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Syntactic and semantic aspects of natural language processing

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To Liviu, Dan and Maria
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2. Abstract

This work is organized in three main parts. The common topic of these parts is the linguistic notion of discourse, i.e. multi-sentential text uttered in a natural language (as opposed to isolated sentences). Specifically, this thesis is concerned with the semantics of discourse and related phenomena such as anaphora (i.e. an instance of an expression referring to another one, usually located in preceding utterances), quantification, coherence etc. The first part provides an explicit formal account of discourse semantics, starting from Barker & Shan’s (2008) sentence-level semantics based on continuations; the second part of this thesis presents the work on creating and analyzing electronic resources for Romanian language: a Romanian Generative Lexicon and a corpus for the study of differential object marking in Romanian; finally, the third part comprises two experiments of classification by coherence/incoherence criterion of short English and Romanian texts, respectively, using machine learning techniques.

The first part of this thesis puts forward an explicit formal account of discourse semantics in terms of the computer-science notion of continuations. The starting point of this research was Barker & Shan’s (2008) sentence-level continuation semantics. We shifted from sentence level to discourse level (Dinu (2011.a)). A discourse is interpreted in a sequential manner from left to right by interpreting the sentences one at a time. At any moment of this process, some initial segment of the text is already processed, being part of the context in which the current sentence is uttered (the context usually also contains, for instance, common knowledge). No sentence of a text is interpreted in a vacuum; it is always interpreted in a context to which previous sentences have contributed. These were the main observations that lead to the development of the so-called dynamic semantics that formalizes the way in which quantifiers in one formula bind variables in another to achieve cross-sentential binding. Among the most well known dynamic semantics are Dynamic Intensional Logic (DIL), Dynamic Montague Grammar (DMG), Dynamic Predicate Logic (DPL) and Discourse Representation Theory (DRT).

Our original contribution here is the formalization in terms of continuations of the intuitive idea that sentence separators (such as dot or semicolon) semantically operate in discourse as functions that take the denotation of the left discourse (previously uttered sequence of sentences) and the denotation of the current sentence and return the denotation of the newly formed discourse obtained through the conjunction of the old discourse with the new sentence. Formally, we gave to the dot the following interpretation (Dinu, 2011.a):

\[
S/S \rightarrow \lambda p \lambda q. p \land q
\]

The first layer expresses the dot’s syntactic category, that is, the dot requires a sentence (category $S$) as an argument at its left, then a sentence as an argument at its right to give a new sentence. The second layer is the expression itself (the dot) and the third layer is the semantic interpretation: the conjunction of the old sentence (discourse) and the current sentence. Discourses begin with an initial sentence, then, in a recursive process, dot interpretation adds the meaning of a new sentence to the meaning of the old discourse.

We use the term denotation (extension) of an expression in its usual model-theoretic sense, employing the common convention to mark denotations by bold typeface: for instance $j$ is the denotation (reference) of the proper name John, $\text{man}$ is the denotation of the noun man (i.e. the function that assigns the truth value one to the entities that have the property of being a man and zero to the entities that do not have that property), see is the denotation of the verb see (i.e. a function that assigns the truth value one to the pairs of entities that are in see relation and truth value zero to the pairs that are not in see relation), etc.

The computer science concept of continuations has been previously used to account for: intra-sentential linguistic phenomena such as focus fronting, donkey anaphora,
presuppositions, crossover or superiority in a series of papers (Barker 2002, Barker 2004, Shan 2005, Shan and Barker 2006, Barker and Shan 2008); cross-sentential semantics in (de Groote 2006); and for analyzing discourse structure in (Asher and Pogodalla 2010).

The merit of continuations in the dynamic semantics context is that they abstract away from assignment functions that are essential to the formulations of DIL, DMG, DPL and DRT; thus do not have problems like the destructive assignment problem in DPL or the variable clash problem in DRT.

We will refer to the semantics of a natural language fragment which uses the notion of continuations as *continuation semantics*. We use in this thesis its variant as it is presented in (Barker and Shan 2008). This variant uses as underlying syntactic formalism Categorial Grammars, a well established syntactic formalism with large linguistic coverage. Generally, the term Categorial Grammar (CG) names a group of theories of natural language syntax and semantics in which the complexity is moved from rules to lexical entries. Historically, the ideas of categorial grammars were introduced in Ajdukiewicz (1935), in Bar-Hillel (1953) and in Lambek (1958). Formally, a Categorial Grammar is a quadruple \((\Sigma, \text{Cat}, S, ::=)\), where \(\Sigma\) is a finite set of symbols, \(\text{Cat}\) is a finite set of primitive categories, \(S \in D(\text{Cat})\) and the relation :: is the lexicon which relates categories to symbols : ::= \(D(\text{Cat}) \times \Sigma\). \(D(\text{Cat})\) is the least set such that \(\text{Cat} \subseteq D(\text{Cat})\) and if \(A, B \in D(\text{Cat})\) then \((A/B), (A\backslash B) \in D(\text{Cat})\). \(A/B\) and \(BA\) represent functions from \(B\) into \(A\), where the slash determines that the argument \(B\) is applied to the right (/) or to the left (\(\backslash\)) of the functor, respectively. There are two rules: application \(A/B + B = A\) or \(B + A'B = A\) and composition \(A/B + B/C = A/C\). + stands for concatenation.

Continuations are a standard tool in computer science, used to control side effects of computation (such as evaluation order, printing or passing values). They are a notoriously hard to understand notion. Actually, understanding what a continuation is per se is not so hard. What is more difficult is to understand how a grammar based on continuations (a ‘continuized’ grammar) works. The basic idea of continuizing a grammar is to provide subexpressions with direct access to their own continuations (future context), so subexpressions are modified to take a continuation as an argument. A continuized grammar is said to be written in *continuation passing style* and it is obtained from any grammar using a set of formal general rules. Continuation passing style is in fact a restricted (typed) form of lambda-calculus. Historically, the first continuation operators were undelimited (for instance, \(\text{call}, \text{cc}\) or \(J\)). An undelimited continuation of an expression represents “the entire (default) future for the computation” of that expression. Felleisen (1988) introduced delimited continuations (sometimes called ‘composable’ continuations) such as control (‘C’) and prompt (‘%’). Delimited continuations represent the future of the computation of the expression up to a certain boundary. Interestingly, the natural-language phenomena discussed in this thesis make use only of delimited continuations.

