) corpus that was annotated in the Cardiff Transitivity style during the PhD work of Anke Schulz published in 2015. The BTC was created at the University of Bremen by Kerstin Fischer, Anatol Stefanowitsch and Anke Schulz. It consists of comparable and parallel texts. The comparable part consists of a series of newsgroup texts of about 10,000 words of English text and another 10,000 words of German, taken from the same register. The parallel part, called EDNA, is much larger and comprises about 100,000 words of parallel English-German text. Schulz used in her thesis 10,000 words of parallel text and about the same of comparable text (Schulz 2015: 31). In this evaluation only the English part is considered, which is called the OE corpus. It comprises 31 files spanning 1503 clauses and 20864 words.

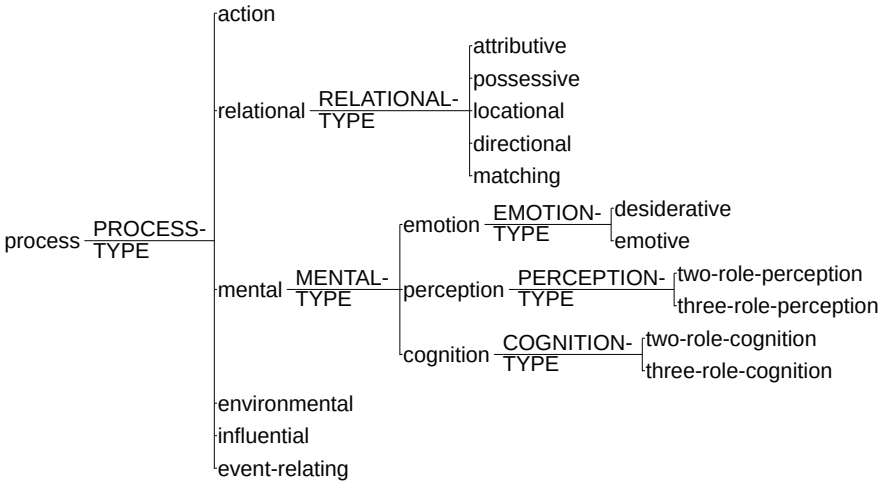


Fig. 10.1 The fragment of the TRANSITIVITY system network that has been used in the corpus

The corpus annotations, developed by Anke Schulz and Tatsiana Markovic (Schulz 2015: 36), cover the Cardiff TRANSITIVITY, THEME and MODIFICATION system networks. The grammatical details and the annotation methodology are covered in detail in Schulz (2015: 48-161). In addition, Schulz provided a set of annotations performed in the same manner for the "Little Red Riding Hood" fairy tale comprising 157 clauses which are also included in this evaluation as part of the OE corpus.

For the purpose of the current evaluation only the TRANSITIVITY system was considered. The extent to which the system network is covered in the corpus annotations is limited to the top part of the original TRANSITIVITY system network. The used system network fragment is depicted in Figure 10.1, while the whole system network was

provided in Chapter 4. Employing the entire system network in the annotation process increases in difficulty as the delicacy increases due to the time needed to perform the task (McEnery et al. 2006: 33). The challenge of providing delicate (or fine-grained) corpus annotations using large if not the entire extent of a system network, still has to be addressed in the SFL community at large.

10.1.2 OCD corpus

The OCD corpus was created by Ela Oren and myself during a two week scientific mission at the psychology faculty of Tel-Aviv University. The aim of the mission was to design an empirical evaluation for the Parsimonious Vole parser (at that time still under development) using texts consisting of self reports on the challenge of overcoming Obsessive Compulsive Disorder (OCD).

My role was to offer technical support for the annotation tool (UAM Corpus Tool), to prepare the annotation guidelines (provided in Appendix I), present relevant literature and support with the annotation process. Oren selected English texts based on relevance to her research, which was on people recovering from OCD; and after receiving training in using the UAM Corpus Tool she annotated those texts. The texts represent blog articles of people diagnosed with (OCD), who self-report on the challenge of overcoming OCD. The annotations contain syntactic constituency elements and clause MOOD features. The corpus contains four texts comprising all together 529 clauses and 8605 words.

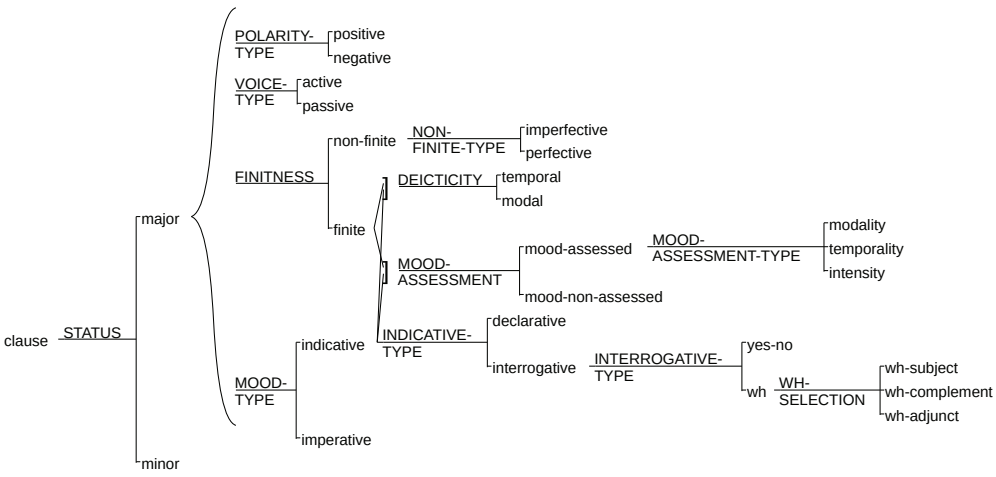


Fig. 10.2 The part of the MOOD system network that has been used in OCD corpus annotation

The corpus annotations account for the main unit classes and the main clause elements. The constituency annotation is based on the Cardiff grammar (Fawcett 2008) with some consulting of traditional grammar (Quirk et al. 1985) for clarification. The MOOD systemic selections are based on the Sydney grammar (Halliday & Matthiessen 2013b) using the network fragment presented in Figure 10.2.

The systemic selections are restricted to the network fragment depicted in Figure 10.2. It is a sub-part of the MOOD system network supported by the Parsimonious Vole parser (described in Chapter 4 and depicted in Figure 4.1). Employing the entire system network in the annotations was difficult because, as the delicacy increases, the time spent for the annotation process increases drastically making the annotation process very tedious and labour intensive (McEnery et al. 2006).

10.1.3 Differences between corpus annotation and parser output

This section describes the main differences between how the parser structures output and the methodology used to annotate each of the corpora. These differences are mainly due to text normalisation and different treatments of conjunctions and punctuation. In the OCD corpus there are also some segmentation errors as described below.

The Parsimonious Vole parser first normalises the input text before further processing. In this process the tab characters and extra spaces between words are reduced and special characters such as quotes, parenthesis, dashes and other orthographic characters are re-represented in a uniform way. In the OE corpus most of the text is uniformly formatted, but there are few deviations.

Listing 10.3 Sample of non-normalised raw text from the corpus

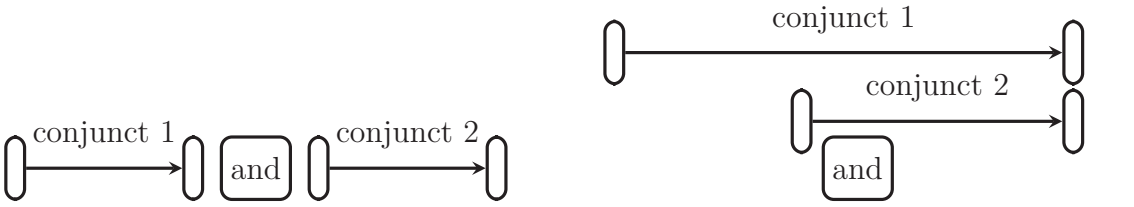
```
0 0Red riding hood excerpt24
1 25"What have you in that basket,   Little Red Riding Hood?"82
2 83
3 84"Eggs and butter and cake, Mr. Wolf."111
```

Listing 10.3 presents an example of raw text from the annotation dataset containing an initial title line and two sentences separated by an empty line. The greyed index numbers at the beginning and end of each line indicate character offsets. In OE corpus files, the first line plays the role of a header containing the title or the file name and is not considered for annotation or parsing. The extra spaces are eliminated during the normalisation process causing an index shift.

Before the annotation of the OCD corpus started the normalisation was not at all addressed and so the text contains some irregularities. Mostly it is organised as one sentence per line, but there are instances of extra blank lines or missing new line characters leading to a few sentences per line as a block. The text may also contain tabs and extra blank spaces or blank lines as in Listing 10.3 at index [82,84].

It is noteworthy to mention that there are segmentation errors in a few cases from the OCD corpus. Some segments are either shifted and include the adjacent spaces (e.g. " getting this push" instead of "getting this push") or, the converse, leaveing out one or two characters of a marginal word (e.g. "the balanc" instead of "the balance").

In the OCD and OE corpus annotations, punctuation marks such as commas, semicolons, three dots and full stops are not included in the constituent segments while the parser includes them at the end of each adjacent segment. An example of such a case was provided in Listings 10.1 and 10.2 in the beginning of this chapter.



(a) Conjuncts annotated as parallel segments

(b) Conjuncts annotated as subsumed segments

Fig. 10.3 Treatment of conjunctions in the corpus compared to the parser

The treatment of conjunctions that was discussed in Section 3.4.6 differs as well. In the corpus, the conjunctions (such as "and", "but", "so", etc.) are excluded from the conjunct segments; they are considered markers in the clause/group complexes rather than part of the constituent. The parser, on the other hand, includes the conjunctions into the succeeding adjacent segment. For example, in the corpus we find the segment "forced me into treatment" while the parser produces a slightly larger segment "and forced me into treatment." that includes the conjunction at the beginning and the full-stop at the end.

Moreover, the spans of the conjunct segments differ as well due to differences in treatment. Instead of being analysed in parallel, having sibling status as depicted in Figure 10.3a, the parser-generated conjunct segments are subsumed in a cascade from the former to the latter as depicted in Figure 10.3b. This is one of the main reasons for long distances between the matched segments when "conjunct 1" in Figure 10.3a is matched to its counter part "conjunct 1" from Figure 10.3b.

In this section were mentioned the most important aspects by which the corpora annotations and parser output diverge. The evaluation methodology has been developed to take segmentation discrepancies into consideration in order to provide a wider evaluation ground to the systemic associations. The next section explains how this is done.

10.2 Evaluation methodology

This section explains the design of the current evaluation and how it was conducted. I start by explaining how the corpus annotations and the parser output are brought to a common representation as batches of mono-labelled segments. Then I discuss the method to compare the batches of segments in order to find (exact and partial) matches between segments. The matches mean that the parser has produced the same output as in the corpus annotations that is considered to be correct. The number of matched and of non-matched segments is counted for each feature as part of the evaluation data. More details on the method, the matching algorithm and different types of distance measures that help dealing with partial matches in a controlled manner are presented in Section 10.2.3.

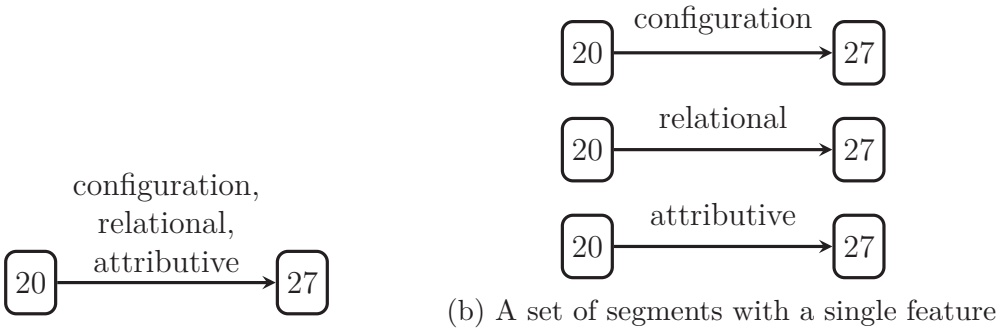
10.2.1 Corpus annotations as a set of mono-labelled segments

To compare the segment labels and boundaries we need to understand how they are represented in the annotations and parser output and how they can be brought to a common form for comparison. This section explains the UAM Corpus tool representation of the corpus annotations and how are they treated for the purpose of this evaluation.

Both OCD and OE corpora annotations were created with the UAM Corpus Tool (O'Donnell 2008a,b) version 2.4. They are recorded as segments spanning in the text file from a start to an end index position and the set of features (selected from a systemic network) attributed to that segment. There are no constituency or dependency relations between segments. An example XML representation of an annotation segment is provided in Listing 10.4. The *id* attribute indicates the unique identification number within the annotation dataset, the *start* and *end* attributes define the segment between two character offsets relative to the beginning of the text file, and the *features* attribute represents all the systemic features attached to this segment (as labels), separated by semicolons.

Listing 10.4 Segment example in UAM corpus tool

```
<segment id="4" start="20" end="27"
features="configuration;relational;attributive"
state="active"/>
```



(a) A segment with a set of features

(b) A set of segments with a single feature each

Fig. 10.4 Example of breaking down a segment with multiple features into multiple segments with a single feature

In order to provide the possibility of evaluating each feature in a simple and transparent fashion, the annotation segments are constrained to carry only one label each. This means that the representation employed by the UAM corpus tool, with multiple labels per segments, as depicted in Figure 10.4a, is not suitable as such and needs an adaptation. When it is read from the input, the segments with multiple features are broken down into multiple segments (over the same index span) for each feature in the original segment, as depicted in Figure 10.4b. Doing so permits the evaluation to focus on one or a set of features by freely and conveniently selecting only the segments that contain exactly those features.

The representation of the parser output, to be suitable in the current evaluation, needs a similar adaptation. In the next section I present how this is done.

10.2.2 Parser output as a set of mono-labelled segments

In order to compare the parser output to the corpus segments they need to be turned into the same form. In this section, I describe the task of turning rich constituency graphs (CG) into labelled segments similar to those from the corpus presented in the previous section.

To make the parser output segments comparable to the ones in the corpus they need to refer, in terms of their offsets and indexes, to the same raw text. This is not the

case for two reasons. First, the parser identifies sentence boundaries and then processes them one sentence at a time. This means that the original input text is chunked based on punctuation and the indexes are reset for each sentence. Correspondingly the parser output is produced with respect to the new indexes. Second, the text after being chunked is normalised. This means that the word indexes are readjusted within the sentence text and is directly reflected in the parser output. Before the evaluation can take place the parser output segments need to be re-indexed with respect to the original raw text.

To fulfil this task, the text processed by the parser is re-indexed back into the original raw text at the level of words (tokens), constituents and sentences. Algorithm 16 provides pseudo-code of the re-indexing process.

Algorithm 16: Sentence level re-indexing of CG according to the raw text

```
   input  : CG bundle, text
1  begin
2      offset ← 0
3      for cg in CG bundle:
4          generate segments for cg indexed on text given the offset
5          offset ← the end of cg
6  end
```

Section 8.3 explained that the parser processes one sentence at a time. If more than one sentence is provided as input text, then the produced output is not only one but a set of constituency graphs. This is reflected in the input for Algorithm 16 which is the array of CGs produced by the parser and the original text. The result of this algorithm is a set of mono-labelled segments indexed according to the raw text, just as the corpus annotations.

This task is performed by sequentially iterating the array of output constituency graphs and re-indexing each of them with respect to the offset calculated after re-indexing its predecessor. The process of re-indexing a CG structure is presented in Algorithm 17. The returned result is a set of segments from the constituency graph considering a given offset.

In Algorithm 17, the indexing is performed first at the word (token) level. At the same time the mono-labelled segments are generated for each token. Then the CG constituent nodes that are group or clause rank are re-indexed based on constituents below them, i.e. words that have just been re-indexed in the step before. The indexes of the constituent segments are set to be the beginning of the first word and the end of the last word. The labels assigned to the segments are the constituent unit class,

Algorithm 17: Constituent level re-indexing at the level of constituents according to the raw text

```
   input  : cg, text, sentence offset
 1 begin
 2     words ← get cg the list of words
 3     for word in list of sentence word segments:
 4         find the word in the text after a given sentence offset
 5         if word found:
 6             start ← get first word start index
 7             end ← get the last word end index
 8             create a new segment (start, end, word)
 9         else:
10             generate a warning (manual adjustment needed)
11     for node in cg in BFS postorder:
12         find the word span of the constituent
13         start ← get first word start index
14         end ← get the last word end index
15         labels ← get node class, function and features
16         create new segment (start, end, labels)
17     return set of segments
18 end
```

function(s) and all the systemic features. As the segments can carry a single label only then for every feature, function and unit class a new segment is created. This is in line with the practice described above concerning usage of mono-labelled segments.

Now that I have shown how the parser output is aligned to the original text in the corpus and is represented as a set of mono-labelled segments, it is possible now to compare the parser output and the corpus annotations in order to asses the parser accuracy. The next section explains how this is done.

10.2.3 Segment alignment method and evaluation data

Both the corpus annotations and the parser output are represented as a set of mono-labelled segments on the raw corpus text and can be compared to evaluate the parser accuracy. This section explains how this comparison is done. I first present a strict method of evaluation and then introduce a more permissive/tolerant method of evaluation based on segment similarity and distance measurements.

First, a straight-forward evaluation method is to check for a perfect match between every segment in the parser output and a corresponding segment in the corpus anno-

tations. A perfect match means that each parser segment has a counterpart in the corpus annotations whose start index, end index and label are equal. This signifies that the parser generated segment is correct.

Using this method of evaluation the resulting data contain the counts of (a) how many segments with the same label are matching, (b) how many corpus segments are not matching and (c) how many parser segments are left unmatched. Then the data is aggregated for each label in the corpus annotation and parser output combined.

In Section 10.1.3 I presented some differences between the parser output and the corpus annotations. Most of these differences are comparable especially in that they manifest as slight variations in the segment spans, i.e. shifted start and/or end segment index, while the segment labels are exactly the same. The above presented method is not satisfactory for the current evaluation because by design it leaves out about (20%) of valuable partial matches. I present next an alternative evaluation approach where I address how the differences between segments can be judged in an objective controlled manner.

A simple metric for the difference between the segments taking into account their start and end indexes is that of *geometric distance*. For two segments $S(start_S, end_S)$ and $T(start_T, end_T)$ the geometric distance is defined in Equation 10.1. We can replace the difference between start and end indexes with Δ_{start} and Δ_{end} notation and obtain the reduced form provided in Equation 10.2. This distance metric penalises errors in proportion to the length difference and the shift between segments.

$$d = \sqrt{(start_S - start_T)^2 + (end_S - end_T)^2} \tag{10.1}$$

$$d = \sqrt{\Delta_{start}^2 + \Delta_{end}^2} \tag{10.2}$$

Accounting for differences in the segment spans is a well known task in mainstream computational linguistics called *text segmentation evaluation*. A variety of segmentation evaluation metrics have been proposed among which the most known are P_k (Beeferman et al. 1999: 198–200), *WindowDiff* (Pevzner & Hearst 2002: 10), *Segmentation Similarity* (Fournier & Inkpen 2012: 154-156) and *Boundary Edit Distance* (Fournier 2013). Each of these metrics have been shown to have strengths and flaws. For example both P_k and *WindowsDiff* under-penalise errors (Lamprier et al. 2007) and have a bias towards favouring segmentation with few or tightly-clustered boundaries (Niekrasz & Moore 2010), while segmentation similarity tends to overly optimistic values due to its

normalisation (Fournier 2013). Based on the evaluation data, these distances will be further discussed in Section 10.3.1.