For instance, if we take the local context to be restricted to the sentence, when computing the meaning of the sentence *John saw Mary*, the default future of the value denoted by the subject is that it is destined to have the property of seeing Mary predicated of it. In symbols, the continuation of the subject denotation \(j\) is the function \(\lambda x. \text{saw } m \ x\). Similarly, the default future of the object denotation \(m\) is the property of being seen by John, i.e. the function \(\lambda y. \text{saw } y \ j\); the continuation of the transitive verb denotation *saw* is the function \(\lambda R.R \ m \ j\); and the continuation of the VP *saw Mary* is the function \(\lambda P.P \ j\). This simple example illustrates two important aspects of continuations: that every meaningful subexpression has a continuation and that the continuation of an expression is always relative to some larger expression containing it. Thus, when *John* occurs in the sentence *John left yesterday*, its continuation is the property \(\lambda x. \text{yesterday left } x\); when it occurs in *Mary thought John left*, its continuation is the property \(\lambda x. \text{thought } (\text{left } x) \ m\) and when it occurs in the sentence *Mary or John left*, its continuation is \(\lambda x. (\text{left } x) \ V \ (\text{left } x)\) and so on.
Continuation semantics has some desirable properties, namely it is:
- dynamic;
- directly compositional (in the sense of (Jacobson 1999));
- extensional (but intentionality could be in principle accounted for in this framework);
- variable free (there are no free variables, so there is no danger of accidentally binding a free variable, one only need to rename the current bound variable with a fresh variable name cf. Barendregt’s variable convention).

We shortly comment on those property in what follows.

Informally, some semantics is said to be dynamic if it allows quantifiers to bind outside their syntactic scope. Traditional dynamic semantics (Kamp 1993, Heim 1983, Groenendijk and Stokhof 1991) treats sentence meaning as context update functions. Barker and Shan’s (2008) continuation-based semantics (at the sentence level) is dynamic in a slightly different sense: it considers the meaning of an expression as having a (dynamic) double contribution, e.g. its main semantic contribution on local argument structure and the expression’s side effects, for instance long distance semantic relationships, including scope-taking and binding.

A continuized grammar is compositional in the sense that the meaning of a complex syntactic constituent is a function only of the meanings of its immediate subconstituents and the manner in which they are combined. Taking the principle of compositionality seriously means preferring analyses in which logical form stays as close to surface syntax as possible. Allowing Logical Form (LF) representations to differ in unconstrained ways from surface syntax removes all empirical force from assuming compositionality. This is the sense in which LF based theories of quantification such as quantifier raising (QR) weaken compositionality. The ideal is what Jacobson (1999) calls Direct Compositionality, in which each surface syntactic constituent has a well-formed denotation, and there is no appeal to a level of Logical Form distinct from surface structure. Continuations are compatible with direct compositionality.

Compositionality, at least as Montague formulated it, requires that a syntactic analysis fully disambiguates the expression in question. We will admit, contra Montague, that there is such a thing as semantic ambiguity, i.e. a single syntactic formation operation may be associated with more than one semantic interpretation. The resulting notion of compositionality is: the meaning of a syntactically complex expression is a function only of the meaning of that expression’s immediate subexpressions, the syntactic way in which they are combined, and their semantic mode of composition. This places the burden of scope ambiguity on something that is neither syntactic, nor properly semantic, but at their interface: scope ambiguity is metacompositional.

In some elaborate linguistic treatments, sentences denote functions from entities, times and worlds to truth values, with an analogous shift for expressions of other types. In the parlance of linguists, a treatment in terms of truth values is ‘extensional’, and a system with times and worlds is ‘intentional’. Intentionality is not crucial for any of the discussions in this thesis, and the types will be complex enough anyway, so we will use an extensional semantics on which sentences denote truth values. We will currently use the types e (entity), t (truth value) and functions build from them, as, for example (e->t)->t written <<e, t>t>. For eventualities, we will use a third type, conveniently notated with capital E (to distinguish it from e). Expressions will not directly manipulate the pragmatic context, whether it is a set of worlds (although perfectly plausible as in Shan& Barker (2006)), a set of assignment functions, or another kind of information state.

It is worth mentioning that some results of traditional semantic theories are particular cases of results in continuation-based semantics, for example:
• The generalized quantifier type from Montague grammar \(<<e,t>,t>,t>\) is exactly the type of quantificational determiners in continuation-based semantics;

• The \(<<t,t>,t>\) type of sentences in dynamic semantics is exactly the type of sentences in continuation-based semantics. In fact, dynamic interpretation constitutes a partial continuization in which only the category S has been continuized.

This is by no means a coincidence, MG only continuizes the noun phrase meanings and dynamic semantics only continuizes the sentence meanings, rather than continuizing uniformly throughout the grammar as it is done in continuation-based semantics.

Starting from the discourse continuation semantics which we introduced (by explicitly giving a semantics for cross-sentential punctuation marks such as dot or semicolon), we show how continuations and a type shifting mechanism are able to account for a wide range of natural language semantic phenomena, such as: binding pronominal (singular or plural) anaphora, quantifier scope, negation, focus, hierarchical discourse structure, ellipsis or accommodation. Formally, we explicitly give semantic denotations for some of the lexical entries responsible for those phenomena. For instance, we give to the negation and to the focus maker (operator) F the following denotations, respectively:

\[
\frac{S[S]}{A/F} \quad \frac{S[S]}{\lambda x. (\lambda k. k(x)) \land \forall y. (y = x \lor \neg (k(y))) (\lambda z. [\ ])}
\]

We also discuss some problematic aspects of plural dynamic semantics such as the distribution or the maximality condition, pointing out that singular and plural anaphora are not parallel phenomena (as we might expect at a first sight) and that plurality introduces complexities not present in singular analysis.

We further shift from quantifying over entities and truth values to quantifying over entities, truth values and eventualities (Dinu 2011b). Thus, we are able to account for quantification over eventualities and for anaphora to eventualities, giving specific denotations to the adverbial quantifiers always and never and to a silent adverbial quantifier which we consider responsible for the meaning of expressions with no overt adverbial quantifiers. For instance, always and never receive the denotation:

\[
\frac{S[S]}{S_E} \quad \frac{S[S]}{\forall e, \text{RelevEvent}(e) \rightarrow [\ ]} \quad \frac{S[S]}{\exists e, \text{RelevEvent}(e) \land [\ ]} \quad \frac{S[S]}{\neg e. \text{RelevEvent}(e) \land [\ ]}
\]

We argue that the Scope Domain Principle (adapted from Landman 2000), cf. Parsons 1987), which says that the eventuality quantifier always takes lowest possible scope with respect to other quantifiers, is too strong. Instead, we propose that the scope behavior of eventuality quantifiers is ambiguous and it is a discourse matter to decide which reading is preferred. We only provide enough details to make plausible the interpretation of eventualities in continuation semantics framework, leaving for further research important issues such as: a complete specification of eventualities semantics, that is obviously not possible without taking into consideration thematic roles, aspect, modality and tense; a way of representing the imprecision of the eventuality restriction, etc.
Another original proposal of this thesis is a mechanism (left underspecified in previous work on continuation semantics) which ensures that no lexical entry having the scope bounded to its minimal clause (such as *not*, *no*, *every*, *each*, *any*, etc.) will ever take scope outside (Dinu 2011.c). In order to do so, we introduce a new category for clauses: $C$, of the same semantic type as the category $S$, namely *t*. $C$ is the minimal discourse unit, whereas $S$ is composed from at least one such unit. We constrain by definition the lexical entries with clause-bounded scope to take scope only at clauses. For instance, here there are the lexical entries for *not*, *no* and *every*:

\[
\begin{align*}
C | C & \quad (D|C)/(D|C) \\
D | P & \quad (N|P) \\
\neg &[1] & \quad \lambda P. \neg \exists x. (P(x) \land [1]) \\
[1] & \quad \forall x. [1] \\
[1] & \quad \lambda P. P(x) \rightarrow [1]
\end{align*}
\]

After the full interpretation of the minimal clause which they appear in, the category $C$ has to be converted to category $S$. Specifically, one can use the following silent lexical entry:

\[
S/C \\
\phi \\
\lambda P. \phi([1])
\]

This step ensures that clauses (of category $C$) can be further processed as pieces of discourse (of category $S$), because all discourse connectors (such as the *dot* or *if*) are allowed to take only expressions of category $S$ as arguments.

We argue that continuations are a versatile and powerful tool, particularly well suited to manipulate scope and long distance dependencies, phenomena that abound in natural language semantics. Once we get the scope of the lexical entries right for a particular discourse, we automatically get the right truth conditions and interpretation for that piece of discourse. No other theory to our knowledge lets indefinites, quantifiers, pronouns and other anaphors interact in a uniform system of scope taking, in which quantification and binding employ the same mechanism.

We leave for future research:
- completing an algorithm that generates all possible interpretations for a given piece of discourse in continuation semantics framework;
- the possibility to express situation semantics using continuations;
- the comparison of our approach to anaphora to other approaches of anaphora, like, for instance, anaphora in algebraic linguistics framework (Marcus 1967).

The second part of this thesis presents the work on creating and analyzing electronic resources for Romanian language: a Romanian Generative Lexicon and a corpus for the study of differential object marking in Romanian.

The construction and annotation of a Romanian Generative Lexicon (RoGL), along the lines of Generative Lexicon Theory (GLT) (Pustejovsky 2006), represents an on-going research (Dinu 2010.a, Dinu 2010.b).

Currently, there are a number of ‘static’ machine readable dictionaries for Romanian, such as Romanian Lexical Data Bases of Inflected and Syllabic Forms (Barbu 2008), G.E.R.L. (Gavrila and Vertan 2005), Multext, etc. Such static approaches of lexical meaning are faced with two problems when assuming a fixed number of “bounded” word senses for lexical items:
In the case of automated sense selection, the search process becomes computationally undesirable, particularly when it has to account for longer phrases made up of individually ambiguous words.

The assumption that an exhaustive listing can be assigned to the different uses of a word lacks the explanatory power necessary for making generalizations and/or predictions about words used in a novel way.

GLT (Pustejovsky 1995) is a type theory (see for instance Proceedings of The first/second/third International Workshop on Generative Approaches to the Lexicon 2001/2003/2005) with rich selectional mechanisms, which overcomes these drawbacks. The structure of lexical items in language over the past ten years has focused on the development of type structures and typed feature structures (Levin and Rappaport 2005, Jackendoff 2002). Generative Lexicon adds to this general pattern the notion of predicate decomposition. Lexicons built according to this approach contain a considerable amount of information and provide a lexical representation covering all aspects of meaning. In a generative lexicon, a word sense is described according to four different levels of semantic representation that capture the componential aspect of its meaning, define the type of event it denotes, describe its semantic context and positions it with respect to other lexical meanings within the lexicon. The four levels of semantic interpretation in GLT are (Lexical Data Structures in GLT):

- Lexical typing structure: giving an explicit type for a word positioned within a type system for the language;
- Argument structure: specifying the number and nature of the arguments to a predicate;
- Event structure: defining the event type of the expression and any subeventual structure;
- Qualia structure: a structural differentiation of the predicative force for a lexical item.

GLT places natural language complexity at lexical level instead of formation rules. Semantic types constrain the meaning of other words, for instance the verb eat imposes on its direct object the interpretation [[Food]]. The theory uses the full predicative decomposition, with an elegant way of transforming the subpredicates into richer argument typing: argument typing as abstracting from the predicate. Thus, GLT employs the “Fail Early” Strategy of Selection, where argument typing can be viewed as pretest for performing the action in the predicate. If the argument condition (i.e., its type) is not satisfied, the predicate either: fails to be interpreted, or coerces its argument according to a given set of strategies. Composition is taken care of by means of typing and selection mechanisms (compositional rules applied to typed arguments). The Argument and Body structure in GLT looks like:

```
<table>
<thead>
<tr>
<th>Environ</th>
<th>AS</th>
<th>ES</th>
<th>Body</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>λx₂ · · · λx₁ λc₃ · · · λc₁</td>
<td>[Q₁ ∧ Q₂ ∧ Q₃ ∧ Q₄; C]</td>
<td></td>
</tr>
</tbody>
</table>
```

where AS means Argument Structure, ES means Event Structure, Qi means Qualia Structure and C stands for Constraints.

The Qualia Structure has four levels:

- Formal: the basic category which distinguishes it within a larger domain;
- Constitutive: the relation between an object and its constituent parts;
- Telic: its purpose and function, if any;
- Agentive: factors involved in its origin or “bringing it about”.

The Type Composition Language of GLT is formed by the following rules:

- e is the type of entities; t is the type of truth values. (σ and τ, range over simple types and subtypes from the ontology of e.)
If $\sigma$ and $\tau$ are types, then so is $\sigma \rightarrow \tau$; 
If $\sigma$ and $\tau$ are types, then so is $\sigma \bullet \tau$; 
If $\sigma$ and $\tau$ are types, then so is $\sigma \oslash Q \tau$, for $Q = \text{const}(C)$, telic($T$), or agentive($A$). 

The Compositional Rules in GLT are:
- **Type Selection**: Exact match of the type; 
- **Type Accommodation**: The type is inherited; 
- **Type Coercion**: Type selected must be satisfied. 

The domain of individuals (type e) is separated into three distinct type levels:
- **Natural Types**: atomic concepts of formal, constitutive and agentive; 
- **Artifactual Types**: Adds concepts of telic; 
- **Complex Types**: Cartesian types formed from both Natural and Artifactual types. 

Generative Lexicons had been already constructed for a number of natural languages. Brandeis Semantic Ontology (BSO) is a large generative lexicon ontology and lexical database for English. PAROLE – SIMPLE – CLIPS lexicon is a large Italian generative lexicon with phonological, syntactic and semantic layers. The specification of the type system used both in BSO and in CLIPS largely follows that proposed by the SIMPLE specification (Busa et al. 2001), which was adopted by the EU-sponsored SIMPLE project (Lenci et al. 2000). Also, (Ruimy et al. 2005) proposed a method for semi-automated construction of a generative lexicon for French from Italian CLIPS, using a bilingual dictionary and exploiting the French-Italian language similarity. 

Creating a generative lexicon from scratch for any language is a challenging task, due to complex semantic information structure, multidimensional type ontology, time consuming annotation etc. Thus, we used the experience and structures of the existing generative lexicons for other languages such as Italian CLIPS or English BSO. 

RoGL contains a corpus, an ontology of types, a graphical interface and a database from which we generate data in XML format. The interface and the data base where the annotated lexical entries are stored and processed are hosted on the server of Faculty of Mathematics and Computer Science, University of Bucharest: http://ro-gl.fmi.unibuc.ro. 