Now that the metrics for comparing segments have been introduced I move on to present the second evaluation method, which, in addition to accounting for the exact matches, accounts for close matches between segments using the distance measurements presented above.

The second evaluation method is to align two sets of segments taking into consideration exact and partially matching pairs. This task is similar to the well known problem in computer science called the *stable marriage problem* (Gusfield & Irving 1989). I adopt here the computer science framing of the problem to explain the second evaluation method.

The standard enunciation of the stable marriage problem is provided below and is solved in an efficient algorithm named Gale-Shapley (Gale & Shapley 1962).

> Given n men and n women, where each person has ranked all members of the opposite sex in order of preference, marry the men and women together such that there are no two people of opposite sex who would both rather have each other than their current partners. When there are no such pairs of people, the set of marriages is deemed stable (Iwama & Miyazaki 2008).

In the context of this evaluation the group of men is associated with the segments generated automatically by the parser and the group of women with the segments available from the manual analysis.

The standard stable marriage problem is formulated such that there is a group of men and a group of women and each individual from each group expresses their preferences for every individual from the opposite group as an ordered list. The assumption is that the preferences of every individual are known and expressed as a complete ordered list of individuals from the opposite group ranging from the most to the least preferred one. Thus the preference list must be *complete* and *fully ordered*.

Algorithm 18 represents a modified version of Gale-Shapley algorithm. In the process each parser segment is attempted to match with the closest corpus segment. A match is established if there is no another parser segment that is even closer to the candidate corpus segment. The remaining corpus and parser segments are marked as non-matching.

Using this method of evaluation we can count for every distinct label (a) how many segments match perfectly, i.e. the distance is zero, (b) how many segments

Algorithm 18: The algorithm for matching parser and corpus segments

```
   input  : parser segments, corpus segments
 1 begin
 2     mark all parser segments and corpus segments free
 3     compute distances from each corpus segments to every parser segments
 4     while exist free segments in parser segments:
 5         parser segment ← first free segment from parser segments
 6         if exist in corpus segments un-compared segment to parser segment:
 7             corpus segment ← the nearest among corpus segments to parser segment
                with identical label
 8             if corpus segment is free:
 9                 match parser segment and corpus segment
10                 mark parser segment and corpus segment as non-free
11             else:
12                 parser segment′ ← the current match of corpus segment
13                 if parser segment is closer to corpus segment than parser segment′:
14                     match parser segment and corpus segment
15                     mark parser segment and corpus segment as non-free
16                     mark parser segment′ as free
17         else:
18             mark parser segment as non-free and non-matching
19     fintq
20 end
```

partially match, i.e. the distance is greater than zero, (c) how many corpus segments are unmatched and (d) how many parser segments are unmatched. Hence, we get a four frequency counting numbers per label for each label used in the corpus annotation and parser output combined. These frequency numbers are used to compute parser accuracy metrics. Furthermore, the partial matches can be analysed to estimate the degree of the deviation and derive insights what can be done about it.

10.3 Evaluation of syntactic structure generation

Having presented the evaluation method, I further proceed with presenting the evaluation results in two parts: the first part focuses on the syntagmatic aspects and the second part deals with paradigmatic aspects of the parser output. In this section, I present the evaluation results for the parser accuracy to generate the syntagmatic aspects of an SFL analysis (described in Chapter 8). The discussion of evaluation results covers the accuracy of parser segmentation, the distribution of distances among

the matched segments, and the accuracy to detect the main unit classes and clause main Mood and Transitivity elements.

10.3.1 Segmentation evaluation

This section presents the evaluation data on text segmentation. As we will see below, over 60% of the parser segments coincide with the corpus segments. The differences, which were described in Section 10.1.3, are mainly due to differences in annotation approach, text normalisation and some segmentation errors in the OCD annotations (e.g. missing or including some extra characters).

The segmentation counts are provided in Table 10.2. The columns represent the number of matched segments, the segments from the corpus that have not been matched and the parser output segments left unmatched. There are 6665 segments that perfectly align and 11073 segments that align partially or completely.

	Matched	Corpus non-matched	Parser non-matched
Exact matches only	6665	1319	4332
Exact and close matches	11073	1319	4332

Table 10.2 Count statistics of matched and non-matched segments

	Precision	Recall	F1
Exact matches only	0.61	0.83	0.71
Exact and close matches	0.72	0.89	0.80

Table 10.3 Segmentation accuracy

The statistics provided in Table 10.2 translate into precision, recall and F_1 scores as provided in Table 10.3. The parser segmentation accuracy is 71% for exactly matching segments and 80% for partially matching ones. The distances between segments are measured in several ways. Next follows an analysis of these measurements.

The segmentation differences are measured, as introduced in Section 10.2, using several distance metrics: (a) geometric (Euclidean) distance, (b) edit (Levenshtein), (c) generalised hamming distance (GHD) (Bookstein et al. 2002), P_k (Beeferman et al. 1999: 198–200), *WindowDiff* (Pevzner & Hearst 2002: 10). The data is calculated on a number of over 12500 segment pairs out of which 62% are exact matches and 38% are close matches.

Before providing the interpretations to the data, I first show it is sufficient to discuss two of these distances as the other ones are strongly correlated to them and thus can be omitted from the discussion. Table 10.4 represents the Pearson correlation matrix for the distance types.

	Levenshtein	Geometric	Generalised Hamming	Pk	WindowDiff
Levenshtein	1.00	0.99	0.53	0.45	0.54
Geometric	0.99	1.00	0.52	0.45	0.54
Generalised Hamming	0.53	0.52	1.00	0.84	0.92
Pk	0.45	0.45	0.84	1.00	0.92
WindowDiff	0.54	0.54	0.92	0.92	1.00

Table 10.4 Pearson correlation coefficients for pairs of distance measure types

The Pearson correlation coefficient measures the direction and strength of a linear correlation between two variables. In this case, the variables are distance types. The standard interpretation for this coefficient is as follows. A coefficient value between 0.1 and 0.3 indicated a weak linear relationship between the variables. If it is between 0.3 and 0.5 the relation is moderate, between 0.5 and 0.7 it is strong; and a score over 0.7 indicates a very strong correlation of variables.

Using the above interpretation we can partition the correlation matrix into two groups of strongly correlated variables. At the same time both groups are only moderately (~50%) correlated to each other. The Levenshtein and Geometric distances are nearly identical with a 99% correlation though from this point on I will exclude the Levenshtein distance and employ the geometric distance only as representative for both.

The generalised Hamming distance, P_k and WindowDiff bear a strong correlation of 92% to WindowDiff. I exclude, from now on, P_k and generalised hamming distance from further discussions and use WindowDiff as the representative of the three distances. This choice is also based on the fact that WindowDiff was proposed to overcome weaknesses of P_k (Pevzner & Hearst 2002: 10).

Above, I have shown that the geometric distance and WindowDiff distance are the significant measures of distance in this segmentation evaluation. Next, I provide descriptive data (in Table 10.5) and offer interpretations for each of them.

Table 10.5 presents the descriptive statistics (columns) for every distance type (rows). The first three columns provide min, max and mean (M) values. The *SD* column

	Min	Max	Mean	SD	Rel SD	Skewness	Kurtosis
Levenshtein	0.00	219.00	5.37	15.99	2.98	5.57	42.63
Geometric	0.00	219.00	4.99	14.67	2.94	5.56	43.14
Generalised Hamming	0.00	8.00	1.84	2.87	1.56	1.30	0.09
Pk	0.00	1.00	0.18	0.29	1.62	1.40	0.57
WindowDiff	0.00	0.86	0.15	0.23	1.59	1.32	0.28

Table 10.5 Descriptive statistics for each set of distance measurements between corpus and parser segments

means *standard deviation* while the *Rel SD* represents *relative standard deviation* (or coefficient of variation). The Skewness and Kurtosis are the last statistical indicators for describing the distance distribution, which I will explain below.

The relative standard deviation is the ratio between the standard deviation and mean value, i.e. (SD/M) and measures how concentrated the data is around the mean: the more concentrated, the smaller the standard deviation. It is considered that a relative standard deviation between 0 and 0.5 indicates tightly clustered data around the mean; if it is situated between 0.5 and 1 then it means the data is more spread out; if, however the value is over one then it means the data is very scattered.

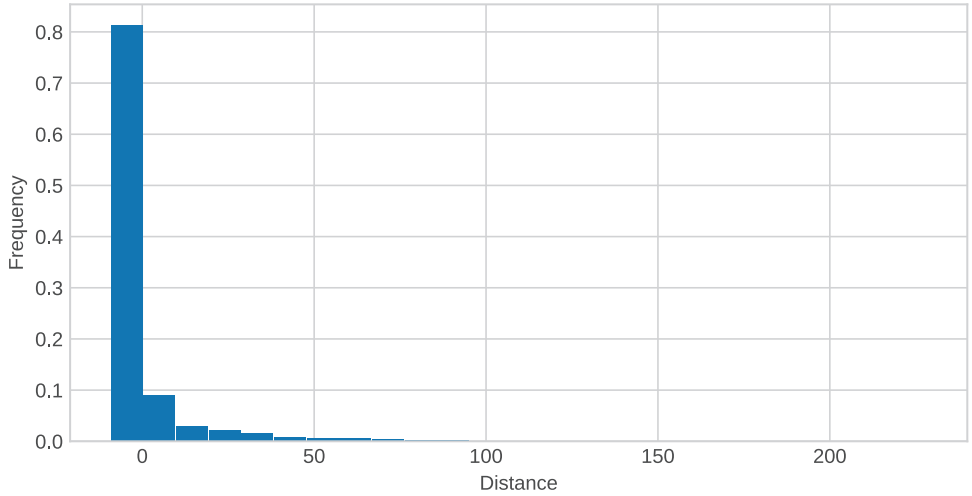


Fig. 10.5 Matched segments geometric distance distribution histogram (binning=25)

In the current evaluation, the geometric distance between corpus and parser segments spans from a minimum 0 to maximum 219 characters. The mean distance is 4.99, which is close to the minimum point, with a standard deviation of 14.67 (deviation

of almost 30 times the mean). The skew over 1, in this case 5.56, indicates a strong asymmetry to the right, and the kurtosis of 43.14 (almost 15 times the threshold of 3) indicates that most of the data, about 80%, gravitate towards the left, between 0 and slightly over the mean, while the rest of the data point continue into a very long tail to the right. This is depicted in Figure 10.5.

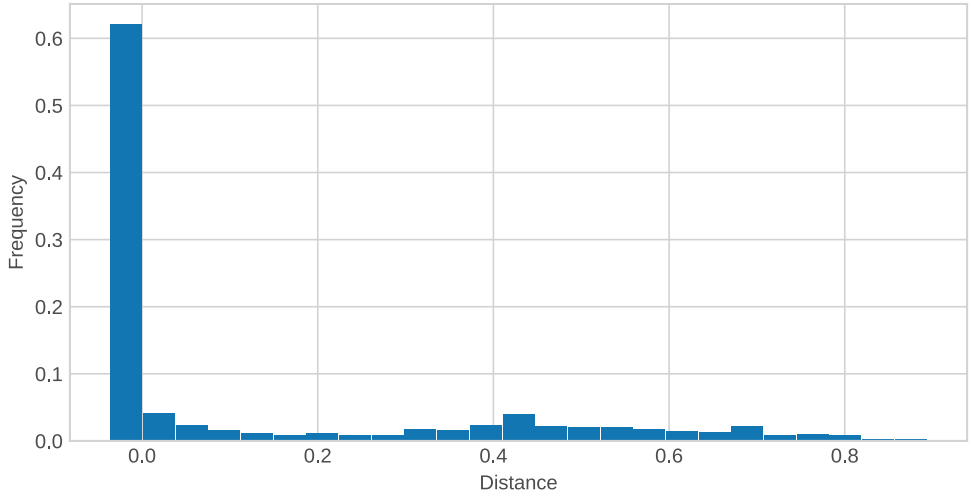


Fig. 10.6 Matched segments WindowDiff distance distribution histogram (binning=25)

As appears in Figure 10.5, the data does not follow a normal but a power law distribution (Newman 2005). This means that 62% of the segments are not shifted at all and 83% of the segments are slightly shifted up to 5 characters. The rest (17%) of the segments are shifted by more than 5 characters. These ratios approximate Patetto 80-20 distribution law but may as well fit Zipf's law (Newman 2005). In future work, properties of these data should further be analysed, including the distribution fitting, that is selection of the theoretical distribution that fits best this dataset.

The next distance measure that I discuss is WindowDiff distance between corpus and parser segments. One crucial difference to geometric distance is the normalisation to a [0,1] interval. In the current evaluation, the WindowDiff distance distribution, depicted in Figure 10.6, spans from a minimum 0 to maximum score of 0.86. The mean distance is 0.15 with a standard deviation of 0.23. The mean value is close to the minimum point, the relative standard deviation of 159%, the skew over 1 indicates a strong asymmetry to the right, and the kurtosis of 0.28 indicates the distribution does not have many outliers in the tail. These parameter values are similar to those of the geometric distance but to a lesser degree.

One positive aspect of WindowDiff distance distribution is that the tail is not so long due to its normalised structure. This results in aggregation of the outliers we

have observed in geometric distance distribution into a compact spectrum. This way, diminishing the kurtosis below 3, which no longer indicates an abnormally long tail to fit a normal distribution.

The histogram in Figure 10.6 also resembles a power law distribution and more analysis work needs to be done in the future, including the distribution fitting and relation to the causes of partial matches in the first place.

This section presented the segmentation evaluation. The data shows that the parser generates exact segments as provided in the corpus with an accuracy of 0.71 F_1 score, and segments that partially correspond to those in the corpus with an accuracy of 0.8 F_1 score. The distances of the partially matched segments, in about 83% of the cases do not exceed 5 characters, but can span, most probably by mistake, over 200 characters in less than 17% of cases. Next I present the evaluation of the label assignments for the segments corresponding to constituency units, i.e. (unit) classes and functions.

10.3.2 Unit class evaluation

In this and the next section I present the parser syntactic accuracy. It aims to measure, in this section, how well the main unit classes, and in the next sections, the clause main elements have been generated by the parser compared to the corpus. The unit class evaluation is performed on the OCD corpus. This evaluation comprises the following unit classes: clause and nominal, prepositional, adverbial and adjectival groups. No clause complexes, group complexes or word types are included. The evaluation data is depicted in Figure 10.7. The names of the unit classes are provided on the x axis at the bottom of the graph while on the y axis the absolute number of occurrences is provided.

The meaning of exact and close match has been explained in Section 10.3.1 and from now on the label “Matched” will mean the segments that are either exactly or closely matched all together, while the label with a remark “(exact only)” means that it applies to only the portion of the exactly matched segments.

To make the data easier to read and interpret I present the evaluation data in a table form using values relative to the number of matched segments. The absolute values of the evaluation statistics are contained in the graphical form and also available in the appendices in the table form. The relative evaluation data in this and the following sections will be presented in tables with the same structure. Using Table 10.6 as example, the column meaning is as follows. The first column contains the name of the unit class, element or feature. The column “Matched” contains the absolute number of matched segments with a specific label. The three other columns represent

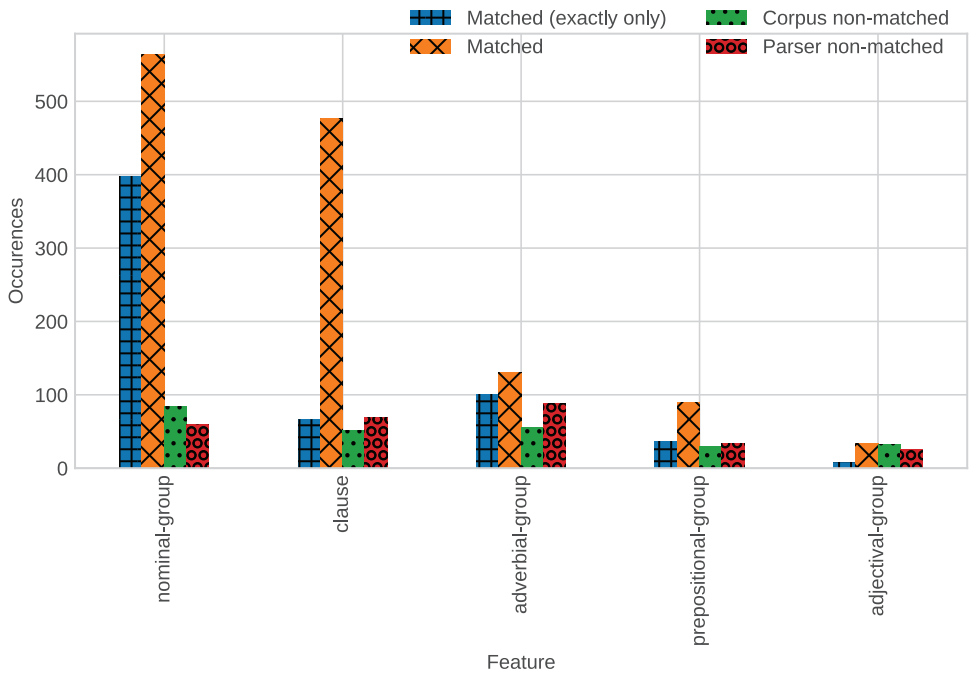


Fig. 10.7 Bar chart of matched and non-matched segments for the main unit classes

the number of segments relative to the "Matched" ones. So the column "(%) Matched (exactly only)" means that out of all the matched segments that many represent exact matches and the rest up to 100% are partially matched segments. The column "(%) Corpus non-matched" represent the number of segments relative to the total number of segments of particular type in the corpus, which remain unmatched. The column "(%) Parser non-matched" represents the number of segments (relative to the total number of segments of particular type in the parser output) in the parser output that do not have a correspondent in the corpus.

	Matched	(%) Matched (exactly only)	(%) Corpus non-matched	(%) Parser non-matched
nominal-group	564.00	70.39	12.96	9.47
clause	477.00	13.84	9.83	12.64
adverbial-group	131.00	76.34	29.95	40.18
prepositional-group	90.00	41.11	25.00	27.42
adjectival-group	33.00	24.24	49.23	44.07

Table 10.6 The evaluation statistics relative to the number of matched segments for the main unit classes

The evaluation data from Table 10.6 indicate that most (over 70%) of the nominal and adverbial groups are identified with the exact same borders as in the corpus while clause borders exhibit the most disagreement reflected by their low score of exact matches, only 13.84%. The proportion of unmatched unit class segments in both the corpus and parser output varies between 9% for clauses and nominal groups, and over 40% for adjectival and adverbial groups. These proportions, however, are better interpreted when they are embedded into precision and recall scores, which are provided in Table 10.7.

	Exact match only			Exact and close match		
	Precision	Recall	F1	Precision	Recall	F1
nominal-group	0.87	0.83	0.85	0.91	0.87	0.89
adverbial-group	0.53	0.64	0.58	0.87	0.90	0.89
prepositional-group	0.52	0.55	0.54	0.73	0.75	0.74
clause	0.49	0.56	0.52	0.60	0.70	0.65
adjectival-group	0.24	0.20	0.22	0.56	0.51	0.53

Table 10.7 Parser accuracy statistics for for the main unit classes

The scores provided in the first three columns are calculated with respect to exact matches only and the last three columns with respect to all the matches. This can be seen reflected in the lower precision, recall and F_1 scores when compared to their correspondents in the last three columns. The exact match scores, nonetheless, constitute an appropriate baseline for the parser. Note that in all cases of a match, close or exact, the segments bear the same label, and so, as explained in Section 10.1.3, the source of the divergence is mainly in the segment index span.

The last three columns in Table 10.7 show that nominal- and adverbial-group units are identified with almost 0.9 F_1 measure, which is an encouraging result, while the prepositional group and clause score 0.74 and 0.65 indicates that there is some space for improvement. Further investigation is needed to discover the reason for the lower scores as there seems to be no obvious cause other than corpus and/or parser errors. There may possibly be errors in the corpus because it has been annotated by a single annotator which may be unreliable. Also, as visible in Figure 10.7, there is a contrast in the number of segments between the first two unit types and the last three with a ratio of one to four or more. The lower number of exemplars (close to and below 100) in this evaluation contributes, to a certain extent, to the lower accuracy statistics.

10.3.3 Clause Mood elements evaluation

In this section I describe the evaluation statistics reflecting the parser capacity to identify the main elements of a clause. The data available in the corpus unfortunately does not permit us to evaluate elements of the lower rank units such as nominal, prepositional, adjectival and other groups. Next, I present statistics on the clause Mood elements, which were described in Chapter 4. These elements are present in the annotations of the OCD corpus as explained in the beginning of this chapter in Section 10.1.

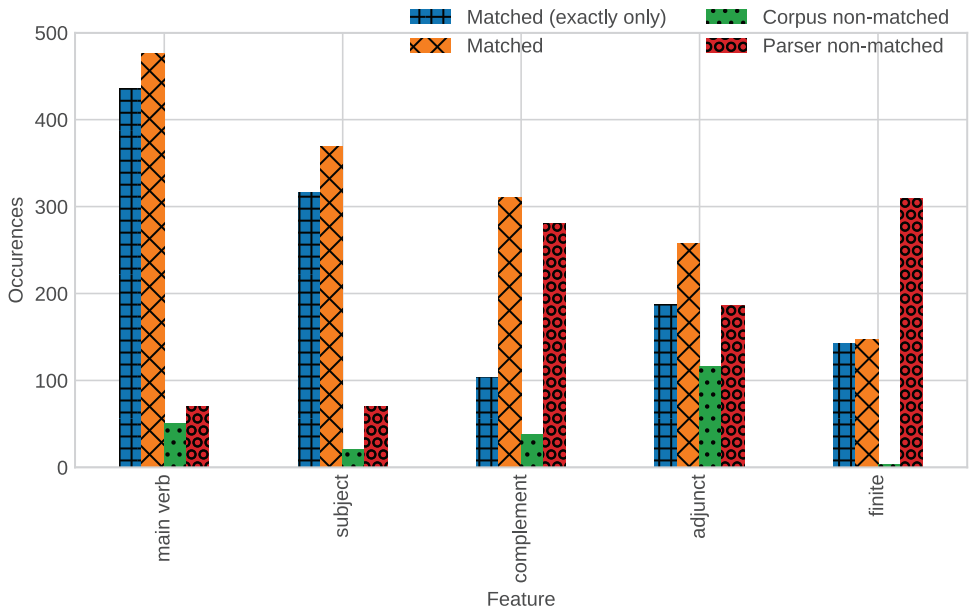


Fig. 10.8 Bar chart of matched and non-matched segments for the clause main Mood elements

The OCD corpus annotations provide the main syntactic (Mood) elements in the clause. Some of them, such as Auxiliary verbs, Main verb extension, Negation particle, and others have been omitted in the corpus annotation and are thus missing in the present evaluation. Figure 10.8 reflects the absolute values from the empirical data.

The parser accuracy measurements for the main syntactic functions are contained in Table 10.8. The F_1 score for subjects and main verbs is nearly 0.9 while the complements and adjuncts are over 0.6. Finite element scores nearly 0.5 which is surprisingly low for this element. The reason for this lays in the incomplete corpus annotations. In the annotation process the conflated Finite and Main verb elements were not distinguished. So, when there was a main verb that was also a finite, only the main verb function was marked, which is incomplete by SFL standards. This

incompleteness is clearly reflected in the contrast between low precision of 0.32 and high recall of 0.98.

	Exact match only			Exact and close match		
	Precision	Recall	F1	Precision	Recall	F1
main verb	0.86	0.90	0.88	0.87	0.90	0.89
subject	0.82	0.94	0.88	0.84	0.95	0.89
complement	0.27	0.73	0.39	0.53	0.89	0.66
adjunct	0.50	0.62	0.55	0.58	0.69	0.63
finite	0.32	0.98	0.48	0.32	0.98	0.49

Table 10.8 Parser accuracy statistics for the clause main Mood elements

The number of complements unmatched in the parser output is nearly the same as the number of matched complements. This is reflected in the 0.53 precision score and nearly 0.9 recall rate which overall lead to an F_1 score lower than that of subject and main verb elements. This can be explained by a flaw, mentioned in Section 10.1, in the annotation methodology as follows: the clausal complements were often annotated as a new clauses omitting to draw the same segment and marking it to be a complement in the clause above. This requires corpus revision and correction. However, adjuncts have a higher number of unmatched segments on both sides and this may be due to bugs in the parser and other mistakes or omissions in the corpus.

10.3.4 Clause Transitivity elements evaluation

The OE corpus, provides elements of Transitivity parsing as described in Chapter 9. The elements employed in this evaluation are Configuration, Participant role and Main verb while Circumstances are excluded from the study because they are not provided in the corpus annotations. Figure 10.9 presents the evaluation data.

The configuration segments, in SFG, correspond to clause segments, the participant role segments have as correspondents either the subject or complement segments, while the Main verb segments are shared. The aggregation of Subjects and Complements can be observed in Figure 10.9 where the number of participant roles is approximately double the number of configurations. A configuration can have between one and three participants, and current data shows an average of two participants per clause.

Note that in Figure 10.9 the scale stretches over 2500 which reflects a much larger number of segments in the OE corpus than that available in the OCD corpus. The size, and certainly a higher quality of annotations, is reflected in the fairly uniform

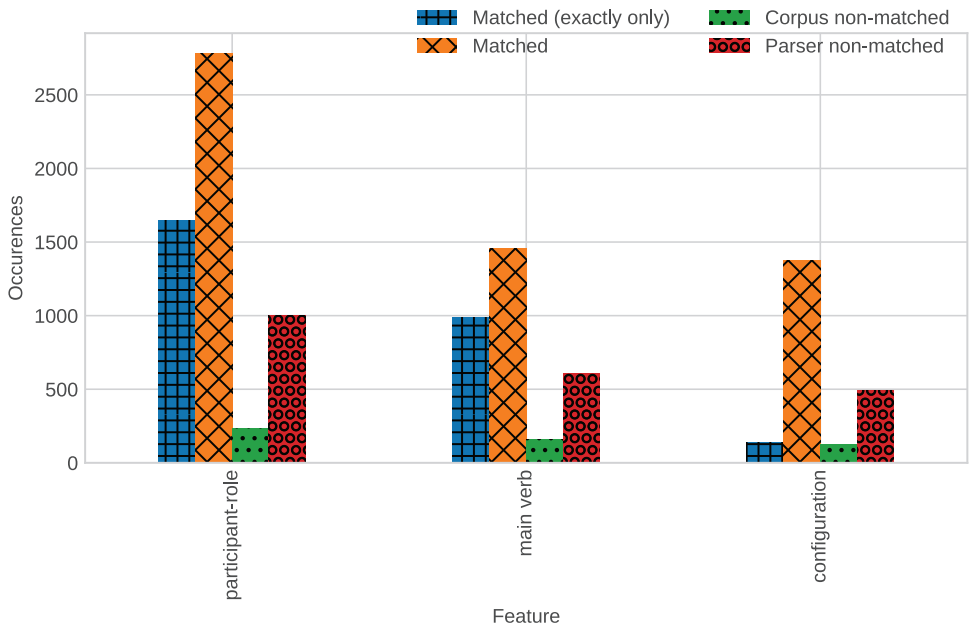


Fig. 10.9 Bar chart of matched and non-matched segments for the clause main Transitivity elements

evaluation results. The F_1 (0.82), precision (0.74) and recall (0.92) scores vary very little across elements when compared to scores of the syntactic elements shown in Table 10.8, which vary substantially from one element to another.

	Exact match only			Exact and close match		
	Precision	Recall	F1	Precision	Recall	F1
participant-role	0.62	0.88	0.73	0.74	0.92	0.82
configuration	0.22	0.52	0.30	0.74	0.92	0.82
main verb	0.62	0.86	0.72	0.71	0.90	0.79

Table 10.9 Parser accuracy statistics for the clause main Mood elements

In case of exact matches the evaluation scores are lower for the participant roles and main verbs, situating at 0.73 F_1 score, while the configuration accuracy plummeted to 30%. As configurations correspond in SFG to clauses, boundary establishment methodology plays a significant role in achieving exact matches. Thus the discrepancy in the F_1 score between exact and combined matches is explainable by a discrepancy in the clause boundaries establishment and was already addressed in Section 10.1.3.

We come to the end of the syntactic structure evaluation where I have shown that the parser generated segments exactly like those in the corpus with an accuracy of 70%

on average; and partially matching segments with an average accuracy of 80%. The parser detects unit classes on average with 52% accuracy for exact matches and 74% for close matches. The Mood and Transitivity elements are detected on average with 71% and 81% accuracy.

A constituency parser that produces a syntactic analysis using comparable unit classes and functions (using phrase structure grammars) such as for example Chen & Manning (2014), Stern et al. (2017) or Kitaev & Klein (2018) reached an accuracy of 95% for English. This state of the art in parsing with other grammars reflects that there is a large space to improve the accuracy of Parsimonious Vole constituency. But it should not be separated from the context of this work which is to parse with constituency structures enriched with features from the system networks.

10.4 Evaluation of systemic feature assignment

In this section I present the evaluation results for the parser accuracy to generate the paradigmatic aspects of an SFL analysis. It constitutes an evaluation of the approach described in Chapter 9. The discussion of evaluation results covers selection of MOOD and TRANSITIVITY features.

In this section the differentiation between exact and close matches is not considered. The reason for this is the nature of the feature selection and assignment task, which is concerned with the paradigmatic aspect of grammar. The systemic features are assigned to already formed constituent units and are not directly affected by the segmentation errors relevant at the constituent creation.

10.4.1 Evaluation of MOOD systemic feature assignment

In this section, I present the evaluation results for the systemic selections from the MOOD system network that were assigned to clause units in the constituency structure. These features are only available in the OCD corpus annotations. The fragment of the MOOD system network that is covered by the corpus was presented in Section 10.1. It is noteworthy that the parser provides more feature selections in the MOOD system network, as described in Section 4.2.1, and that the current evaluation is limited to only what is available in the OCD corpus annotations.

Table 10.10 provides the evaluation results for each of the MOOD features grouped by system names, which are marked with capital letters. On average the parser assigns systemic features with a precision of 59%. I do not discuss here the evaluation of each

feature in part but analyse the results as a whole taking a few systems as discussion examples. A detailed discussion addressing each system in part and aiming at deeper evaluation understanding should be tackled in future work.

	Match	Corpus non-matched	Parser non-matched	Precision	Recall	F1
POLARITY-TYPE						
positive	485	125	55	0.90	0.80	0.84
negative	57	10	70	0.45	0.85	0.59
VOICE-TYPE						
active	553	102	68	0.89	0.84	0.87
passive	11	11	28	0.28	0.50	0.36
FINITNESS						
non-finite	99	19	38	0.72	0.84	0.78
finite	526	33	554	0.49	0.94	0.64
NON-FINITE-TYPE						
perfective	71	12	16	0.82	0.86	0.84
imperfective	26	9	24	0.52	0.74	0.61
DEICTICITY						
temporal	446	74	55	0.89	0.86	0.87
modal	12	33	6	0.67	0.27	0.38
MOOD-ASSESSMENT-TYPE						
temporality	35	17	27	0.56	0.67	0.61
modality	15	32	8	0.65	0.32	0.43
intensity	12	14	43	0.22	0.46	0.30
MOOD-TYPE						
indicative	455	216	37	0.92	0.68	0.78
imperative	4	1	31	0.11	0.80	0.20
INDICATIVE-TYPE						
declarative	355	260	27	0.93	0.58	0.71
interrogative	47	7	63	0.43	0.87	0.57
INTERROGATIVE-TYPE						
wh	40	6	57	0.41	0.87	0.56
yes-no	5	3	8	0.38	0.62	0.48
WH-SELECTION						
wh-subject	9	3	7	0.56	0.75	0.64
wh-adjunct	11	15	3	0.79	0.42	0.55
wh-complement	8	0	62	0.11	1.00	0.21

Table 10.10 The evaluation statistics available for the MOOD system network

The order in which the features appear in Table 10.10 roughly corresponds to an increase in systemic delicacy. As delicacy increases there are increasingly fewer occurrences where a system is employed. This is associated also with a decrease in the accuracy although there are multiple factors influencing this among which parser errors, corpus quality and small population size.

The precision and recall values vary quite a lot from a minimum of 11% up to a maximum of 93% and their harmonic mean, the F_1 score, between 30% and 87% averaging to almost 60%. The details can be read in Table 10.11. The graphical representation of these values distribution can be seen in Figures 10.10 and 10.11. A noticeable feature is the presence of two peaks in the precision and recall distributions:

	Precision	Recall	F1
mean	0.57	0.73	0.59
standard deviation	0.27	0.18	0.21
min value	0.11	0.32	0.20
25% quantile	0.41	0.62	0.48
50% quantile	0.56	0.80	0.61
75% quantile	0.82	0.86	0.78
max value	0.93	1.00	0.87

Table 10.11 Descriptive statistics of the precision, recall and F1 scores for evaluated MOOD features

one around 50% and the other one around 90%. They translate into a similar F_1 distribution with peaks at 60% and 85%, a phenomena which I address next.

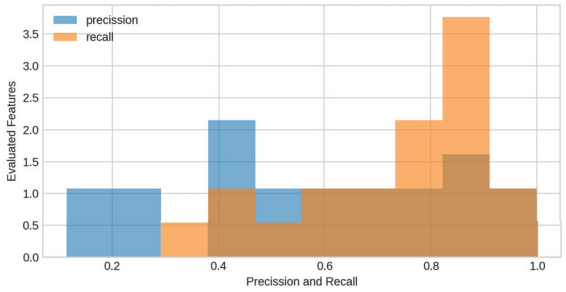


Fig. 10.10 The distribution of precision and recall for evaluated MOOD features

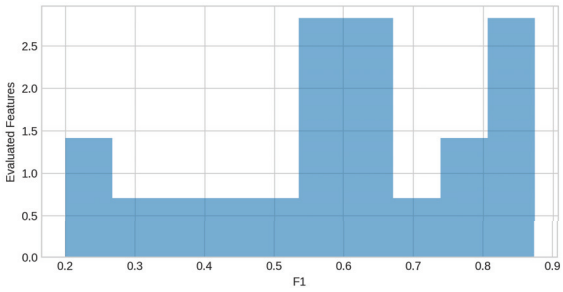


Fig. 10.11 The distribution of F1 score for evaluated MOOD features

Within most systems, the F_1 scores exhibit a contrast from one feature to the other. What this possibly means is discussed in the next two cases. For example in the POLARITY-TYPE system the positive polarity feature scores 84% accuracy while the negative one almost 60%. As per Definition 3.2.10, the system features are mutually exclusive. The polarity of an English clause is positive by default unless a negation marker is found and this represents only 10% of the clauses in the corpus. This leads us to the hypothesis that it should be sufficient for the parser to detect one feature with a reasonably high accuracy then the converse feature should be detectable with a similar accuracy if a selection in that system is expected. Yet the current data invalidate this hypothesis as the grammar fails to represent exclusivity.

In the case of the POLARITY-TYPE system, the phenomena may be explained as an incomplete parser implementation. The current version of implementation deter-

mines polarity by checking for the presence of the negation verbal marker only without considering cases of nominal and adverbial negative markers. Nonetheless a more delicate polarity testing will have to take into consideration polarity indicators from the subject, complement and adjuncts of various types that have been taken into consideration during the annotation process. An incomplete, less delicate, implementation for systemic choices is certainly a source of errors but it requires further investigation to what extent it impacts these results.

Another way to look at the high discrepancy between the feature accuracy scores can be as follows. Considering POLARITY-TYPE as example, it might be the case that most instances of positive polarity are easy to detect. But, there is a portion of cases, regardless of the polarity, that are difficult for the parser to distinguish and that the negative polarity selections fall mostly within these ambiguous cases.

The phenomena of unbalanced accuracy scores among features of the same system can be seen in multiple other cases. Let's look at the VOICE-TYPE system. The detection mechanism for VOICE-TYPE is implemented similarly to POLARITY-TYPE. The parser checks whether there is a passive order of elements in the clause, otherwise the active voice is selected. The detection of the active voice scores a significantly higher accuracy of 87% than the passive one of only 36%. There is no delicacy variation problem and still the discrepancy between the F_1 scores of the two features is there. But this could be explained by small sample of passive voice instances: only 22 are annotated in the corpus.

This section presented the evaluation results for the MOOD systemic selections. On average the parser assigns to clause constituents MOOD features with an accuracy of almost 60%. A more thorough analysis for each system individually would indicate how to improve the current parser. At the same time the quality of the OCD annotations has not been assessed and therefore a more reliable corpus with MOOD annotations is highly desirable for a similar evaluation.

10.4.2 Evaluation of TRANSITIVITY systemic feature assignment

In this section I present the evaluation of the TRANSITIVITY system network. As was explained in Section 10.1 above, the OE corpus contains annotations covering only a fragment of the TRANSITIVITY system, which is depicted in Figure 10.1. The full Cardiff TRANSITIVITY system network was presented in Figure 4.4 in Chapter 4. The parser provides more feature selections than those available in the corpus, which

are described in Section 4.2.2, but the current evaluation is limited to only what is available in the corpus.

Cardiff Transitivity analysis is semantic in nature and poses challenges in meaning selection beyond constituent class or function. The approach of assigning this sort of features was explained in Chapter 9. Here I would like to remind about an important aspect of this approach that impacts the evaluation results, explaining in some cases abnormally high recall rates.

In the grammar, described in Chapter 4, a clause can be assigned a single process configuration and the participant constituents can take only one role each. In the semantic role labelling task the situation is similar: a clause takes one semantic frame and each constituent only one semantic label. This means that a parser shall produce as output one semantic configuration that fits best the text.

The approach implemented in the Parsimonious Vole parser is such that it does not always provide a single semantic configuration. Instead, it generates one or several possible configurations for each clause instead of providing exactly one. The reason for this is the mechanism by which semantic analysis is done. The constituency structure is tested against a set of semantic graph patterns and the matching patterns enrich the constituency structure with semantic features immediately. In some cases more than one pattern matches the constituency structure leading to enrichment by multiple graph patterns, which is not entirely correct.

Multiple feature assignments from the same system, however, are represented as disjunctive sets in the constituency structure which ought to be interpreted as alternating possibilities rather than actual assignments. This interpretations was explained in Chapter 7 when the disjunctive sets were introduced.