To implement the generative structure and the composition rules, we have chosen the functional programming language Haskell. Our choice was determined by the fact that reducing expressions in lambda calculus (obviously needed in a GL implementation), evaluating a program (i.e. function) in Haskell, and composing the meaning of a natural language sentence are, in a way, all the same thing. 

The most important work which still needs to be done in RoGL framework is to annotate more lexical entries. The manual annotation, although standardized and mediated by the graphical interface is notoriously time consuming especially for complex information such as those required by a generative lexicon. 

We also buildt and analyze a Romanian corpus for the study of Differential Object Marking (Dinu and Tigau 2010). The motivation for this work is that in Romanian the uses of the accusative marker “pe” with the direct object in combination or not with clitics involve mechanisms which are not fully understood and seeming messy for the non-native speaker: sometimes the accusative marker is obligatory, sometimes it is optional and even forbidden. The Differential Object Marking (DOM) parameter draws a line between languages such as Spanish, Romanian, Turkish, or Russian which show a propensity for overtly marking those objects which are considered to be ‘prominent’, i.e. high in animacy, definiteness or specificity and other languages, such as German, Dutch and English, where such a distinction between types of direct objects is not at stake (they rely mostly on word order to mark the direct object). Thus, this research tackles a specific linguistic difference among those languages. It presents a systematic account for these linguistic phenomena based on empirical evidence present in corpora. Such an account may be used in subsequent studies to improve statistical methods with targeted linguistic knowledge.
In order to find empirical evidences for the way DOM with accusative marker “pe” is interpreted in Romanian, we semi-automatically constructed a corpus of Romanian phrases. The construction of the corpus was straightforward: we only included the phrases containing the word “pe” from a given set. The only problem was to manually detect and delete from the corpus the occurrences of “pe” which lexicalized the homonym preposition meaning on. By doing so, we obtained 960 relevant examples from present day Romanian: 560 of these were automatically extracted from publically available news paper on the internet; the other 400 examples (both positive and negative) were synthetically created, because we needed to test the behaviour of the direct object within various structures and under various conditions, which made such sequences rare in the literature.

We manually annotated the direct objects from the corpus with semantically interpretable features we suspected, based on previous studies, are relevant for DOM, such as [±animate], [±definite],[ ±human].

We also assembled a corpus containing 779 examples from XVI-th and the XVII-th century texts (approx. 1000 pages of old texts were perused), in order to study the temporal evolution of DOM in Romanian. From this old Romanian corpus we noticed that prepositional PE came to be more extensively employed in the XVII-th century texts and by the XVIII-th century it had already become the syntactic norm. It seems that the Accusative was systematically associated with P(R)E irrespective of the morphological and semantic class the direct object belonged to. This is in line with the results arrived at by Heusinger & Onea (2008) who observe that the XIX-th century was the epitome in what the employment of DOM is concerned. This evolution was then reversed around the XIX-th –XX-th centuries so that the use of PE today is more restrained than it was two centuries ago, but more relaxed if we were to compare it to the XVI-th century.

We present a systematic account for these linguistic phenomena based on empirical evidence from the corpus:

- **Pronouns** (personal pronouns, pronouns of politeness, reflexive pronouns, possessive pronouns and demonstrative pronouns) are obligatorily marked by means of PE irrespective of the status of the referent on the animacy scale (il vad pe el/*il vad el – pers.IIIsg.masc.clitic see pe-marker him/* pers.IIIsg.masc.clitic see him).

- For **proper names** the use of PE is conditioned by the animacy scale which overrides the parameter of determined reference: it is obligatory with proper names pointing to [+ human] Determiner Phrases (o vad pe Maria/*o vad Maria – pers.IIIsg.fem.clitic I see pe-marker Maria/* pers.IIIsg.fem.clitic I see Maria) and optional with [+ animate] DPs, and ungrammatical with [-animate] proper names (vad cartea/*vad pe cartea – I see the book-the/*I see pe-marker book-the).

- **Definite descriptions** are optionally marked by means of PE; the parameter of determined reference still imposes obligatoriness of DOM on those DPs that have determined reference. Nevertheless, in the case of definite descriptions, this parameter is overridden by the animacy scale. This accounts for both the obligatory nature of DOM with [+human, + determined reference] definite descriptions (normally DOM is optional with [+ human, - def] definite descriptions) and for the behaviour of [- human, +/- animate, + determined reference] definite DPs.

- **Indefinite Description**: Only specific Indefinite Descriptions are optionally marked by means of PE. The others cannot be marked.

The third part of the thesis comprises two experiments of classification by coherence/incoherence of short English and Romanian texts, respectively, using machine learning techniques (Dinu 2010.c, Dinu 2008). These experiments are instances of a quantitative approach to a text categorization problem: classifying texts by the choherence criterion. The typical text categorization criterions comprise categorization by topic, by style (genre classification, authorship identification (Dinu et al. 2008), by language (Dinu
and Dinu 2005, Dinu and Dinu 2006), by expressed opinion (opinion mining, sentiment classification), etc. Very few approaches consider the problem of categorizing text by degree of coherence, as in (Miller 2003).

The first experiment (Dinu 2010.c) deals with one of the new strategies adopted by spammers to send (unwanted) messages to personal e-mail accounts: encoding the real message as picture, impossible to analyze and reject by the text oriented classical filters and accompanying it by a text especially designed to surpass the filter. For humans, the text in the picture is easily comprehensible, as opposed to the accompanying text, which as either syntactically incorrect (collection of words), or semantically incorrect, or pragmatically incorrect (collection of proverbs or texts obtained by putting together phrases or paragraphs from different text). We only deal with recognizing text belonging to the last category, i.e. incoherent text.

For classical spam filters, which usually relay on algorithms that use as features content words, the picture offers no information and the accompanying text may pass as valid (because it contains content word usually not present in spam messages).

We propose a quantitative approach that relies on the use of ratios between morphological categories from the texts as discriminant features, assuming that these ratios are not completely random in coherent text. We use a number of supervised machine learning techniques on a small corpus of English e-mail messages (with both positive examples, i.e. coherent messages and negative examples, i.e. incoherent messages of the spam type described above); we employed supervised learning algorithms to extract important features from all the pos ratios.

Because of the relative small number of examples in our experiment, we used leave one out cross validation, which is considered an almost unbiased estimator of the generalization error. Leave one out technique consists of holding each example out, training on all the other examples and testing on all examples.

The first and the simplest technique we used was the linear regression (Duda et al. 2001), not for its accuracy as classifier, but because, being a linear method, allows us to analyze the importance of each feature and so determine some of the most prominent features for our experiment of categorizing coherent/ incoherent texts. Its l.o.o accuracy was of 68.18%, which we used further as baseline for next experiments. From among the other four machine learning techniques (ν support vector classifier with linear kernel, Kernel Fisher discriminant with linear kernel, support vector machine with polynomial kernel, Kernel Fisher discriminant with polynomial kernel), the Kernel Fisher discriminant with polynomial kernel achieved the best performance, with a l.o.o. accuracy of 85.48%. We consider this as a good result, because there are inherent errors, transmitted from the part of speech tagger and from the subjective human classification into the two classes and, most importantly, because using only the frequencies of the parts of speech disregards many other important feature for text coherence, such as, for example, the order of phrases, coreferences resolution, rhetorical relations, etc.