Intuitively, this should reduce accuracy on all the elements but the effects are mostly manifested at the level of participant roles as will be described below. First, let's discuss the evaluation results for the process types, which are provided in Table 10.12, and after, we will turn to the evaluation of participant roles.

In Table 10.12 *mental* and *relational* processes are the ones with highest F_1 scores: 0.64 and 0.59. They are followed by *influential* and *action* process types while results for the *event-relating* are not conclusive because of the very small number of occurrences in the dataset. Note that considerable volume of annotations for process type sub-types are provided for mental and relational processes as explained in Schulz (2015: 153-155).

Among the *mental* processes, *two-role-cognition* and *three-role-cognition* are parsed with the highest accuracy of 51% and 50% correspondingly; whereas among *relational* ones the *attributive* process type scores the highest, 49% while the rest of them score

	Match	Corpus non-matched	Parser non-matched	Precision	Recall	F1
PROCESS-TYPE						
mental	277	231	87	0.76	0.55	0.64
relational	338	297	174	0.66	0.53	0.59
influential	38	51	62	0.38	0.43	0.40
action	170	231	352	0.33	0.42	0.37
event-relating	1	28	0	1.00	0.03	0.07
RELATIONAL-TYPE						
attributive	169	239	107	0.61	0.41	0.49
directional	30	13	127	0.19	0.70	0.30
locational	39	20	207	0.16	0.66	0.26
matching	2	0	69	0.03	1.00	0.05
MENTAL-TYPE						
three-role-cognition	45	51	34	0.57	0.47	0.51
two-role-cognition	95	102	86	0.52	0.48	0.50
two-role-perception	13	12	102	0.11	0.52	0.19
three-role-perception	0	2	6			
desiderative	0	0	81			
emotive	0	0	87			

Table 10.12 The evaluation statistics available for the PROCESS-TYPE system and few of its subsystems from the TRANSITIVITY system network

much lower. This can be seen also in the higher number of non-matched segments for each process type for every feature.

	Precision	Recall	F1
mean	0.35	0.48	0.36
standard deviation	0.32	0.26	0.19
min value	0.00	0.00	0.05
25% quantile	0.07	0.42	0.24
50% quantile	0.33	0.48	0.39
75% quantile	0.59	0.55	0.51
max value	1.00 (0.76)	1.00 (0.70)	0.64

Table 10.13 Descriptive statistics of the precision, recall and F1 scores for evaluated TRANSITIVITY features

Looking at the entire set of evaluation results for process types, the precision and recall values vary quite a lot from a minimum of 3% up to a maximum of 100% and the F_1 score, between 7% and 64% averaging to 41%. The summary of the descriptive statistics can be read in Table 10.13. The maximum of 100% precision is a bit unfortunate because there is one instance of the event-relating process found by the parser which also failed to find the other 28 thus the recall of 3% only. Hence, I decided to ignore this value and use the next maximum which is 76% corresponding to the mental process types. A similar case of 100% is for recall of the matching process

type which was provided only two times in the corpus, but the parser generated 67 different instances of it. Therefore, I consider the next maximum recall value, 70% for the directional process type.

Next, I provide an analysis of the evaluation data indicating a potential relation between the increase in the delicacy and effect it has on the parser accuracy. The accuracy of mental process detection is 64% whereas the average accuracy for the mental sub-types (cognition, perception, desiderative and emotive) is 40%. The same holds for relational process whose accuracy is 59%, whereas the average of its sub-types (attributive, directional, locational, matching) is only 26%. I start by comparing the number of mental and relational segments to the sum of mental sub-type segments and sum of relational sub-type segments correspondingly.

Features	**Manual**	**Parse**	/
mental	508	364	**0.72**
mental sub-types (sum of)	320	549	**1.72**
/	**0.63**	**1.51**	

Table 10.14 The ratios between *mental* segments and the sum of mental sub-type segments

Features	**Manual**	**Parse**	/
relational	635	512	**0.8**
relational sub-types (sum of)	512	750	**1.47**
/	**0.8**	**1.47**	

Table 10.15 The ratios between *relational* segments and the sum of mental sub-type segments

Table 10.14 and 10.15 contain four frequency counts and four ratios. The total number of segments available in the corpus and produced by the parser are provided by column and the features are provided in rows. On the bottom and right sides of the table two pairs of ratios between frequency numbers are provided.

Next, I discuss only the case of the mental process type (see Table 10.14) because the values of the ratios are very similar and the same holds for relational processes. Perhaps this holds for other process types but we still lack data for testing this hypothesis further.

The first pair of ratios, provided in the lowest row, compare the number of segments with *mental* feature to the sum of segments with any sub-type of *mental* feature (i.e. *cognition*, *perception*, *emotive*, etc.). This ratio measures how well the feature dependencies are preserved across delicacy levels. The second pair of ratios, provided in the last column, compares the number of segments provided by the parser to that available in the corpus for both the mental feature and the sum of its sub-types.

Table 10.14 shows that in the corpus the number of segments with the *mental* feature is almost one fourth higher than what the parser provides (72 %). This result means that probably not all the instances of a mental process have been detected by the parser (i.e. 28% undetected). The same comparison ran on the sub-types of

	Match	Corpus non-matched	Parser non-matched	Precision	Recall	F1
emoter	91	70	57	0.61	0.57	0.59
phenomenon	359	223	294	0.55	0.62	0.58
carrier	267	263	244	0.52	0.50	0.51
cognizant	82	84	104	0.44	0.49	0.47
agent	267	210	428	0.38	0.56	0.46
possessed	71	24	155	0.31	0.75	0.44
attribute	162	241	170	0.49	0.40	0.44
affected	93	70	663	0.12	0.57	0.20

Table 10.16 The evaluation statistics available for the PARTICIPANT-ROLE-TYPE system from the TRANSITIVITY system network

mental process shows diametrically opposite results, i.e. three quarters more parser results than in the corpus (172%) which is an indication of multiple false positives. A possible explanation is the correlation between increase in delicacy and uncertainty, i.e. the more delicate features are less precise in the parser results. As mentioned in the beginning of this section, uncertainty, in this case, is manifested as excessive production of process types represented in disjoint sets of possible options. Currently, no ranking mechanism is put in place that would suggest the best option from the candidate ones. Hence, the parser provides multiple feature selections from the same system (in this case MENTAL-TYPE) for a constituent, whereas there should be a single one. In the future this needs to be addressed by introducing a discrimination mechanism. It could, for instance, collect all the possible matches first and then only the most suitable to be assigned to the constituent unit, possibly by using frequencies available from a corpus annotations like OE or other sources.

If we look again at Table 10.14 and compare the number of all mental sub-type occurrences to the number of mental type occurrences, then we see that the ratio is quite low (63%). As the delicacy of the features increases fewer of these features are provided in the corpus. This is a direct manifestation of difficulty in annotating with ever more delicate features. This ratio, therefore, measures the degree of incompleteness at this level of delicacy. Comparing the same ratio for the parser generated segments we notice an opposite result (151%). This ratio represents a measurement of the noise (false positives) produced by the parser due to an increase in uncertainty resulting from advancing to a more delicate system in the network (as was already explained above).

So far we have discussed evaluation for the process types and now let's turn attention towards the feature assignments from the PARTICIPANT-ROLE-TYPE system. Table 10.16 presents the data considered for this evaluation along with the precision, recall and F_1 score for each participant role sorted according to F_1 score in descending order.

In this evaluation only the participant roles that appear at least 100 times in the corpus are considered. This restriction is inherited from Schulz (2015: 160-162) study on the OE corpus.

The evaluation results for considered set of participant roles is summarised in Table 10.17. The precision varies from 12% to 61% with an average of 43%, and the recall varies between 40% and 75% with an average of 56%. The data is characterised by lower precision and higher recall, which is directly reflected in the F_1 score averaging to 46%.

The distribution of precision, recall and F_1 scores can be seen in Figures 10.12 and 10.13. The noticeable feature is the peak of precision near the 0.5 mark and that of recall around 0.6. They translate into F_1 distribution as three groups: a small first group near the minimum pole, formed by the affected feature; a second tall tower at 45% accuracy formed by cognizant, agent, possessed and attribute features; and a third group around 55% accuracy on the right side of the graph formed by the emoter, phenomenon and carrier.

	Precision	Recall	F1
mean	0.43	0.56	0.46
standard deviation	0.16	0.10	0.12
min value	0.12	0.40	0.20
25% quantile	0.37	0.50	0.44
50% quantile	0.46	0.56	0.46
75% quantile	0.53	0.58	0.53
max value	0.61	0.75	0.59

Table 10.17 Descriptive statistics of the precision, recall and F1 scores for evaluated PARTICIPANT-ROLE features

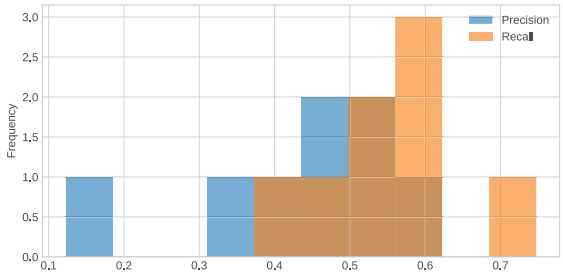


Fig. 10.12 The distribution of precision and recall for evaluated PARTICIPANT-ROLE features

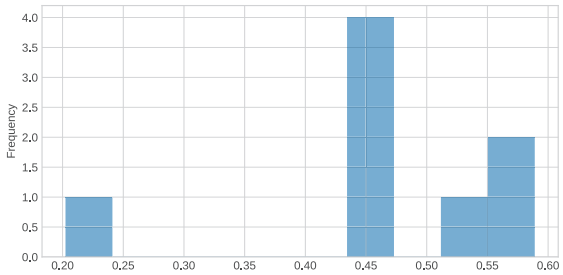


Fig. 10.13 The distribution of F1 score for evaluated PARTICIPANT-ROLE features

In Table 10.16 a suite of eight features have F_1 scores descending from almost 60% to 44%. The affected features follow with half of the previous (20%). As the accuracy decreases we can notice that few features display high recall especially in the case of the *affected* feature, which spiked to 600% the number of matched segments. This is a direct manifestation of the assignment of multiple roles to one participant by multiple graph patterns (for the reasons explained in the beginning of this section). This abnormally high number of participants produced by the parser must be addressed in future work starting with an investigation of the Transitivity graph patterns generated from the PTDB, in particular for the affected feature. The next section will conclude this evaluation chapter.

10.5 Summary

In this chapter we have discussed how the empirical evaluation of Parsimonious Vole parser has been conducted. The stage is set through a general presentation of the corpora and what the task at hand is, i.e. identifying and comparing segments available in the corpus annotations to those generated automatically by the parser. The accuracy is determined by the parser ability to generate identical or partially overlapping segments to those in the corpus.

Section 10.1 presented the OCD and OE corpora, which are employed in the current evaluation exercise. The OCD corpus is used for measuring the accuracy of the constituency structure produced by the parser and MOOD feature assignments to clause units. The OE corpus is used to evaluate TRANSITIVITY feature assignments to configuration and participant constituents. The parser output does not follow

entirely the annotation methodology used in annotation of the corpus, therefore there are a few differences to account for, which were explained in Section 10.1.3.

Section 10.2 explained how the current evaluation is performed. It starts by defining what is evaluated, i.e. labelled segments, then explains how corpus annotations and parser output are represented as sets of segments, and finally presents how these batches are compared to one another deriving from that parser accuracy measurements and how the measurement data is structured. The alignment algorithm, presented in the same section, takes into consideration not only the exact but also the partial matches.

The following two sections, 10.3 and 10.4, presented the evaluation data and discussed the findings. The evaluation of the segmentation task revealed that 71% of the segment have identical spans and that 83% of the segments are identical or shifted slightly (up to 5 characters). There are several ways to measure distance and among the tested ones the most significant were the geometric distance and the WindowDiff distance, while the other distances were omitted from the discussion because they strongly correlated to one of these two. The results showed that, the parser assigns classes to the constituent units with an accuracy of 74%; furthermore, clause main Mood elements are assigned with an accuracy of 71.2% while the Transitivity elements with an accuracy of 81%.

The current parser accuracy is similar to that reported by Souter (1996), i.e. 76% for the first six solutions. This score, however, means that the correct parse tree is found among the first six ones generated by the parser, which is a non practical approach.

O'Donoghue (1991a), using Vertical Strip Parsing, scored 81%, which is about 5% higher than that of the current parser. However his evaluation was based on a much narrower coverage of English than that found in the OE and OCD corpora because he used an extract from the COMMUNAL NL generator GENESYS PG 1.5 version.

When it comes to evaluating the accuracy of systemic assignments, the measured accuracy varies across delicacy levels and between sibling features within the same system, which was addressed for MOOD and especially for TRANSITIVITY in Section 10.4. The accuracy measurements are provided for a fraction of the MOOD system network and a fraction of TRANSITIVITY system network. This is based on their availability in the corpus annotations, which was described in Section 10.1. The features from the MOOD system network are assigned, on average, with an accuracy of 59%. The accuracy of TRANSITIVITY system network was measured for the PROCESS-TYPE system and the PARTICIPANT-ROLE-TYPE system separately. The accuracy of the former, on average, is 36% and the latter, on average, is 46%.

The present evaluation results are significant in at least two major respects. First, the parser overall accuracy is comparable to or slightly lower than the accuracy achieved by previous attempts of generating SFL constituency structures e.g. 76% by Souter (1996) and 81% by O'Donoghue (1991a). Moreover, the parser produces feature rich output which sets apart Parsimonious Vole from other parsers. The features in the produced output could be already considered useful in some practical situations where identifying in text Mood or Transitivity features is needed. Second, this study shows which areas are in need of improvement and provides some hints on what could be the reason for the poor performance. Also, this evaluation is the first one and constitutes the baseline for further incremental developments.

Even if it is a completely separate action, this evaluation can be useful for further corpus improvements as well. When I mention corpus improvement I bear in mind the OCD corpus in particular, which needs to be annotated by at least one more annotator and tested for reliability. In addition, the corpora size is fairly small and many systemic features are under-represented or missing completely as is the case, for example, of event-relating, environmental, action sub-types and other processes. It would be desperately necessary but quite unlikely to happen, as it is a practical resource issue (McEnery et al. 2006: 33), to extend the corpus annotation to include more delicate MOOD and TRANSITIVITY features. This would enable the study of how the features vary and how accurately the parser detects them.

The next chapter concludes the work done so far providing new ideas and setting a tone for what needs to be done in future work to improve the current results.

Chapter 11

Conclusions

This thesis aims at a reliable modular method for parsing English text with Systemic Functional Grammars. To achieve this goal I designed a pipeline, which, starting from a dependency parse of a sentence, generates a SFL-like constituency structure serving as a syntactic backbone, and then enriches that structure with various systemic features.

In this process, the first milestone is the creation of the constituency structure. Chapter 3 describes the essential theoretical foundations of two branches of SFL: the Sydney and Cardiff schools. It also provides a critical analysis in order to reconcile the diverging points on the rank scale, unit classes, the constituency structure, treatment of coordination, grammatical unit structure and clause boundaries; and states what is the adopted position on each point.

In order to create the constituency structure from the dependency structure there needs to be a mechanism in place to provide a mapping between the two both at the theoretical and grammatical levels. The theoretical account of the dependency grammar and how it is related to SFL was described in Chapter 5. The practical aspects of the process, such as the algorithms and the enactment of inter-grammatical mapping rules, were described in Chapter 8.

Before describing the parsing pipeline, to make clear what the basic ingredients of this implementation are and how the algorithms are coded, Chapter 7 introduced the basic data structures and operations. These structures were defined from a computer science point of view emulating the needed SFL concepts. The main structures are attribute-value dictionaries, ordered lists with logical operators and a few graph types. In addition, the basic operations relevant for the parsing pipeline such as conditional traversal and querying of nodes and edges, graph matching, pattern-based node selection, insertion and update were also described.

Once the constituency structure is created, the second milestone is to enrich it with systemic features. Because systemic features can be associated with or derived from the (dependency and constituency) graph fragments, in this work, graph pattern matching is a cornerstone operation used for adding features to constituent units and inserting new or missing constituents. These operations were described in detail in the second part of Chapter 7, and Chapter 9 outlined how these operations are used for the enrichment of the constituency backbone with systemic features.

The quality of graph patterns impacts directly on the outcome of the parser. The more precise the graph patterns are the smaller the false omission and miss rate in the parser output is, and thus the number of errors in general decreases while the accuracy of feature enrichment increases. This was shown in the evaluation result discussion in Chapter 10 in general, and in Section 10.4 in particular.

It is often the case for the TRANSITIVITY network that the graph patterns, in their canonical form, list the mandatory participants of a semantic configuration. In practice, however, instances of such configurations may leave unrealised up to two mandatory participants. And so, if applied in their canonical form the patterns will not identify such instances. In this thesis, mock constituents (null elements) are created in the places where the presumed constituents should be, allowing in this way matches with canonical graph patterns.

To identify and create the covert participants I turned to Government and Binding theory, which accounts for this. In doing so, this thesis brings two more contributions: (a) the theoretical mapping from GBT into dependency structures covered in Chapter 6 and (b) a concrete implementation of how to perform creation of the null elements described in Chapter 6.3.

In Chapter 10 was described the empirical evaluation. The aim of the assessment, in general, was to determine how accurately the text analysis is generated; and, in particular, how well the parser performs at unit boundary detection (i.e text segmentation), unit class assignment, element assignment and feature selections.

The data show that the parser assigns classes to the constituent units with an accuracy of 74% and clause main Mood elements were detected with an accuracy of 71.2%, while the Transitivity elements were detected with an accuracy of 81%.

When it comes to evaluating the accuracy of systemic assignments, the measured accuracy varies drastically across delicacy levels and between the sibling features within the same system. This has been addressed for the MOOD and TRANSITIVITY systems in Section 10.4. The features from the MOOD system network were assigned, on average, with an accuracy of 59%. The accuracy of the TRANSITIVITY system network was

measured separately for the PROCESS-TYPE system and the PARTICIPANT-ROLE-TYPE system. The accuracy of the former, on average, is 36% and of the latter, on average, is 46%.

Next I present how the main research questions were addressed and what the main contributions of this thesis have been.

11.1 Research questions and main findings

In Chapter 1 six research questions were asked. This section shows how those research questions are addressed in the current thesis and what the theoretical and practical outcomes are.

One of the main theoretical contributions of this thesis is the investigation to what degree cross-theoretical bridges can be established between SFL and other theories of grammar, formulated as Research question 1. The approach to answering this broad question was to further ask more specific questions. In particular I have focused on studying correspondences to Dependency Grammar and Government and Binding Theory, formulated in Research questions 2 and 3.

First, Research question 2 on the degree to which the syntactic structure of the Dependency and that of Systemic Functional Grammar are compatible to undergo a transformation from one into another was fully addressed in this thesis showing that they are compatible and that the goal of transforming from one into the other is feasible. The support for this claim is provided in Section 5.6, which addresses in detail the cross-theoretical links between the Dependency and the Systemic Functional theory of grammar. This cross-theoretical bridge constitutes a fundamental principle for further deriving transformation rules from a dependency representation into a systemic functional one. Such rules are enacted, in the parsing pipeline, to create the systemic constituency structure as laid out in Section 8.3.

Second, Research question 3 about the usability of GBT for detecting places of null elements in the context of SFL constituency structure was explored in depth with positive results. This is addressed in Section 6.3, where rules, principles and generalisations from GB theory are translated into DG and SFG frameworks. These translations serve directly the goal of identifying places where (and by which relations) the null elements should be injected. The translated rules are realised in the form of graph patterns explained in detail in Section 9.3.

Addressing Research questions 2 and 3 and establishing cross-theoretical bridges to DG and GBT constitute answers for Research question 1. The conducted theoretical

investigation accompanied by the practical implementation and the evaluation results show that aiming at reuse, in SFL contexts, of positive results from other areas of computational linguistics constitutes not only a desirable but also a feasible goal. This, however, does not guarantee in practice maximal accuracy and the extent to which the goal is achieved depends to a large extent on the implementation.

As another contribution, this thesis offers an investigation on how suitable graph patterns are in detecting systemic features and enriching the constituency structure. In the current approach to parsing, graph patterns play a similar role as the realisation rules play in the process of natural language generation with SFG. They serve as a language for systematising grammatical realisations, and constitute a convenient form of representing grammatical features employing both structural and lexico-structural patterns. Graph patterns and the matching methods developed in this thesis can potentially be applied for expressing many other grammatical features than the ones presented here such as the remaining more delicate MOOD and TRANSITIVITY features, those covered in the THEME or and other system networks.

Research question 5 on the extent to which graph patterns can be used to represent systemic features based solely on structural aspects was addressed in Section 9.1 (focused MOOD system network). It is shown that some of the least delicate systems can be dealt with only by structural patterns, however, as delicacy increases, the inclusion of lexis into the graph patterns is inevitable. Moreover, for TRANSITIVITY features, escaping the lexis is not possible at all, and constitutes the main reason for employing a lexical-semantic resource such as PTDB. This only confirms the already known strong link between grammar and lexis, which SFL considers a unitary lexico-grammar (defined in Section 3.1).

In the end, Research question 6 on whether the PTDB is suitable as a lexical-semantic resource for Transitivity parsing was addressed in Chapters 9 and 10. I explained how graph patterns can be generated automatically from PTDB before describing how it was turned into a machine readable resource. Nonetheless, the evaluation of the currently implemented method to assign Transitivity features does not provide encouraging results, reaching only 42% accuracy (10% less that for Mood features). These performance indicators are explained in Section 10.4.2, and further discussed in Section 10.5. This level of accuracy, among others, is due to the currently implemented enrichment mechanism, which applies all the matching graph patterns to the constituency structure instead of applying the one with highest probability. This means that higher accuracy can be achieved provided that the implemented approach is improved by reducing the number of patterns per feature. The degree to which the

accuracy will improve if the enrichment mechanism is enhanced remains a question for future work.

Finally, the evaluation results presented in Chapter10 are significant in at least two major respects. First, the parser accuracy of generating SFL constituency structures is comparable to or slightly lower than the accuracy achieved by previous attempts, e.g. 76% by Souter (1996) and 81% by O'Donoghue (1991a). However, the parser generates feature rich output which sets apart Parsimonious Vole from other parsers. The features in the generated output could be already considered useful in some practical situations where identifying in text Mood or Transitivity features is needed. Second, this study shows which areas are in need of improvement and provides hints on what can be improved. Also, this evaluation can be considered an initial baseline for incremental development in future work.

11.2 Limitations and future work

This work has a number of limitations. This section introduces the most important ones along with improvements that are desirable or worth considering.

Parsimonious Vole parser grammar

The grammar proposed in Chapter 4 is a combination of elements taken from both the Cardiff and the Sydney grammars. Even if the chosen grammar parts have been carefully motivated, explained and argued for as a whole, how well they fit together still requires scrutiny by grammarians and a validation with larger corpora.

The graph patterns were manually created, which is error prone and requires careful validation. This work can be supported and facilitated by a workbench editor, debugger and validator for graph patterns and systemic features combined. The workbench could build on top of and extend the UAM Corpus tool with these new functionalities. As no editor for grammatical graph patterns exists yet, developing one in the future is desirable.

Graph patterns from Nigel grammar

One important experience this thesis provides is the use of graph patterns for detecting systemic features, based on structural and lexical cues in the provided constituency structures. For the parser implementation, all of the MOOD patterns were created

manually while the TRANSITIVITY patterns were created from a simple lexical-semantic database, the Process Type Database (Neale 2002).

At the same time, the Nigel grammar (Matthiessen 1995), the largest existing SFL grammar (Bateman 2008: 27), was not employed in this work even if it is very relevant. In part this is due to the reasons explained in Chapter 2, i.e. the previous attempts to parse with full SFL grammars directly had to accept certain limitations. In future work, however, investigating how graph patterns can be generated from the system network realisation rules available in Nigel will be very valuable and highly desirable work. Not only can it save time and reduce potential errors of the manual authoring of graph patterns, but it can provide a very rich set of graph patterns covering system networks outside the scope of this work.

Adoption of verbal group

The current grammar does not include the verbal group unit but treats the elements of what would be a verbal unit as elements of the clause. This decision is motivated in Section 4.1.1 and is in line with the Nigel grammar and with the proposal put forward by the Cardiff grammar. This resolves the problem of discontinuity in the syntactic units which was an issue for the current implementation.

(127) Are you feeling cold?

A simple example of a discontinuity is provided in Example 127. The verbal group here is formed of the Auxiliary "are" and the Main verb "feeling". In principle, in the syntactic analysis, the units of analysis should be continuous. This is known to not always be the case as illustrated by Example 127 where the subject "you" splits the verbal group in two.

Adopting a gap resilient constituency structure would permit inclusion into the generated analysis not only of verbal groups but also enable Thematic analysis, which often employs discontinuous units, and the adoption of other unit classes.

Transition to semantically motivated unit classes

Cardiff unit classes are semantically motivated when compared to the more syntactic ones in the Sydney grammar. This is stated in Fawcett (2000: 193–194) and was briefly presented in Section 3.3 and further discussed in Section 4.1.

For example, the nominal structure proposed in the Cardiff grammar (discussed in Section 4.1.3), uses elements that are more semantic in nature than the syntactic and functionally motivated ones offered in the Sydney grammar. For example compare

various types of determiners: representational, quantifying, typic and partitive, in the Cardiff grammar and only the deictic determiner in the Sydney grammar where the distinctions by types are provided in systemic features rather than distinct unit classes.

In order to shift towards semantically motivated nominal unit structure two problems need to be addressed: (a) how to detect semantic heads and (b) how to craft (if none exists) a lexical-semantic resource to support detection of various determiners in the nominal group. Building lexical-semantic resources asked at point (b) represents a potential solution for point (a) as well. Employing some of the existing resources such as the Nigel grammar, because it is built in Sydney style, could and most likely be a suitable starting point for addressing point (b). In addition, other non-SFL lexical resources such as WordNet (Miller 1995) or FrameNet (Baker et al. 1998) could be considered in this context. Yet resorting to these lexical resources would not be a straightforward solution and would require more adaptations so that they are useful in the SFL domain.

The same holds for Adverbial and Adjectival groups (Section 4.1.4), which in the Cardiff grammar are split into Quality and Quantity groups. Existent lexical resources such as WordNet (Miller 1995) or FrameNet(Baker et al. 1998) combined with the delicate classification proposed by Tucker (1997) may yield positive results in parsing with Cardiff unit classes. Just as in the case of verb groups discussed in the previous sections, moving towards semantically motivated unit classes would greatly benefit applications requiring deeper natural language understanding. However, this will likely come at the cost of making the parsing much harder and thus a trade-off might be needed.

More delicate TRANSITIVITY graph patterns

The PTDB (Neale 2002) is the first and only lexical-semantic resource for the Cardiff Transitivity metafunction. In its original form, this resource was not machine readable, with its usability limited to dictionary-like search by linguists in the process of manual text analysis. It was rich in human understandable comments and remarks across all fields and so not fully formal enough to be employed in computational tasks. In the scope of the current work the PTDB has been cleaned and brought into a machine readable form.

In mainstream computational linguistics, there are several lexical-semantic resources used for Semantic Role Labelling (a task similar to Transitivity parsing), such as FrameNet (Baker et al. 1998) and VerbNet (Kipper et al. 2008). Mapping or combining

PTDB with these resources into a new one would yield benefits for both: potentially inspiring the internal organisation for VerbNet and extending the coverage of PTDB.

Combining PTDB with VerbNet for example, would be my first choice in the task of improving Transitivity analysis for the following reasons. PTDB is well semantically systematised according to the Cardiff Transitivity system, however, it lacks any links to syntactic manifestations. VerbNet, on the other hand, contains an excellent mapping to the syntactic patterns in which each verb occurs, each with associated semantic representations of participant roles and some first order logic representation. Also, the lexical coverage of VerbNet is twice as wide as than that of PTDB.

Resorting to resources like FrameNet or WordNet could bring other benefits. For example, FrameNet has a set of annotated examples for every frame which, after transformation into the Transitivity system, could be used as a training corpus for machine learning algorithms.

Towards speech function analysis

As Robin Fawcett explains (Fawcett 2011), Halliday's approach to Mood analysis differs from that of Transitivity in the way that the former is not "pushed forward towards semantics" as the latter is. This claim, however, is controversial and not endorsed by the Sydney grammarians. The meaning proposed by Fawcett in the Cardiff MOOD system network is similar to and incorporates concepts from Speech Act Theory (Austin 1975) or its later advancements (Searle 1969). Such theories, in mainstream linguistics, are placed under the umbrella of pragmatics (which Sydney grammarians reject). Operating with concepts such as speech acts, called in SFL *speech functions* (Hasan 1984), would take the interpersonal text analysis to a new level of meaning with potential benefits in applications where interactivity is a feature of primary concern.

Halliday proposes a simple system of speech functions (Halliday & Matthiessen 2013b: 136) (considered as part of semantics and outside grammar) which Fawcett develops into a quite delicate system network (Fawcett 2011). It is worth exploring ways to implement Fawcett's latest developments especially that the two are not conflicting but complementing each other. In future work it can be explored how to use the Hallidayan MOOD system as a foundation to transit towards the Cardiff MOOD system (a merger of semantic and grammatical systems). Such exploration can be facilitated by the fact that Sydney MOOD system network has already been implemented and described in the current work.

Adoption of group complexing

The group complexing structures are well described in the Sydney grammar (Halliday & Matthiessen 2013b: 567–592). Such structures are not considered in the current work except for the particular case of conjunction treatment, which is described in Section 3.4.6. Adopting a general framework of unit complexing is highly beneficial as it contributes to a more meaningful analysis. The immediate applications of group complexing, in the context of this thesis, can be seen in the case of verbal group complexes presented next.

The *one main verb per clause* principle of the Cardiff school that I adopted in this thesis (briefly discussed in Section 4.1.1) provides a basis for simple and reliable syntactic structures. Also, it represents a simple clause boundary detection rule. The alternative is adopting the concept of verbal group, simple and complex, as proposed by the Sydney school in Halliday & Matthiessen (2013b: 396–418, 567–592), a much richer and complex approach. The verb complex provides a richer semantically motivated description (Halliday & Matthiessen 2013b: 567–592), however, analysing text with such constructs is difficult and subject to ambiguities.

Ants	*keep*	*biting*	*me*
Subject	Finite	Predicator	complement
Actor	Process: Material		Goal/Medium
	Verbal group complex expansion, elaborative, time-phase, durative $\alpha \longrightarrow = \beta$		

Table 11.1 Sydney sample analysis of a clause with a *verbal group complex*

Ants	*keep*	-	*biting*	*me*
Subject	Finite/Main Verb	Complement		
Agent	Process: Influential	Phenomena		
		Subject (null)	Main Verb	Complement
		Agent	Process: Action	Affected

Table 11.2 Cardiff sample analysis of a clause *embedded* into another

One way to approach this is in two steps (similarly to semantic head detection discussed in Section 3.4.5): first, generating the syntactic analysis and then enriching it to a more meaningful analysis. Even though an approach in two steps such as the one suggested here is subject to criticism, in part, it can already be implemented

by considering Cardiff influential process types (implemented as part of Transitivity parsing).

Consider the sample analyses in Tables 11.1 and 11.2. The two-clause analysis proposed by the Cardiff school can be quite intuitively transformed into a single experiential structure with the top clause expressing a set of aspectual features of the process in the lower (embedded) clause just like the Sydney analysis in Table 11.1.

The class of *influential* processes proposed in the Cardiff transitivity system was introduced to handle expressions of process aspects through other lexical verbs. I consider it as a class of pseudo-processes with a set of well defined and useful syntactic functions but with incomplete semantic descriptions. The analysis with influential process could be used as an intermediary step towards a more meaningful analysis, such as the one suggested by the Sydney grammar. Alternatively, the analysis process could be redesigned to generate complex verbal units directly taking into account the available lexical-syntactic resources. This rule of thumb is described in Generalisation 11.2.1.

Generalisation 11.2.1 (Merging influential clauses)**.** When the top clause has an influential process and the lower (embedded) one has any of the other processes, then the two clauses can be merged into one and the two verbs into a verb complex enriched with aspectual features.

Of course, this raises a set of problems that are worth investigating. First, the connections and mappings between the influential process system network described in the Cardiff grammar and the system of verbal group complex described in the Sydney grammar (Halliday & Matthiessen 2013b: 589) should be investigated. Second, one should investigate how this merger impacts the syntactic structure.

The benefits of such a merger lead to an increased comprehensiveness, not only of the Transitivity analysis, illustrated by the examples in Tables 11.1 and 11.2, but potentially apply to the modal assessment illustrated by Examples 128 and 129 and similar phenomena.

(128) *I think* I've been pushed forward; *I don't really know*, (Halliday & Matthiessen 2013b: 183)

(129) *I believe* Sheridan once said you would've made an excellent pope. (Halliday & Matthiessen 2013b: 182)

Taxis analysis

In the Sydney grammar, the logico-semantic relations employed to describe inter-clausal relations are called taxis relations (Definition 3.2.14). Currently, the Parsimonious Vole parser implements a simple taxis analysis technique based on graph pattern matching, similar to the one described in Sections 7.4 and 7.5. Description of this work, however, is not included in this thesis because it has not yet been tested.

A database of clause taxis patterns, represented as regular expressions, is listed in Appendix D. It has been developed according to a systematisation in IFG 3 (Halliday & Matthiessen 2004). Each relation type has a set of patterns ascribed to it which represent clause order and presence or absence of explicit lexical markers or clause features.

In the taxis analysis process, each pair of adjacent clauses in the sentence is tested for compliance with TAXIS pattern in the database. The matches (there may be multiple ones for a single system feature) represent potential manifestations of the corresponding relation with no way to distinguish at the moment which pattern is, in fact, more likely to be correct. A similar problem was described for the TRANSITIVITY system and a potential solution was also described in terms of a discrimination mechanism in Section 10.4.2. More work, however, needs to be conducted in this area.

Dealing with covert elements and ellipsis

In the current approach to Transitivity parsing, accounting for the covert (or the so-called null) elements was taken as an instrumental goal to increase accuracy of parsing. Whether such elements should be accounted for in the grammar or whether they exist at all is still under debate in the linguistic literature, and, of course, arguments exist for and against the null elements.

One future development would be to change the way graph patterns are generated from PTDB. The resulting graph patterns would need to be shaped such that the null elements are no longer a requirement for Transitivity parsing. This would, among other things, eliminate the need to create null element units in the constituency structure and would make the cross-theoretical links to GBT obsolete in this task.

I need to make, however, a reference here to *ellipsis*, a well studied linguistic phenomenon. An elliptical construction is the omission from a clause of one or more words that are nevertheless understood in the context of the remaining elements. There is a variety of ellipsis types, among which are the null elements mentioned above. Whether to fill the gaps in the syntactic structure and which ones is a question that

should not be abandoned too soon as providing rich and explicit structures can have positive outcomes in practical contexts.

Bridges to other grammars and linguistic theories

In this thesis exploration of cross-theoretical bridges is limited to two other traditions: that of Dependency grammars (specifically Stanford Dependency Grammar) and that of Phrase-Structure Grammars (specifically Government and Binding Theory). There is a wider set of useful cross-theoretical correspondences to establish that can materialise as positive reuse outcomes.

Due to compatible approaches to language analysis and because some work has already been done in this direction, among the most interesting correspondences would be Lexical Functional Grammars (Bresnan et al. 2015), Head-Driven Phrase Structure (Pollard & Sag 1994), Combinatory Categorial Grammar (Steedman 1993, 2000) and Tree Adjoining Grammars (Kroch & Joshi 1985), to name just a few. LFG has a functional layer in many respects similar to the functional layer of a (Nigel-style) SFG. Correspondences from TAG to SFG were already addressed by Yang et al. (1991) and in the last section of Bateman (2008) in order to address among others the gap in the syntagmatic representation. Bateman & Teich (1991) explored the possibility to adopt some aspects of HPSG for unit complexing. Having traced these new correspondences it will become possible to create the constituency backbone in the SFL style in a similar fashion as it is currently done from the Dependency Grammar.

The current implementation also requires an immediate upgrade to the latest version of the Stanford parser. Between 2006 and 2015 the Stanford parser (Marneffe et al. 2006) was employing the Stanford dependency model for English (and a few other languages). Afterwards, in 2016, Nivre et al. (2016) proposed the language independent Universal Dependency scheme which was integrated into the Stanford Parser and replaced the Stanford dependency model. Around 2015–2016 the Parsimonious Vole parser was developed based on the Stanford dependency model. No transition to universal dependency was considered at that time because it was not mature or stable enough. For this reason the current thesis employs the legacy Stanford grammar and so a transition to universal dependency model must be considered in future work, in order to keep up the pace with the latest developments in the Stanford dependency parser.

Efficient graph rewriting method

In the current work the SFL style constituency backbone is created from dependency graphs. This is treated in computer science as *graph/tree rewriting*. There is extensive literature addressing this task such as Barendregt et al. (1987), Courcelle (1990), Plasmeijer et al. (1993) and Grzegorz (1999).

As at the time of developing the Parsimonious Vole parser I was exploring the precise properties necessary for transforming from the dependency into systemic functional constituency structures. Now that they are known, a more specific graph rewriting method can be considered. And so in the prototype implementation no pre-existing algorithm has been used. Future work needs to integrate the state of the art methods in graph rewriting and potentially improve or replace the current graph rewriting algorithm. Such a decision would need to be based on the efficiency and ease of providing the transformation rules.

Execution order of graph patterns

For a given constituency structure the current enrichment mechanism fires all the available graph patterns and any of the matching ones enrich the constituency structure. This can be costly when the number of patterns increases dramatically. Such a risk is imminent if, for example, the graph patterns are generated from the Nigel grammar as mentioned above. That richness poses the danger that too many graph patterns will make the parsing if not uncomputable, then at least too slow to be practical.

This risk can be countered, to an extent, by putting in place a selection mechanism that would seek to minimise the number of fired graph patterns for a given constituent unit. Such a mechanism needs to implement a search mechanism in the space of features covered by the graph patterns taking into account the systemic dependency between features and, therefore, between patterns. Moreover, a fitness function measuring information gain per graph and execution cost must be considered. Such a mechanism may already speed up the current implementation to an extent.

Dealing with multiple patterns per systemic feature

In the current implementation for each process type configuration in PTDB multiple patterns graphs were generated. This is one of the leading causes of decreased TRANSITIVITY parsing accuracy as was described in Section 10.4.2.