It would be interesting to compare our quantitative approach to some qualitative techniques related to text coherence, such as latent semantic analysis (Dumais et al. 1988 ), lexical chains (Hirst and St.-Onge 1997), or textual coherence vs. textual cohesion approach (Marcus 1980). Also, it would be useful to train the machine to have an error as small as possible for positive examples (coherent texts sent into Bulk folder), even if the error for negative examples would be bigger (incoherent texts sent into Inbox).

The second experiment (Dinu 2008) applies the same techniques as the first one, this time for classifying Romanian short texts as coherent/incoherent. The experiment is performed on a small corpus of Romanian text from a number of alternative high school manuals. During the last two decades, an abundance of alternative manuals for high school was produced and distributed in Romania. Due to the large amount of material and to the relative short time in which it was produced, the question of assessing the quality of this
material emerged; this process relied mostly of subjective human personal opinion, given the lack of automatic tools for Romanian. Debates and claims of poor quality of the alternative manuals resulted in a number of examples of incomprehensible / incoherent paragraphs extracted from such manuals. Our goal was to create an automatic tool which may be used as an indication of poor quality of such texts.

We created a small corpus of representative texts from 6 Romanian alternative manuals. We manually classified the chosen paragraphs from such manuals into two categories: comprehensible/coherent text and incomprehensible/incoherent text. As some annotators observed, the yes or no decision was overly restrictive; they could have gave a more fine grained answer such as very difficult to follow, easy to follow, etc, but we decided to work with 2 class categorisation from reasons of simplicity. Obviously, the two class classification is a rather dramatic classification. It would be useful to design a tool that produces as output not just a yes/no answer, but a score or a probability that the input (text) is in one of the two categories, such that a human expert may have to judge only the texts with particular high probability to be in the class of incoherent texts. We leave this for further work, as well as creating a larger corpus.

By using the same machine learning techniques as for the first experiment, (linear regression, ν support vector classifier with linear kernel, Kernel Fisher discriminat with linear kernel, support vector machine with polynomial kernel, Kernel Fisher discriminant with polynomial kernel) we obtained similar results, in terms of l.o.o. accuracy. The best performance was achieved, as in the case of English e-mail messages, by the Kernel Fisher discriminant with polynomial kernel, with a l.o.o. accuracy of 85.12%.

All machine learning experiments were performed in Matlab, or using Matlab as interface (Chang and Lin 2001).

The final section concludes, summarizing the main results of the thesis and presenting further directions for the research.
3. Terminology and notations

Terminology

Discourse: A piece of text formed of several sentences;
Anaphora: an instance of an expression referring to another one, usually located in preceding utterances;

Denotation or extension of an expression: its usual model-theoretic sense, employing the common convention to mark denotations by bold typeface: for instance \( j \) is the denotation (reference) of the proper name \( John \), \( man \) is the denotation of the noun \( man \) (i.e. the function that assigns the truth value one to the entities that have the property of being a man and zero to the entities that do not have that property), \( see \) is the denotation of the verb \( see \) (i.e. a function that assigns the truth value one to the pairs of entities that are in see relation and truth value zero to the pairs that are not in see relation), etc.;

Quantifier: a quantifier is a type of determiner, such as all or many, that indicates quantity, number or amount;

Ellipses: is an intentional omission of an expression;
Accommodation: a linguistics term meaning grammatical acceptance of unstated values as in accommodation of presuppositions;
Continuations: computer science term, meaning the future of the computation of an expression;

Event, Eventuality, Situation, Possible world: the notion of event is often used sloppily to mean eventuality, or situation, or sometimes even possible world. Roughly speaking, the difference between these notions is as follow: event is a particular case of eventuality; an eventuality is a situation with a minimality condition included; a situation is a partial possible world.

Abbreviations

BSO Brandeis Semantic Ontology;
C clause;
DIL Dynamic Intensional Logic;
DMG Dynamic Montague Grammar;
DOM differential object marking;
DP determiner phrase;
DPL Dynamic Predicate Logic;
DRT Discourse representation Theory;
GLP Generative Lexicon Theory;
l.o.o. accuracy - leave one out accuracy;
N noun;
POS Part of Speech of a word;
RFC Right Frontier Constraint: “the antecedent of a pronoun in the current sentence must be introduced by the previous utterance or one that dominates it in the discourse structure”;
RoGL Romanian Generative Lexicon;
S sentence;
SDP Scope Domain Principle: “the eventuality quantifier always takes lowest possible scope with respect to other quantifiers”;
V verb;
VP verb phrase;
XML Extensible Markup Language, widely used as a format for the exchange of data between different computer systems, programs, etc.
4. Discourse semantics in continuation semantics framework

4.1. Introduction

This section presents an explicit formal account of discourse semantics that extends Barker and Shan’s (2008) (sentential) semantics based on continuations. We shift from sentential level to discourse level. The original contribution here is the formalization in terms of continuations of the intuitive idea that sentence separators (such as dot or semicolon) semantically operate in discourse as functions that take the denotation of the left discourse (previously uttered sequence of sentences) and the denotation of the current sentence and returns the denotation of the newly formed discourse obtained through the conjunction of the old discourse with the new sentence. Using the discourse semantics introduced in this way, we show how continuations, together with categorial grammars and a type shifting mechanism, are able to account for a wide range of natural language semantic phenomena, such as: binding pronominal (singular or plural) anaphora (i.e. an instance of an expression referring to another one, usually located in preceding utterances), quantifier scope, negation, focus, hierarchical discourse structure, ellipsis or accommodation. Formally, we explicitly propose semantic denotations for some of the lexical entries responsible for those phenomena. We also discuss some problematic aspects of plural dynamic semantics such as the distributivity or the maximality condition, pointing out that singular and plural anaphora are not parallel phenomena (as we might expect at a first sight) and that plurality introduces complexities not present in singular analysis.

We further shift from quantifying over entities and truth values to quantifying over entities, truth values and eventualities. Thus, we are able to account for quantification over eventualities and for anaphora to eventualities, giving specific lexical entries for the adverbial quantifier always and never and for a silent adverbial quantifier which we consider responsible for the meaning of expressions with no overt adverbial quantifiers. We argue that the Scope Domain Principle (adapted from Landman 2000, cf. Parsons 1987), which says that the eventuality quantifier always takes lowest possible scope with respect to other quantifiers, is too strong. Instead, we propose that the scope behavior of eventuality quantifiers is ambiguous and it is a discourse matter to decide which reading is preferred. We only provide enough details to make plausible the interpretation of eventualities in continuation semantics framework, leaving for further research important issues such as: a complete specification of eventualities semantics, that is obviously not possible without taking into consideration thematic roles, aspect, modality and tense; a way of representing the imprecision of the eventuality restriction, etc.

We also propose a (left underspecified in previous work on continuation semantics) which ensures that no lexical entry having the scope bounded to its minimal clause (such as not, no, every, each, any, etc) will ever take scope outside (Dinu 2011.c).

We argue that continuations are a versatile and powerful tool, particularly well suited to manipulate scope and long distance dependencies, phenomena that abound in natural language semantics. Once we get the scope of the lexical entries right for a particular discourse, we automatically get the right truth conditions and interpretation for that piece of discourse. No other theory to our knowledge lets indefinites, quantifiers, pronouns and other anaphors interact in a uniform system of scope taking, in which quantification and binding employ the same mechanism.

The discourse semantics we propose here is dynamic, directly compositional (in the sense of Jacobson (1999)), extensional (but intentionality could be in principle accounted for in this framework) and variable free (there are no free variables, so there is no danger
of accidentally binding a free variable, one only need to rename the current bound variable with a fresh variable name cf Barendregt’s variable convention).

The computer science concept of continuations has been previously used to account for intra-sentential linguistic phenomena such as focus fronting, donkey anaphora, presuppositions, crossover or superiority (Barker 2002, Barker 2004, Shan 2005, Shan and Barker 2006, Barker and Shan 2008), for cross-sentential semantics (de Groote 2006) and for analyzing discourse structure in Asher and Pogodalla (2010). The merit of continuations in the dynamic semantics context is that they abstract away from assignment functions that are essential to the formulations of Dynamic Intensional Logic, Dynamic Montague Grammar, Dynamic Predicate Logic and Discourse Representation Theory, thus do not have problems like the destructive assignment problem in DPL or the variable clash problem in DRT.

Continuations are a standard tool in computer science, used to control side effects of computation (such as evaluation order, print or passing values). They are a notoriously hard to understand notion. Actually, understanding what a continuation is per se is not so hard. What is more difficult is to understand how a grammar based on continuations (a ‘continuized’ grammar) works. The basic idea of continuizing a grammar is to provide subexpressions with direct access to their own continuations (future context), so subexpressions are modified to take a continuation as an argument. A continuized grammar is said to be written in continuation passing style and it is obtained from any grammar using a set of formal general rules. Continuation passing style is in fact a restricted (typed) form of lambda-calculus. Historically, the first continuation operators were undelimited (for instance call, cc or J). An undelimited continuation of an expression represents “the entire (default) future for the computation” of that expression. Felleisen (1988) introduced delimited continuations (sometimes called ‘composable’ continuations) such as control (‘C’) and prompt (‘%’). Delimited continuations represent the future of the computation of the expression up to a certain boundary. Interestingly, the natural-language phenomena discussed here make use only of delimited continuations.

For instance, if we take the local context to be restricted to the sentence, when computing the meaning of the sentence John saw Mary, the default future of the value denoted by the subject is that it is destined to have the property of seeing Mary predicated of it. In symbols, the continuation of the subject denotation $j$ is the function $\lambda x. \text{saw } m \ x$. Similarly, the default future of the object denotation $m$ is the property of being seen by John, the function $\lambda y. \text{saw } y \ j$; the continuation of the transitive verb denotation $\text{saw}$ is the function $\lambda R.R \ m \ j$; and the continuation of the VP $\text{saw Mary}$ is the function $\lambda P.P \ j$. This simple example illustrates two important aspects of continuations:

1. Every meaningful subexpression has a continuation;
2. The continuation of an expression is always relative to some larger expression containing it.

Thus when John occurs in the sentence John left yesterday, its continuation is the property $\lambda x. \text{yesterday left } x$; when it occurs in Mary thought John left, its continuation is the property $\lambda x. \text{thought (left } x) \ m$ and when it occurs in the sentence Mary or John left, its continuation is $\lambda x. (\text{left } m) \lor (\text{left } x)$ and so on.

The discourse semantics we propose is dynamic, directly compositional (in the sense of Jacobson (1999)), extensional (but intentionality could be in principle accounted for in this framework) and variable free (there are no free variables, so there is no danger of accidentally binding a free variable, one only need to rename the current bound variable with a fresh variable name cf Barendregt’s variable convention). We pause here to shortly comment on those properties.
Informally, semantics is said to be dynamic if it allows binding elements to bind outside their syntactic scope. Traditional dynamic semantics (Kamp 1993, Heim 1983, Groenendijk and Stokhof 1991) treats sentence meaning as context update functions. Barker and Shan’s continuation-based semantics (at the sentence level) is dynamic in a slightly different sense: it considers the meaning of an expression as having a (dynamic) double contribution, e.g. its main semantic contribution on local argument structure and the expression’s side effects, for instance long distance semantic relationships, including scope-taking and binding.

A continuized grammar is compositional in the sense that the meaning of a complex syntactic constituent is a function only of the meanings of its immediate subconstituents and the manner in which they are combined. Taking the principle of compositionality seriously means preferring analyses in which logical form stays as close to surface syntax as possible. Allowing LF representations to differ in unconstrained ways from surface syntax removes all empirical force from assuming compositionality. This is the sense in which LF based theories of quantification such as quantifier raising (QR) weaken compositionality. The ideal is what Jacobson (1999) calls Direct Compositionality, in which each surface syntactic constituent has a well-formed denotation, and there is no appeal to a level of Logical Form distinct from surface structure. Continuations are compatible with direct compositionality.

Compositionality, at least as Montague formulated it, requires that a syntactic analysis fully disambiguates the expression in question. We will admit, contra Montague, that there is such a thing as semantic ambiguity, i.e. a single syntactic formation operation may be associated with more than one semantic interpretation. The resulting notion of compositionality is: the meaning of a syntactically complex expression is a function only of the meaning of that expression’s immediate subexpressions, the syntactic way in which they are combined, and their semantic mode of composition. This places the burden of scope ambiguity on something that is neither syntactic, nor properly semantic, but at their interface: scope ambiguity is metacompositional.

In some elaborate linguistic treatments, sentences denote functions from entities, times and worlds to truth values, with an analogous shift for expressions of other types. In the parlance of linguistics, a treatment in terms of truth values is ‘extensional’, and a system with times and worlds is ‘intentional’. Exept for the Eventuality chapter, intentionality is not crucial in any of the discussions below, and the types will be complex enough anyway, so we will use an extensional semantics on which sentences denote truth values. We will currently use types $e$ (entity), $t$ (truth value) and functions build from them, as, for example $(e \rightarrow t) \rightarrow t$ written $\langle\langle e, t\rangle, t\rangle$. For eventualities, we will use a third type, conveniently notated $v$. Expressions will not directly manipulate the pragmatic context, whether it is a set of worlds (although perfectly plausible as in (Shan and Barker 2006), a set of assignment functions, or another kind of information state.

It is worth mentioning that some results of traditional semantic theories are particular cases of results in continuation-based semantics, for example:

- The generalized quantifier type from Montague grammar $\langle\langle e, t, t\rangle, t\rangle$ is exactly the type of quantificational determiners in continuation-based semantics;
- The $\langle\langle t, t\rangle, t\rangle$ type of sentences in dynamic semantics is exactly the type of sentences in continuation-based semantics. In fact, dynamic interpretation constitutes a partial continuization in which only the category $S$ has been continuized.