To prevent features from the same system from being assigned to constituent units simultaneously (even if clearly marked as a disjunctive set of possibilities) a

discrimination mechanism should be implemented. Such a mechanism collects all the possible pattern matches first, and then assigns only the most suitable one to the constituent unit. This mechanism can be based on calculated probabilities or frequency in a corpus. More investigations are needed on these issues.

Analysis of errors from the current evaluation

The evaluation performed in the current work does not go into detail analysing the types of errors the parser commits. In order to improve the performance of the current implementation the known errors need to be investigated down to the level of transformation rules, graph pattern and systemic feature disjunctions. Therefore, it is essential to carry on further investigation of segmentation errors (e.g. distance distribution for each feature) and errors in the constituency structure (false positives in the parser generated analysis and true negatives in the corpus). Results of a deeper error analysis will give information concerning how to correct the transformation rules from the dependency into SF constituency structures. Similar benefits can be achieved by investigating the errors in the systemic feature assignments.

Investigation of probabilistic logics for SFG parsing

The problems of computational complexity in parsing with SFGs is explained in Chapter 1 and treated at length in Bateman (2008). At the heart of this problem lies the combinatorial explosion caused by the complex network of disjunctive systems. One way to deal with large combinatorial spaces is by using search approximations. For logical systems such an approximation is materialised in the form of probabilistic logics.

Martin Kay was the first to attempt formalisation of systemic functional syntagmatic structures that would become known as Functional Unification Grammar (FUG) (Kay 1985). This formalisation was adopted in other linguistic frameworks such as HPSG and Lexical Functional Grammars. For SFGs, however, using first order or even description logic reasoners has been shown to have severe complexity problems (Bateman 2008). Employing probabilistic logics, therefore, may offer a further way of overcoming that complexity issue.

Markov Logic (Domingos et al. 2010; Richardson & Domingos 2006) draws my attention in particular, which I consider a good candidate for parsing with SFGs. It is a probabilistic logic, which applies ideas of Markov networks to first order logic enabling inference under uncertainty. What is very interesting about this logic is that tools implementing it have learning capabilities not only of formulas weights but also of new

logical clauses. Moreover, it has been shown to be computationally feasible on large knowledge bases. The extent of such clauses should, however, still be investigated.

Markov logics can be employed, in the context of the current work, for addressing the graph pattern creation problem. Besides creating the graph patterns manually or from existing resources such as PTDB or advanced grammars such as Nigel, another possibility worth exploring is learning them from a corpus.

Markov Logic tools, such as Alchemy[1], Tuffy[2] and others, also have machine learning capabilities. Since graph patterns can be expressed via first order functions and individuals, and assuming that a (richly) annotated corpus in SFL style is available, these tools could be employed in an experiment to inductively learn pattern structures (and features) from the corpus. The results of such an exercise are useful to validate or challenge the patterns implemented in the parser, or even discover new patterns.

This suggestion resembles the Vertical Strips (VS) of O'Donoghue (1991b). The similarity is the probabilistic learning of patterns from a corpus. The difference is that VS patterns are syntactic segment chains from the root node down to tree leafs while with machine learning more complex patterns can be learned independently of their position in the syntactic tree.

11.3 Practical applications

A wide variety of tasks in natural language processing, such as document classification, topic detection, sentiment analysis, word sense disambiguation, do not need parsing. These are tasks that can achieve high performance and accuracy with no linguistic features or with shallow syntactic information such as lemmas or parts of speech by using powerful statistical or machine learning techniques. What these tasks have in common is that they generally train on a large corpus and then operate again on large input text to finally yield a prediction for a single feature or set of features that they have been trained for. Consider for example the existing methods for sentiment analysis: they often provide a value between -1 and 1 estimating the sentiment polarity for a text that can be anything from one word to a whole page.

Conversely, there are tasks where extracting from texts (usually short) as much knowledge as possible is crucial for the success of the task. Consider a dialogue system, where deep understanding is essential for a meaningful, engaging and close to natural interaction with a human subject. It is no longer enough to assign a few shallow

[1] http://alchemy.cs.washington.edu/
[2] http://i.stanford.edu/hazy/hazy/tuffy/

features to the input text, but a deep understanding is required for planning a proper response. Or consider the case of information extraction or relationship mining tasks, when knowledge is extracted at the sub-sentential level. In these scenarios the deeper linguistic understanding possible the better.

A parser of the type aimed at in this thesis would be useful to solve the latter set of tasks. The rich constituency parses could be an essential ingredient for further tasks such as anaphora resolution, clausal taxis analysis, rhetoric relation parsing, speech act detection, discourse model generation, knowledge extraction. All these tasks are needed for creating an intelligent interactive agent for various domains such as call centres, ticketing agencies, intelligent cars and houses, personal companions or assistants.

In marketing research, understanding the clients needs is one of the primary tasks. Mining intelligence from the unstructured data sources such as forums, customer reviews and social media posts is a particularly difficult task. In these cases the more features are available in the analysis the better. Employing parsers that offer deep feature rich outputs such as Parsimonious Vole satisfies this need. With the help of statistical methods feature correlations, predictive models and interpretations can be conveyed for the potential task at hand such as satisfaction level, requirement or complaint discovery.

11.4 Final word

In this work I have advanced the work on automatic text analysis in SFL style. The current implementation did not succeed to employ a full SF grammar, and, just like previous attempts, had to accept limitations in the grammar size while maintaining broad language coverage. This task is particularly difficult because of the richness of such grammars. Nonetheless, modern applications desperately need deep feature-rich text analysis functionalities.

My view is that building on top of successful results achieved with other grammars by mapping them to parts of SF grammar constitutes a viable solution to the creation of SFL style constituency structures. Furthermore, employing graph patterns to enrich the structure with systemic features is the key ingredient for performing a delicate feature-rich text analysis.

By further advancing the proposed methods and exploring new ways to cut through complexity, my hope is that one day automatically generating feature-rich text analysis will become the *de facto* approach employed in truly intelligent agents that can, to a large extent, do with language what people do.

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Appendix A

SFL Syntactic Overview

A.1 Cardiff Syntax

Elements found in all groups: Linker (&), Inferer (I), Starter (st), Ender (e)
Units: Sentence (Σ), Clause (Cl), Nominal Group (ngp), Prepositional Group (pgp), Quality Group (qlgp), Quantity Group (qtgp), Genitive Cluster (gencl)

A.1.1 Clause

Relative Order of Elements in the Unit Structure:
& |B |L |F |A |C |O |S |O |N |A |I |X |M |Mex |C |A |V |E
Clause May fill: Σ (85%), C (7%), A (4%), Q (2%), f (0.5%), s, qtf, S, m, cv, po
Elements of the Clause: Adjunct (A), Binder (B), Complement (C), Formulaic Element (F), Infinitive Element (I), Let Element (L),Main Verb (M), Main Verb Extension (Mex), Negator (N), Operator (O), Subject (S), Vocative (V), Auxiliary Verb (A), X extension (Xex), Linker (&), Starter (St), Ender(E)

A.1.2 Nominal Group

Possible Relative Order of Elements in the Unit Structure:
& |rd |v |pd |v |qd |v |sd |v |od |v |td |v |dd |m |h |q |e
Filling probabilities of the ngp: S (45%), C (32%), cv (15%), A (3%), m (2%), Mex, V, rd, pd, fd, qd, td, q, dt, po
Elements of the ngp: Representational determiner (rd), Selector (v), Partitive Determiner (pd), Fractionative Determiner (fd), Quantifying Determiner (qd), Superlative

Determiner (sd), Ordinative Determiner (od), Qualifier-Introducing Determiner (qid), Typic Determiner (td), Deictic Determiner (dd), Modifier (m), Head (h), Qualifier (q)

A.1.3 Prepositional Group

Possible Relative Order of Elements in the Unit Structure:
& |pt |p |cv |p |e
Filling Probabilities of the pgp: C (55%), a (30%), q (12%), s (2%) Mex, S, cv, f, qtf
Elements of the pgp: Preposition (p), Prepositional Temperer (pt), Completive (c)

A.1.4 Quality Group

Possible Relative Order of Elements in the Unit Structure:
& |qld |qlq |et |dt |at |a |dt |s |f |s |e
Filling probabilities of the qgp: c (38%), m (36%), A (24%), sd (0.5%), Mex, Xex, od, q, dt, at, p, S
Elements of the qlgp: Quality Group Deictic (qld), Quality Group Quantifier (qlq), Emphasizing Temperer (et), Degree Temperer (dt), Adjunctival Temperer (at), Apex (a), Scope (s), Finisher (f)

A.1.5 Quantity Group

Possible Relative Order of Elements in the Unit Structure:
ad |am |qtf |e **Filling probabilities of the qtgp:** qd (85%), A (8%), dt (6%), B, p, ad, fd, sd **Elements of the qtgp** Adjustor (ad), Amount (am), Quantity Finisher (qf)

A.1.6 Genitive Cluster

Possible Relative Order of Elements in the Unit Structure:
& |po |g |o |e
Filling probabilities of the gencl: dd (99%), h, m, qld
Elements of the gencl: Possessor (po), Genitive Element (g), Own Element (o)

A.2 Sydney Syntax

A.2.1 Logical

Possible Relative Order of Elements in the Unit Structure:
Pre-Modifier |Head |Post-Modifier

A.2.2 Textual

Possible Relative Order of Elements in the Clause Structure:
Theme |Rheme
New |Given |New

A.2.3 Interactional

Possible Relative Order of Elements in the Clause Structure:
Residue |Mood |Residue |Mood tag
Adjunct |Complement |Finite |Subject |Finite |Adjunct |Predicator |Complement| Adjunct

A.2.4 Experiential

Possible Relative Order of Elements in the Clause Structure:
Circumstance |Participant |Circumstance |Process| Participant |Circumstance
Possible Relative Order of Elements in the Nominal Group Structure:
Deictic |Numerative |Epithet | Classifier| Thing |Qualifier
Possible Relative Order of Elements in the Verbal Group Structure:
Finite |Marker |Auxiliary |Event
Possible Relative Order of Elements in the Adverbial and Preposition Group Structure: Modifier |Head |Post-Modifier
Possible Relative Order of Elements in the Prepositional Phrase Structure:
Predicator |Complement
Process |Range

A.2.5 Taxis

Possible Relative Order of Elements in the Parataxis Structure:
Initiating |Continuing
Possible Relative Order of Elements in the Hypoataxis Structure:
Dependent |Dominant |Dependent

Appendix B

Stanford Dependency schema

The Stanford dependency relations as defined in Stanford typed dependencies manual (Marneffe & Manning 2008a)

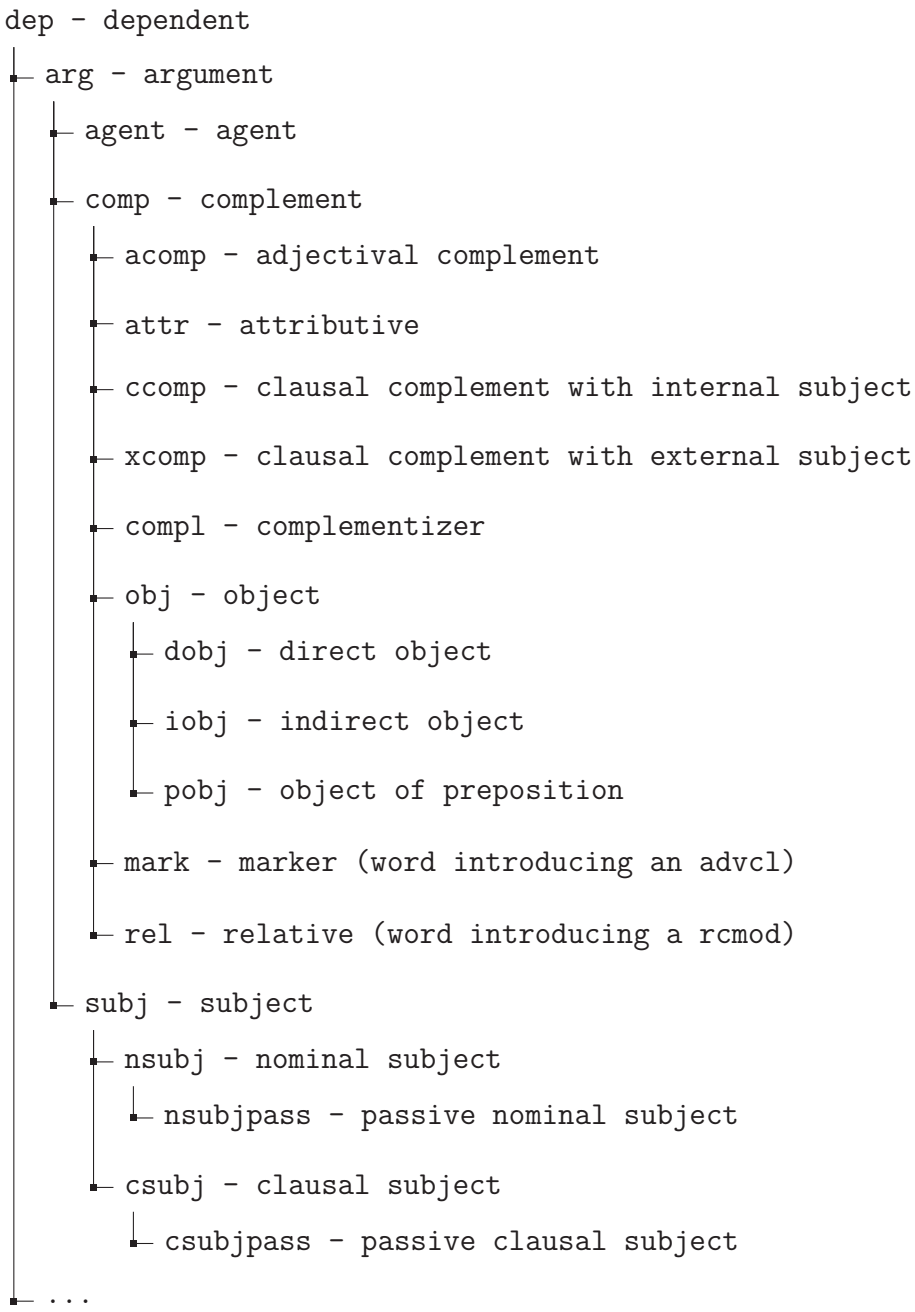


Fig. B.1 The Stanford dependency scheme - part one

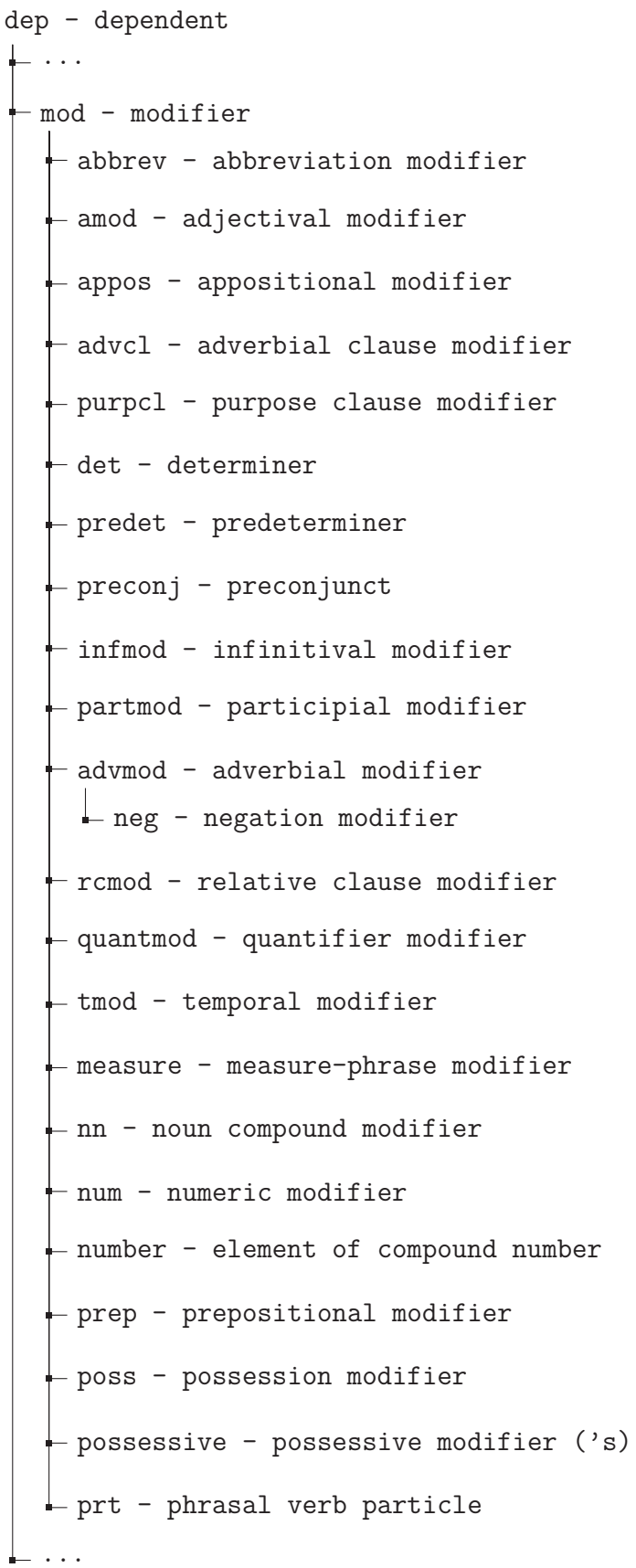


Fig. B.2 The Stanford dependency scheme - part two

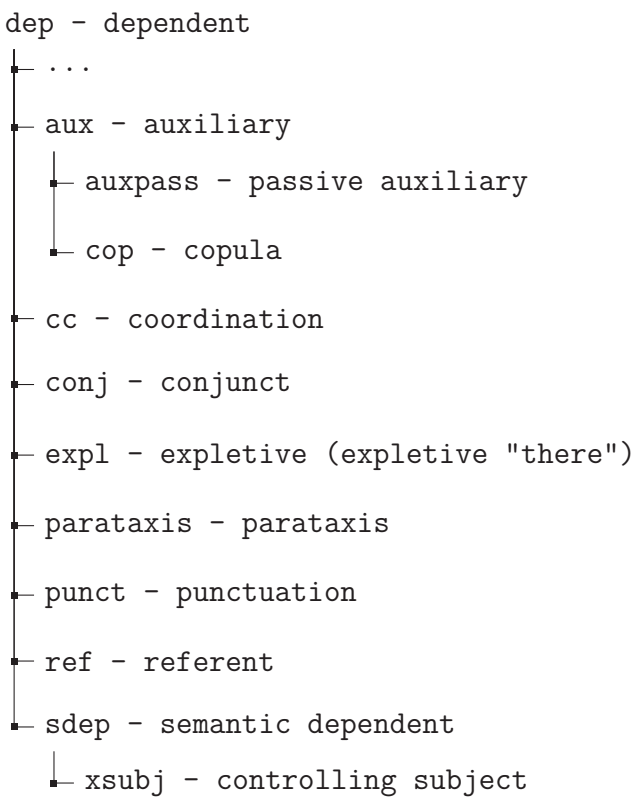


Fig. B.3 The Stanford dependency scheme - part three

Appendix C

Penn treebank tag-set

Tag	Description	Example
CC	conjunction, coordinating	and, or, but
CD	cardinal number	five, three, 13%
DT	determiner	the, a, these
EX	existential there	there were six boys
FW	foreign word	mais
IN	conjunction, subordinating or preposition	of, on, before, unless
JJ	adjective	nice, easy
JJR	adjective, comparative	nicer, easier
JJS	adjective, superlative	nicest, easiest
LS	list item marker	
MD	verb, modal auxillary	may, should
NN	noun, singular or mass	tiger, chair, laughter
NNS	noun, plural	tigers, chairs, insects
NNP	noun, proper singular	Germany, God, Alice
NNPS	noun, proper plural	we met two Christmases ago
PDT	predeterminer	both his children
POS	possessive ending	's
PRP	pronoun, personal	me, you, it
PRP$	pronoun, possessive	my, your, our
RB	adverb	extremely, loudly, hard
RBR	adverb, comparative	better
RBS	adverb, superlative	best
RP	adverb, particle	about, off, up
SYM	symbol	%
TO	infinitival to	what to do?
UH	interjection	oh, oops, gosh
VB	verb, base form	think
VBZ	verb, 3rd person singular present	she thinks
VBP	verb, non-3rd person singular present	I think
VBD	verb, past tense	they thought
VBN	verb, past participle	a sunken ship
VBG	verb, gerund or present participle	thinking is fun
WDT	wh-determiner	which, whatever, whichever
WP	wh-pronoun, personal	what, who, whom
WP$	wh-pronoun, possessive	whose, whosever
WRB	wh-adverb	where, when
.	punctuation mark, sentence closer	.;?*
,	punctuation mark, comma	,
:	punctuation mark, colon	:
(	contextual separator, left paren	(
)	contextual separator, right paren	)

Table C.1 Penn Treebank tag set

Appendix D

Rules for clause complex taxis analysis

Below are presented a set of templates capturing taxis analysis which were derived based on descriptions in IFG3 (Halliday & Matthiessen 2004) and examples provided there.