This is by no means a coincidence, MG only continuizes the noun phrase meanings and dynamic semantics only continuizes the sentence meanings, rather than continuizing uniformly throughout the grammar as it is done in continuation-based semantics.
4.2. Prerequisites

One of the main challenges of interpreting a discourse (giving it a compositional semantics) is interpreting cross-sentential anaphora. Assigning a first order logical representation to a discourse like “A man came. He whistled” is problematic. How can we get from the two first order representations in (1) and (2) the representation in (3), i.e. obtaining the bound variable \( \text{whistled}(x) \) in (3) from the free one in (1)?

\[
\begin{align*}
(1) & \quad \exists x. (\text{man}(x) \land \text{came}(x)) \\
(2) & \quad \text{whistled}(x) \\
(3) & \quad \exists x. (\text{man}(x) \land \text{came}(x)) \land \text{whistled}(x)
\end{align*}
\]


In DRT, the prototypical model theoretic semantics (that uses assignment functions), discourse referents act as existential quantifiers. Nevertheless, from a technical point of view, they must be considered as free variables. Thus, when merging two discourse representation structures, a complication appears: some special variable-renaming mechanism must be stipulated in order to avoid variable clashes. Continuation-based approaches are variable-free, thus, like all variable free accounts, Jacobson’s included, do not have this problem.

We will refer to the semantics of a natural language fragment which uses the notion of continuations from the series of articles of Barker (2002), Barker (2004), Shan (2005), Shan and Barker (2006), Barker and Shan (2008), as ‘continuation semantics’. We use Barker and Shan’s (2008) tower notation for a given expression, which consists of three levels: the top level specifies the syntactic category of the expression coached in categorial grammar\(^1\), the middle level is the expression itself and the bottom level is the semantic value.

\[
\begin{array}{c}
\text{syntactic category} \\
\text{expression} \\
\text{semantic value}
\end{array}
\]

The syntactic categories\(^2\) are written \(\frac{C|B}{A}\), where A, B and C can be any categories. We read this counter clockwise as “the expression functions as a category A in local context, takes scope at an expression of category B to form an expression of category C.”

The semantic value \(\lambda k. f[k(x)]\) is equivalently written vertically as \(\frac{f[ ]}{x}\) omitting the future context (continuation) \(k\). Here, \(x\) can be any expression, and \(f[ ]\) can be any expression with a gap \([ ]\). Free variables in \(x\) can be bound by binders in \(f[ ]\). This notational convention is meant to make easier (more visual) then in linear notation the

---

1 The term Categorial Grammar (CG) names a group of theories of natural language syntax and semantics in which the complexity is moved from rules to lexical entries. Historically, the ideas of categorial grammars were introduced in Ajdukiewicz (1935), in Bar-Hillel (1953) and in Lambek (1958). Formally, a categorial grammar is a quadruple \((\Sigma, \text{Cat}, S, :=)\), where \(\Sigma\) is a finite set of symbols, \(\text{Cat}\) is a finite set of primitive categories, \(S \in D(\text{Cat})\) and the relation \(:=\) is the lexicon which relates categories to symbols : \(\in\subseteq D(\text{Cat}) \times \Sigma\). \((\text{Cat})\) is the least set such that \(\text{Cat} \subseteq D(\text{Cat})\) and if \(A, B \in D(\text{Cat})\) then \((A/B), (A\backslash B) \in D(\text{Cat})\). \(A/B\) and \(B/A\) represent functions from \(B\) into \(A\), where the slash determines that the argument \(B\) is applied to the right (\(\backslash\)) or to the left (\(/\)) of the function, respectively. There are two rules: application \(A/B + B = A\) or \(B + A/B = A\) and composition \(A/B + B/C = A/C\). For a recent survey of Categorial Grammars we refer the reader to Morrill (2010).

2 We denote of the following syntactic categories with: \(S\), the sentence; \(VP\) the verb phrase; \(DP\) the determiner phrase; \(N\) the noun.
combination process of two expressions: a left expression (left-exp) and a right expression (right-exp). Here are the two possible modes of combination (Barker and Shan 2008):

\[
\left( \begin{array}{ccc}
C|D & D|E & C|E \\
A/B & B & A \\
\text{left - exp} & \text{right - exp} & \text{left - exp right - exp} \\
g[f] & h[x] & g[b[ ]] \\
\end{array} \right)
\]

Below the horizontal lines, combination proceeds simply as in combinatory categorial grammar: in the syntax, \( B \) combines with \( A/B \) or \( BA \) to form \( A \); in the semantics, \( x \) combines with \( f \) to form \( f(x) \). Above the lines is where the combination machinery for continuations kicks in. The syntax combines the two pairs of categories by a kind of cancellation: the \( D \) on the left cancels with the \( D \) on the right. The semantics combines the two expressions with gaps by a kind of composition: we plug \( h[ ] \) to the right into the gap of \( g[ ] \) to the left, to form \( g[h[ ]] \). The expression with a gap on the left, \( g[ ] \), always surrounds the expression with a gap on the right, \( h[ ] \), no matter which side supplies the function and which side supplies the argument below the lines. This fact expresses the generalization that the default order of semantic evaluation is left-to-right.

When there is no quantification or anaphora involved, a simple sentence like \textit{John came} is derived as follows.

\[
\left( \begin{array}{ccc}
\text{DP} & \text{DP}\backslash S \\
\text{John} & \text{came} \\
\end{array} \right) = S
\]

In the syntactic layer, as it is usual in categorial grammar, the category under slash (here \( \text{DP} \)) cancels with the category of the argument expression; the semantics is function application.

Quantificational expressions have extra layers on top of their syntactic category and on top of their semantic value, making essential use of the powerful mechanism of continuations in ways proper names or definite descriptions do not. For example, below is the derivation for \textit{A man came}.

\[
\left( \begin{array}{ccc}
\exists x. P(x) & \text{DP}\backslash S \\
\text{x.man} & \text{man came} \\
\end{array} \right) = \exists x. \text{man}(x) \land [ ]
\]

The comparison between the above analysis of “\textit{John came}” and that of “\textit{A man came}” reveals that \textit{came} has been given two distinct values. The first, simpler value is the basic lexical entry, the more complex value being derived through the standard type-shifter Lift, proposed by Partee and Rooth (1983), Jacobson (1999), Steedman (2000), and many others:
Syntactically, Lift adds a layer with arbitrary (but matching!) syntactic categories. Semantically, it adds a layer with empty brackets. In linear notation we have:

\[ \text{Syntactically, } \text{Lift adds a layer with arbitrary (but matching!) syntactic categories. Semantically, it adds a layer with empty brackets. In linear notation we have: } \]

\[ \begin{array}{c}
A \\
expression \\
\text{Lift} \\
x \\
\hline
B | B
\end{array} \]

\[ \frac{A}{x} \]

To derive the syntactic category and a semantic value with no horizontal line, Barker and Shan (2008) introduce the type-shifter Lower. In general, for any category \( A \), any value \( x \), and any semantic expression \( f[[]] \) with a gap, the following type-shifter is available.

\[ \begin{array}{c}
A | S \\
expression + \text{Lower} \\
\frac{A}{x}
\end{array} \]

\[ \frac{f[[]]}{f[x]} \]

Syntactically, Lower cancels an \( S \) above the line to the right with an \( S \) below the line. Semantically, Lower collapses a two-level meaning into a single level by plugging the value \( x \) below the line into the gap \( [ ] \) in the expression \( f[[]] \) above the line. Lower is equivalent to identity function application.