The tables shall be interpreted as follows. First three two columns represent choices in the taxis system network. The third column represents an informal meaning of the choices. Forth column contains an open set of markers that may signal the tactic relation. Last column contains a set of formal patterns in which the taxis relation can be realised.

The syntax for decoding patterns is as follows:

- *@1* means the first clause (for paratactic relations) or higher clause (for hypotactic relations);
- *@2* means the second clause (for paratactic relations) or lower clause (for hypotactic relations);
- *mrkr* stands for any of the markers listed in the fourth column;
- *//* represents delimiter between multiple patterns;
- punctuation marks *, ;* - in the pattern stand for punctuation marks in the sentence;
- round brackets *()* mean that the element is optional, so it may occur but it may as well be absent;

- text in quotes *“”* just like punctuation marks is the text that occurs in the sentence;
- square brackets *[]* immediately after clause symbols mean presence (+) of absence (-) of a *feature* (e.g. +negative means the feature negative must be selected among the clause features) or of a *clause element* (e.g. -Subject means that the clause must not have an element which functions as Subject)

Type	Category	Meaning	Paratactic markers	Paratactic template
Elaboration	Exposition	in other words, I.e	or, or rather, in other words, that is to say, I mean, i.e.,	@1 (,) (mrkr) @2 // @1 ; @2 // @1 , @2 // @1 - @2 //
Elaboration	Exemplification	for example, e.g.	for example, for instance, in particular, e.g.	@1 (,) (mrkr) @2 // @1 ; @2 // @1 , @2 // @1 - @2 //
Elaboration	Clarification	to be precise, viz.	in fact, actually, indeed, at least, i.e., viz.,	@1 (,) (mrkr) @2 // @1 ; @2 // @1 , @2 // @1 - @2 //
Extension	additive:positive	X and Y	and, but also, too, in addition, also, moreover, on the other hand, and that	@1 mrkr @2 // "not only" @1 "but also" @2 // "both" @1 "and" @2 //
Extension	additive:negative	not X and not Y	nor, too, in addition, also, moreover, on the other hand	@1 mrkr @2 // ("neither") @1 "nor" @2 //
Extension	additive:adversative	(but) X and conversely Y	too, in addition, also, moreover, on the other hand, but	@1 (,) mrkr @2 //
Extension	variation:replacive	(instead), not X but Y	but not, not ? but, instead, but instead, on the contrary	@1[+negative] mrkr @2[+positive] // @1[+positive] mrkr @2[+negative] //
Extension	variation:substractive	X but not all X	only, except, but	@1 (,) (mrkr) @2 //
Extension	alternation	X or Y	or, conversely, alternatively, on the other hand	"either" @1 "or" ("else") @2 // @1 (,) mrkr @2 //
Enhancement	temporal: same time	A meanwhile B	and meanwhile, when, and, meanwhile, and at that time,	@1 (,) mrkr @2 //
Enhancement	temporal: later time	a subsequently b	and then, then, and afterwards, afterwards, and soon afterwards, soon afterwards	@1 (,) mrkr @2 //
Enhancement	temporal: earlier time	a previously b	and before that, but before that, and first, but first, and till then, and until then,	@1 (,) mrkr @2 //
Enhancement	spatial: same place	c there d	and there	@1 (,) mrkr @2 //
Enhancement	manner: quality	A in the way B		
Enhancement	manner: means	N is via/by means of M	and in that way, thus, and thus, whereby	@1 (,) mrkr @2 //
Enhancement	manner: comparison	N is like M	and similarly, and so, thus, as if	@1 (,) mrkr @2 //
Enhancement	cause: reason@1	because P so effect Q	and, so, and so, and therefore, therefore	@1 (,) mrkr @2 //
Enhancement	cause: reason@2	effect Q because of cause P	for, because	@1 (,) mrkr @2 //
Enhancement	cause: purpose	because intention Q so action P		@1 (,) mrkr @2 //
Enhancement	cause: result			@1 (,) mrkr @2 //
Enhancement	condition: positive	if P then Q	and then, then, and in that case	@1 (,) mrkr @2 //
Enhancement	condition: negative	if not p then q	or else, or otherwise, otherwise	@1 (,) mrkr @2 //
Enhancement	condition: concessive	if p then contrary to expectations Q	but, yet, and yet, still, but nevertheless, though, however, nevertheless	@1 (,) mrkr @2 // @1 (;) mrkr @2

Table D.1 Parataxis

Type	Category	Meaning	Hypotactic-finite marker	Hypotactic-finite template
Elaboration	Exposition	in other words, I.e		
Elaboration	Exemplification	for example, e.g.		
Elaboration	Clarification	to be precise, viz.	who, whose, whom, which, that, where, when , as	@a (,)(-)(;) mrkr @b // @a mrkr @b //
Extension	additive:positive	X and Y	whereas, while	mrkr @b , @a // @a mrkr @b
Extension	additive:negative	not X and not Y		
Extension	additive:adversative	(but) X and conversely Y	whereas, while	mrkr @b , @a // @a mrkr @b
Extension	variation:replacive	(instead), not X but Y		
Extension	variation:substractive	X but not all X	except that, but for the fact that, but that,	@a (,) mrkr @b // mrkr @b , @a //
Extension	alternation	X or Y		"if" @a{[]+negative{]} (,)("then") @b //
Enhancement	temporal: same time	A meanwhile B	as, while, when, as soon as, the moment, whenever, every time, but as soon as	@a (,)mrkr @b // mrkr @b (,) @a //
Enhancement	temporal: later time	a subsequently b	after, since, ever since, especially since, and since, and after, then	@a (,)mrkr @b // mrkr @b (,) @a //
Enhancement	temporal: earlier time	a previously b	before, until, till, by the time	@a (,)mrkr @b // mrkr @b (,) @a //
Enhancement	spatial: same place	c there d	as far as, where, wherever, everywhere	@a (,) mrkr @b // mrkr @b , @a //
Enhancement	manner: quality	A in the way B	as	@a (,) mrkr @b // mrkr @b , @a //
Enhancement	manner: means	N is via/by means of M	@a (,) mrkr @b // mrkr @b , @a //	
Enhancement	manner: comparison	N is like M	as, as if, like, the way	@a (,) mrkr @b // mrkr @b , @a //
Enhancement	cause: reason@1	because P so effect Q		
Enhancement	cause: reason@2	effect Q because of cause P	because, as, since, in case, seeing that, considering	@a (,) mrkr @b
Enhancement	cause: purpose	because intention Q so action P	in order that, so that	@a (,) mrkr @b
Enhancement	cause: result	so that		@a (,) mrkr @b
Enhancement	condition: positive	if P then Q	if, provided that, as long as, but if, in case	mrkr @b (,) ("then") @a // @a (,) mrkr @b //
Enhancement	condition: negative	if not p then q	unless	@a (,) mrkr @b
Enhancement	condition: concessive	if p then contrary to expectations Q	even if, even though, although, though	mrkr @b (,) @a // @a (,) mrkr @b

Table D.2 Hypotaxis with lower finite clauses

Type	Category	Meaning	Hypo-non-finite marker	Hypo-non-finite template
Elaboration	Exposition	in other words, I.e		
Elaboration	Exemplification	for example, e.g.		
Elaboration	Clarification	to be precise, viz.		@a , @b[-Subj] // @a @b[-Subj] // @a , @b // @a @b // @b, @a //
Extension	additive:positive	X and Y	apart from, besides, with	@a (,) (mrkr) @b// mrkr @b (,) @a// @a , @b //
Extension	additive:negative	not X and not Y		
Extension	additive:adversative	(but) X and conversely Y	without	@a (,) (mrkr) @b// mrkr @b (,) @a// @a ,@b //
Extension	variation:replacive	(instead), not X but Y	instead of	@a (,) (mrkr) @b// mrkr @b (,) @a//
Extension	variation:substractive	X but not all X	other than	@a (,) (mrkr) @b// mrkr @b (,) @a//
Extension	alternation	X or Y		
Enhancement	temporal: same time	A meanwhile B		@a , @b // @b , @a
Enhancement	temporal: later time	a subsequently b		
Enhancement	temporal: earlier time	a previously b		
Enhancement	spatial: same place	c there d		
Enhancement	manner: quality	A in the way B		
Enhancement	manner: means	N is via/by means of M		
Enhancement	manner: comparison	N is like M		
Enhancement	cause: reason@1	because P so effect Q		@a , @b // @b , @a
Enhancement	cause: reason@2	effect Q because of cause P		
Enhancement	cause: purpose	because intention Q so action P		@a , @b // @b , @a
Enhancement	cause: result			@a , @b
Enhancement	condition: positive	if P then Q		
Enhancement	condition: negative	if not p then q		
Enhancement	condition: concessive	if p then contrary to expectations Q		

Table D.3 Hypotaxis with lower non-finite clauses

Type	Category	Meaning	Hypo-non-finite conjunction marker	Hypo-non-finite conjunction template
Elaboration	Exposition	in other words, I.e		
Elaboration	Exemplification	for example, e.g.		
Elaboration	Clarification	to be precise, viz.		
Extension	additive:positive	X and Y		
Extension	additive:negative	not X and not Y		
Extension	additive:adversative	(but) X and conversely Y		
Extension	variation:replacive	(instead), not X but Y		
Extension	variation:substractive	X but not all X		
Extension	alternation	X or Y		
Enhancement	temporal: same time	A meanwhile B	while, when	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	temporal: later time	a subsequently b	since	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	temporal: earlier time	a previously b	until, till	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	spatial: same place	c there d		
Enhancement	manner: quality	A in the way B		
Enhancement	manner: means	N is via/by means of M		
Enhancement	manner: comparison	N is like M	like	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	cause: reason@1	because P so effect Q		
Enhancement	cause: reason@2	effect Q because of cause P		
Enhancement	cause: purpose	because intention Q so action P		
Enhancement	cause: result			
Enhancement	condition: positive	if P then Q	if	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	condition: negative	if not p then q	unless	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	condition: concessive	if p then contrary to expectations Q	even if, even though, though, although	@a (,) mrkr @b // mrkr @b (,) @a

Table D.4 Hypotaxis with lower non finite clause introduced by subordinating conjunction

Type	Category	Meaning	Hypo-non-finite preposition marker	Hypo-non-finite preposition template
Elaboration	Exposition	in other words, I.e		
Elaboration	Exemplification	for example, e.g.		
Elaboration	Clarification	to be precise, viz.		
Extension	additive:positive	X and Y		
Extension	additive:negative	not X and not Y		
Extension	additive:adversative	(but) X and conversely Y		
Extension	variation:replacive	(instead), not X but Y		
Extension	variation:substractive	X but not all X		
Extension	alternation	X or Y		
Enhancement	temporal: same time	A meanwhile B	in, in the course, in process of, on	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	temporal: later time	a subsequently b	after	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	temporal: earlier time	a previously b	before	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	spatial: same place	c there d		
Enhancement	manner: quality	A in the way B		
Enhancement	manner: means	N is via/by means of M	by, by means of	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	manner: comparison	N is like M		
Enhancement	cause: reason@1	because P so effect Q		
Enhancement	cause: reason@2	effect Q because of cause P	with, through, by, at, as a result, because of, in case of, in case	@a (,) mrkr @b
Enhancement	cause: purpose	because intention Q so action P	in order to, so as to, for, for the sake of, with the aim of, for fear of	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	cause: result	to		@a (,) mrkr @b
Enhancement	condition: positive	if P then Q	in the event of	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	condition: negative	if not p then q	but for, without	@a (,) mrkr @b // mrkr @b (,) @a
Enhancement	condition: concessive	if p then contrary to expectations Q	despite, in spite of, without	@a (,) mrkr @b // mrkr @b (,) @a

Table D.5 Hypotaxis with lower non finite clause introduced by a preposition

Appendix E

Mapping dependency to constituency graph

key	***operation***	***parameter***
acomp	new constituent	COMPLEMENT
advcl	new constituent	ADJUNCT
advmod	extend current	None
amod	new constituent	EPITHET_CLASSIFIER_OR_ORDINAL
agent	new constituent	COMPLEMENT_AGENT
appos	new constituent	APPOSITION
aux	extend current	None
auxpass	extend current	None
complm	new constituent	MARKER
conj	extend current	None
csubj	new constituent	SUBJECT
csubjpass	new constituent	SUBJECT
det	new constituent	DEICTIC
dobj	new constituent	COMPLEMENT
expl	new constituent	EXPLETIVE_MARKER
infmod	new constituent	QUALIFIER
iobj	new constituent	COMPLEMENT_DATIVE
mark	new constituent	MARKER
mwe	extend current	None
neg	extend current	None
nn	extend current	None
npadvmod	new constituent	ADJUNCT
nsubj	new constituent	SUBJECT
nsubjpass	new constituent	SUBJECT
num	new constituent	CARDINAL_NUMERATIVE
number	extend current	None
parataxis	new constituent	CLAUSE
partmod	new constituent	QUALIFIER
vmod	new constituent	QUALIFIER
pobj	extend current	None
poss	new constituent	POSESSOR
possessive	new constituent	POSESSOR
preconj	extend current	None
predet	new constituent	PREDEICTIC
prepc	new constituent	COMPLEMENT_ADJUNCT
prt	new constituent	MARKER
punct	extend current	None
purpcl	new constituent	CLAUSE
quantmod	extend current	None
rcmod	new constituent	QUALIFIER
ref	extend current	None
rel	new constituent	CLAUSE
tmod	new constituent	ADJUNCT
xcomp	new constituent	COMPLEMENT
xsubj	new constituent	SUBJECT
discourse	new constituent	DISCOURSE
goeswith	extend current	None

Table E.1 The rule table mapping generic dependency context to generative operations

Key	***Operation***	***Value***
JJ-dep-IN	new constituent	MARKER
VB-dep-IN	new constituent	MARKER
VB-dep-VB	new constituent	CLAUSE
NN-dep-NN	extend current	None
NN-dep-VB	new constituent	CLAUSE
VB-dep-WP	new constituent	COMPLEMENT_ADJUNCT
VB-dep-NN	new constituent	ADJUNCT
RB-dep-IN	extend current	None
WR-dep-JJ	extend current	None
VB-dep-JJ	new constituent	ADJUNCT
VB-conj-VB	new constituent	CLAUSE
VB-cc-CC	new constituent	MARKER
NN-cc-CC	extend current	None
VB-prep-NN	new constituent	COMPLEMENT_ADJUNCT
VB-prep-JJ	new constituent	COMPLEMENT_ADJUNCT
VB-prep-PR	new constituent	COMPLEMENT_ADJUNCT
VB-prep-WP	new constituent	COMPLEMENT_ADJUNCT
VB-prep-CD	new constituent	COMPLEMENT_ADJUNCT
NN-prep-NN	new constituent	QUALIFIER
NN-prep-PR	new constituent	QUALIFIER
RB-npadvmod-NN	extend current	None
NN-npadvmod-NN	extend current	None
VB-npadvmod-NN	new constituent	ADJUNCT
JJ-npadvmod-RB	extend current	None
VB-advmod-RB	new constituent	ADJUNCT
VB-advmod-JJ	new constituent	ADJUNCT
VB-advmod-WR	new constituent	COMPLEMENT
NN-advmod-RB	new constituent	PREDEICTIC
VB-ccomp-NN	new constituent	COMPLEMENT
VB-ccomp-VB	new constituent	COMPLEMENT
IN-pcomp-IN	new constituent	COMPLEMENT_ADJUNCT
IN-pcomp-NN	new constituent	COMPLEMENT_ADJUNCT
IN-pcomp-CD	new constituent	COMPLEMENT_ADJUNCT
IN-pcomp-JJ	new constituent	COMPLEMENT_ADJUNCT
NN-amod-CD	new constituent	CARDINAL_NUMERATIVE
NN-infmod-VB	new constituent	QUALIFIER
CD-prep-NN	new constituent	QUALIFIER
NN-vmod-VB	new constituent	QUALIFIER
NN-prep-JJ	new constituent	QUALIFIER
DT-prep-NN	new constituent	QUALIFIER
JJ-prep-NN	extend current	None

Table E.2 The rule table mapping specific dependency context to generative operations

Appendix F

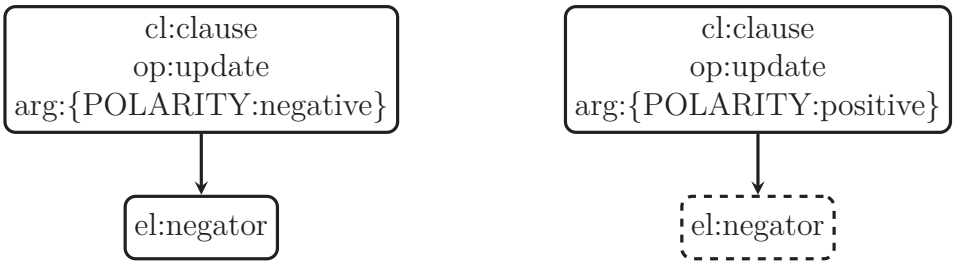
Normalization of PTDB and Cardiff TRANSITIVITY system

The process type column in PTDB contains two words separated by comma. The first one I call *major* as it represents a high level selection in the TRANSITIVITY system and the second one I call *minor* hints at selecting a particular participant configuration. The re-indexing consists of replacing the two features with a more delicate selection in the TRANSITIVITY system.

major	*minor*	*new index*	*min # roles*	*max # roles*
action	one role	one-role-action	1	1
	two role	two-role-action	2	2
	three role	three-role-action	3	3
relational	attributive	attributive	2	3
	locational	locational	2	3
	directional	directional	2	5
	possessive	possessive	2	3
	matching	matching	2	3
emotion	desiderative	desiderative	2	2
	plux xxx	emotive	2	3
perception	xxx	two-role-perception	2	2
	3 p Ag	three-role-perception	3	3
cognition	xxx	two-role-cognition	2	2
	3 p Ag/ matchee	three-role-cognition	3	3
environmental		environmental	x	x
influential	starting	starting	1	2
	continuing	continuing	1	2
	ceasing	ceasing	1	2
	succeeding	succeeding	1	2
	failing	failing	1	2
	causative	causative	1	2
	permissive	permissive	1	2
	enabling	enabling	1	2
	preventing	preventing	1	2
	delaying	delaying	1	2
	tentative	tentative	1	2

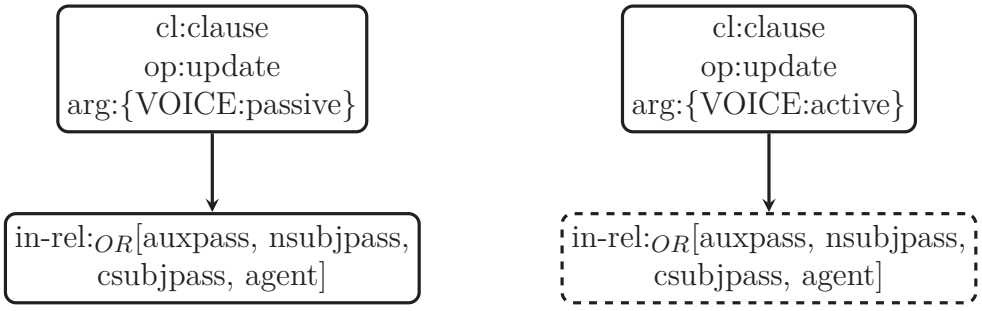
Appendix G

A selection of graph patterns



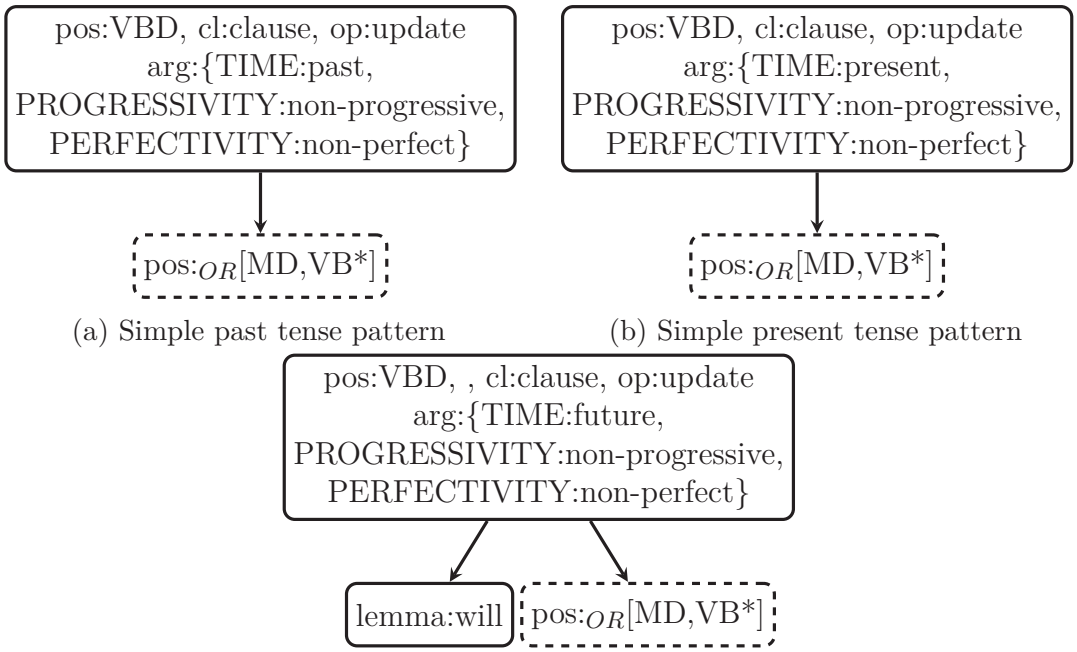
(a) Negative polarity (b) Negative polarity

Fig. G.1 Polarity detection graph patterns



(a) Passive voice (b) Active voice

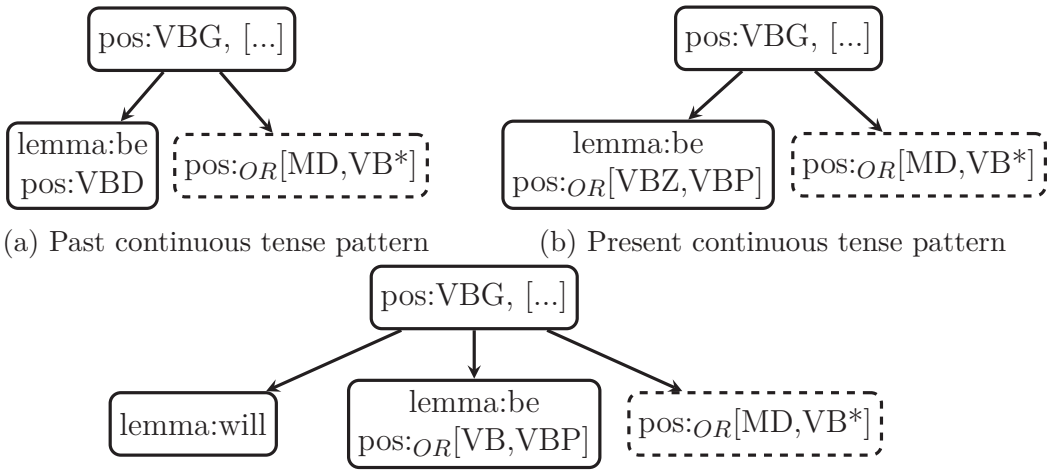
Fig. G.2 Voice detection graph patterns



(a) Simple past tense pattern (b) Simple present tense pattern

(c) Simple future tense pattern

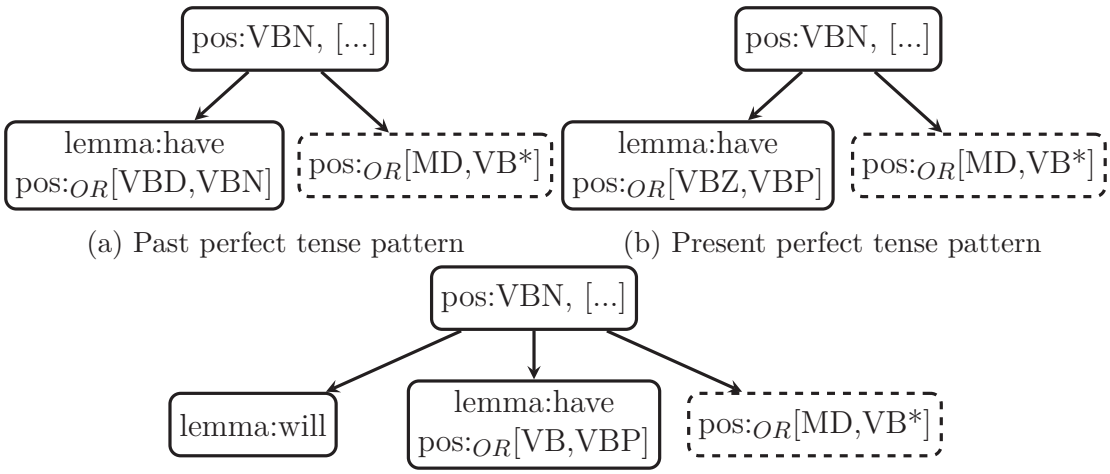
Fig. G.3 Simple past, present and future tense patterns



(a) Past continuous tense pattern (b) Present continuous tense pattern

(c) Future continuous tense pattern

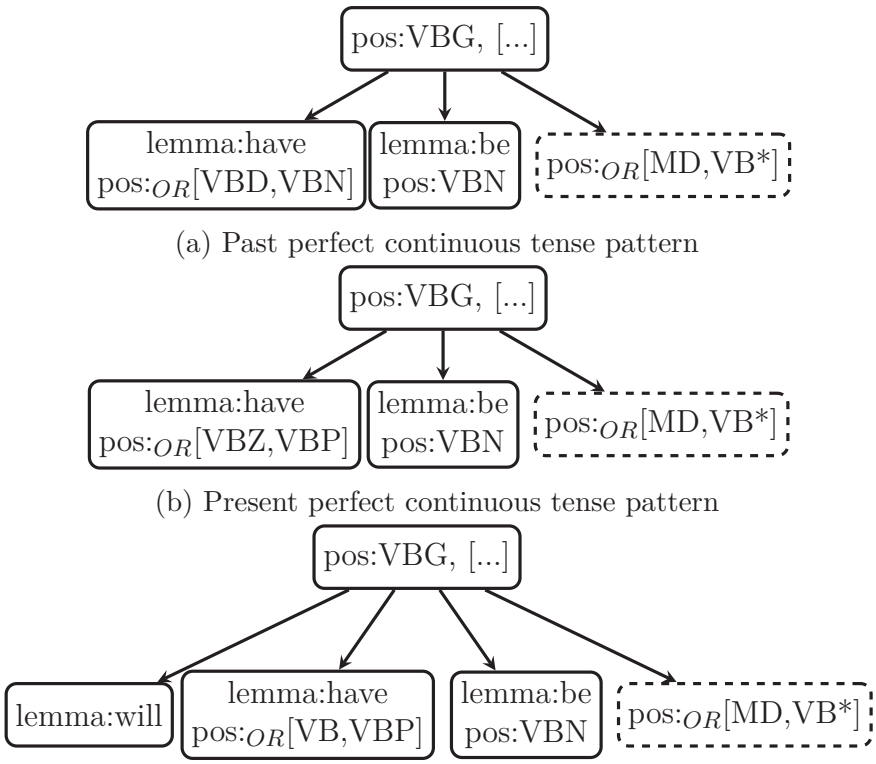
Fig. G.4 Past, present and future continuous tense patterns



(a) Past perfect tense pattern (b) Present perfect tense pattern

(c) Future perfect tense pattern

Fig. G.5 Past, present and future perfect tense patterns



(a) Past perfect continuous tense pattern

(b) Present perfect continuous tense pattern

(c) Future perfect continuous pattern

Fig. G.6 Past, present and future perfect continuous tense patterns

Appendix H

Auxiliary algorithms

The Algorithm 19 and 20 below are part of the Algorithm 12 for creating the Wh null elements.

Algorithm 19: Creating the Adjunct (circumstantial) Wh-traces

```
   input  : wh-group, dg, cg
1  begin
2      check the tense and modality for all the clauses
3      for clause in cg: from the clause of wh-group to lowest
           /* create the adjunct trace in the first clause that has non
              present simple tense                                    */
4          if clause tense is not present simple:
5              create Adjunct Wh-trace for Wh-group
6              return
7  end
```

Algorithm 20: Creating the Theta (participant) Wh-traces

```
   input  : wh-group, dg, cg
 1 begin
 2     get possible configurations for each clause from the PTDB
       /* check if the higher clause is a projection and and has an
          extra argument                                          */
 3     for config in higher clause configurations:
 4         if (config is two role cognition and config takes expletive subject) or
            (config is three role cognition and clause is passive voice):
 5             higher is eligible ← True
 6             break
       /* check if the lower clauses might miss an argument       */
 7     for clause in lower clauses:
 8         for config in clause configurations:
 9             if number of clause theta constituents < number of config arguments:
10                 lower is eligible ← True
11                 break
12     if higher is eligible and lower is eligible:
13         if higher clause has "that" complementizer:
14             create Object Wh-trace in the lowest clause
15         else:
16             if Wh-group has case:
17                 if Wh-group case is nominative(subjective):
18                     create Subject Wh-trace in lowest clause
19                 else:
20                     create Object Wh-trace in lowest clause
21             else:
22                 create Wh-trace with Subject function and attempt to assign theta
                    roles
23                 if theta roles not successfully assigned in lower clause:
24                     change the Wh-trace to Object function and assign theta roles
25 end
```

Appendix I

Annotation guidelines for OCD corpus

I.1 Constituency

The constituency annotation is based on the Cardiff grammar (Fawcett 2008) with some consulting of the traditional grammar (Quirk et al. 1985) for clarification; while MOOD systemic selections are based on the Sydney grammar (Halliday & Matthiessen 2013b). Below follows a set of short descriptions aimed at helping annotators identify main unit types and clause elements.

Clause – the main processing unit onto which meanings of different kinds are mapped and integrated into.

- the punctuation (.?!) at the end of the sentence(the matrix clause) shall be left outside the segment
- in clause complexes, the punctuation(,;“”-), conjunctions(and, or , but . . .) and other nexus markers(if, or,) shall be left outside the segment.

Finite – a part of the verbal group expressing the tense or modality. It either precedes the Predicator or is conflated with it in present and past simple tenses.

- If the finite is conflated with the predicate do not mark it
- The finite is the first auxiliary verb in the verb group before the subject in declarative clauses and the auxiliary that precedes the subject in interrogative clauses.

Subject – the nominal group or a nominal clause that precedes the Predicator in a clause and it is something by reference to which the proposition can be affirmed or denied. The subject is the nearest nominal group or clause that precedes the predicator.

Predicator – the part of verbal group minus the finite constituent when they are not conflated. It specifies additional temporal and aspectual relations, voice and the process type (e.g. action, relation, mental process etc.) that is predicated about the Subject. To enforce the syntactic and functional analysis proposed in the Cardiff analysis methodology (Fawcett 2008), the complex clauses need to be separated into individual clauses so that each comply with the "one main verb per clause" principle (see below). The predicator is the entire verb group(main verb + auxiliaries) minus the first auxiliary(which is the finite element)

Complement – the part of the clause that follows the Predicator and has the potential of becoming a Subject, i.e. it can become an axis of the argument. Usually it is a nominal group and rarely a prepositional phrase.

- The nominal group, prepositional group or clause that follows the Predicator
- exception are the copulative clauses (when the main verb is "to be"), then the adjectives following the verb receive complement function because they receive participant role of attribute (which is a quality)
- prepositions that can introduce complements are enumerated in table 1
- most clauses have 0 - 2 complements, exception are directional processes that can have 0-4 complements

Adjunct – do not have the potential of becoming a Subject; therefore arguments cannot be constructed around adjunct elements. They are realized by adverbial and prepositional groups.

- Prepositional phrases after the clause complements
- adverbs preceding and following the predicator
- Adjuncts can occur in front of the subject, then the clause becomes thematically marked.
- We do not annotate circumstantial adjuncts (bearing experiential information) but ONLY comment adjuncts (serving an interpersonal modification function in modality or appraisal). For more details see Schulz (2015) guidelines.

Markers – prepositions, conjunctions, expletives and verb particles. We do not annotate them. [Looking back at this rule I don't know what was behind this decision back in 2013].

Group – a set of words executing a particular function in a clause. The head of the group dictates the group type and the other words in the group may have other parts of speech and contribute to specifying enriching and further specifying the meaning of the group.

- note: we do not make distinction between a simple group and a group complex
- prepositional group is a nominal group preceded by a preposition

I.2 Clause partition

Follow the "One main verb per clause" rule. Use the semantic analisys to guide the sentence clause division into clauses.

When the clauses are connected by a conjunction and have their own subject/objects then the conjunction is the clause border marker.

(130) The lion chased the tourist but she escaped alive.

(131) The lion[Ag-Ca] chased[Pr] the tourist[Af-Pos]

(132) she[Ag] escaped[Pr] alive[Ra].

When the predicators are conjoined and share subject and/or objects then each predicator will form a new clause and borrow the subject/objects from the other clause.

(133) The lion chased and caught the tourist.

(134) the lion[Ag-Ca] chased[Pr] the tourist[Af-Pos]

(135) the lion[Ag-Ca] caught[Pr] the tourist[Af-Pos]

In the case of mental(e.g. know, think, feel, want, like), influential(e.g. start, stop, try, continue, fail) and event relating (e.g. cause) processes the predicates are often complex. Verbs in these classes are known as control and raising verbs (Haegeman 1991a) where a super-ordinate controls subordinate non-finite verb and binds its participants (Subject/Complement).

In order to comply with "one main verb per clause" principle, each Main Verb of the complex clause becomes a governor of a distinct clause. The subordinate verb with all of its dependent nodes is assigned to a place-holder. The super-ordinate verb

receives the place-holder as Complement with the role of Phenomena. If the subject is missing in the subordinate clause then it is copied from the super-ordinate one.

(136) The lion wanted/began to chase the tourist.

(137) the lion[Cog] wanted/began[Pr] X[Phen]

(138) X= the lion[Ag-Ca] to chase[Pr] the tourist[Af-Pos]

The meaning of complex clause decomposition can be expressed with an equivalent rephrasing by inserting "something that is" between the Main Verbs, as in example below.

(139) The lion wanted/began something that is to chase the tourist.

I.3 The tricky case of prepositional phrases

There are cases in mood analysis when deciding the unit type is impossible by relying solely on syntactic analysis (including typed dependency analysis). Prominent cases are the prepositional phrases. These can fill both a Complement and an Adjunct role. For mood analysis this implies that the same syntactic unit can fill a Complement and an Adjunct, while for transitivity analysis, it implies that the same syntactic unit can fill a Participant or a Circumstance.

(140) John goes home through London.

(141) John is building a house for Bob.

(142) Her teardrop shines like a diamond.

(143) John is building a house for ten years now.

(144) John goes to London by fast train.

In examples 140 and 141 the prepositional phrases "through London"1 and "for Bob" are Complements and Participants (Path and Beneficiary roles) while in the latter examples "like a diamond", "for ten years now" and "by fast train" are Adjuncts and Circumstances (of comparison, temporal duration and manner-means).

I.4 Making selection from the MOOD system network

Here is a brief description how to make selections in the MOOD system network. Agency is of primary concern in this work. The rest of the features are annotated as much as the time permits.

Agency is a clause level feature and is attributed depending on the experiential analysis of the clause (be it via Transitive or Ergative model). It expresses whether there is an active participant that brings about the unfolding of the process. Is the process brought about from within or from outside? With regards to this an important distinction to be made is between doings and happenings. The probing for doings is usually by asking the questions "What did X do (to Y)?" If there is a suitable X then we say that clause has an effective voice. Now effective voice can be (a) operative (that corresponds to active voice in mood analysis) and thus realised with an agent (doer) as subject or (b) receptive (that corresponds to passive voice in mood analysis) and thus goal/medium or beneficiary takes the subject place while the agent is given a secondary role. It can be either overt i.e. agentive (a prepositional phrase complement marked in English via "by" preposition) or covert i.e. non-agentive (unspecified).

Many intransitive verbs (with only one participant) are better analysed from Ergative perspective. In this case no external participant is implied to actuate the process and they are realised with a Medium subject. The best question to probe such clauses is by asking "What happened?". If this probing is more suitable than the one for doing the the clause receives middle selection in the agency system. The middle configurations do not have a active or passive voices thus voice can be used as a probing method (Halliday & Matthiessen 2013b: 336-354).

Modality should be annotated as described in Schulz (2015).

Remaining MOOD features should be annotated as described in (Halliday & Matthiessen 2013b).