The third and the last type shifter we need is the one that treats binding. Binding is a term used both in logics and in linguistics with analogue (but not identical) meaning. In logics, a variable is said to be bound by an operator (as the universal or existential operators) if the variable is inside the scope of the operator. If a variable is not in the scope of any operator, than the variable is said to be free. In linguistics, a binder may be a constituent such as a proper name (\( \text{John} \)), an indefinite common noun (\( \text{a book} \)), an event or a situation. Anaphoric expressions such as pronouns (\( \text{he, she, it, him, himself} \), etc), definite common nouns (\( \text{the book, the book that John read} \)), demonstrative pronouns (like \( \text{this, that} \), etc), act as variables that take the value of (are bind by) a previous binder. We adopt the idea (in line with Barker and Shan (2008)) that the mechanism of binding is the same as the mechanism of scope taking.

As in most variable-free analyses, the presence of bindable pronouns within a clause affects its syntactic category and its semantic type. For instance the sentence “\( \text{John left.} \)” has category \( t \) and it is closed. The pronominal version, “\( \text{He left.} \)” has the type \( e \rightarrow t \) that indicates that it is not closed. The sentence value depends on the choice of an individual for the referent of \( \text{he} \), as opposed to the standard treatment, where this dependence is handled by relativizing the denotation of an expression to an assignment function that specifies the values of pronouns.

In order to give a proper account of anaphoric relations in discourse, we need to formulate an explicit semantics for both the binder and the anaphoric expressions to be bound. Any DP may act as a binder, as the Bind Rule from Barker and Shan (2008) explicitly states:
At the syntactic level, the Bind rule says that an expression that functions in local context as a DP may look to the right to bind an anaphoric expression (Barker and Shan (2008) encode that by the sign $\Rightarrow$). At the semantic level, the expression transmits (copies) the value of the variable $x$. In linear notation, the semantic part of the Bind rule looks like:

$$\lambda k. f[(k(x))x] \Rightarrow \lambda k. f[(k(x))x]$$

As for the elements that may be bound, Barker and Shan give the following lexical entry for singular pronouns (he, she, it):

$$\frac{DP \Rightarrow S\mid S}{\begin{array}{c} DP \\
he \\
\lambda y. [ ] \\
y
\end{array}}$$

To account for multiple anaphoric expressions (and their binders) or for inverse scope of multiple quantifiers, each binder can occupy a different scope-taking level in the compositional tower. With access to multiple levels, it is easy to handle multiple binders. Analyzing pronouns as two level rules is the same thing as claiming that pronouns take scope (see Dowty 2007), who also advocates treating pronouns as scope-takers). Then, a pronoun or another anaphoric expression chooses its binder by choosing where to take scope. So, distinct scope-taking levels correspond to different binders, layers playing the role of indices: a binder and the pronoun it binds must take effect at the same layer in the compositional tower. A superior level takes scope at inferior levels and left expressions take scope at right expressions, to account for left-to-right natural language order of processing. One pleasant consequence of this fact is that (as usual for variable-free treatments) a single lexical entry for each pronoun will do, rather than needing an unbounded number of pronouns distinguished by inaudible indices.

4.3. Extending the continuations-based semantics from sentence to discourse

We propose here the semantics of cross-sentential punctuation marks “.” and “;”. We do not give the semantics of other cross-sentential punctuation marks such as the imperative “!” or the question mark “?”, with controversial truth values. We only treat assertive (affirmative or negative) sentences, considering “.” and “;” as functions that take two sentence denotations and return a sentence denotation (the conjunction of original sentence denotation):

$$\lambda p \lambda q. p \land q$$

We only take the left context into consideration when interpreting a current sentence, and not both the left and the right context as in de (de Groote’s (2006)).
approach is supported by the empirical observation that the default order of interpretation is left to right. There are some linguistic data (such as cataphora, i.e., an instance of an expression referring to another one located in following utterances) that suggest this default order may be sometimes broken, but we consider them marginal.

For two affirmative sentences with no anaphoric relations and no quantifiers, such as *John came. Mary left*, the derivation trivially proceeds as follows:

\[
\begin{align*}
S & \quad S \backslash \langle S/S \rangle \\
\text{John came} & \quad \lambda p \lambda q. p \land q \\
\text{came} & \quad \lambda p \lambda q. p \land q
\end{align*}
\]

As one sees above, there is no need in this simple case to resort to type shifting at all. Nevertheless, type shifting and the powerful mechanism of continuations are employed when dealing with linguistic side effects such as quantifier scope or binding. Thus, to transmit quantificational or anaphoric information, the denotation lifts accordantly, for example like this:

\[
\begin{align*}
S | S & \quad DP \Rightarrow S | DP \Rightarrow S \\
S \backslash \langle S/S \rangle & \quad \lambda p \lambda q. p \land q \\
[1] & \quad [1]
\end{align*}
\]

To derive the denotation of “*A man came. He whistled*”, type lifting, type lowering and the Bind rule become necessary:

\[
\begin{align*}
S | S & \quad DP \Rightarrow S | DP \Rightarrow S \\
DP / N & \quad \exists x. P(x) \land [1] \\
\lambda P. \exists x. P(x) & \quad \exists x. \text{man}(x) \land [1] \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) & \quad \exists x. \text{man}(x) \\
\text{he} & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) & \quad \exists x. \text{man}(x) \\
\text{he} & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) & \quad \exists x. \text{man}(x) \\
\text{he} & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) & \quad \exists x. \text{man}(x) \\
\text{he} & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]

\[
\begin{align*}
\exists x. \text{man}(x) \land ([1] x) & \quad \exists x. \text{man}(x) \land ([1] x) \\
x & \quad \exists x. \text{man}(x) \land ([1] x)
\end{align*}
\]
Note that the denotations of *came* and *whistled* were also lifted so as to match the ones of *a* and *he*, both being scope-takers. The last equality sign is due to routine lambda conversion.

The picture of relating two sentences is of course much more complex than this. *Dot* and *semicolon* are the most simple means of relating two sentences, which leave implicit the specific rhetorical relation between the two (such as Narration, Result, Background, Elaboration, Explanation, Contrast, Parallel, etc). There are a number of explicit discourse connectors, such as *but, also, on the one hand, on the other, so, because, when, nevertheless*, etc. that determine the possible rhetorical relations between the two sentences they relate. In turn, each rhetorical relation has linguistic side effects such as constraining the possible antecedent for pronominal anaphora. We will deal with some of these phenomena in Handling Hierarchical Discourse Structure section.

### 4.4. Handling negation

Negation generally cannot take scope outside the verb phrase it modifies. We give *not* the following denotation:

\[
\frac{S \mid S}{(DP \backslash S) \backslash (DP \backslash S)}
\]

\[
\begin{array}{c}
\text{not} \\
\hline
\neg[[]] \\
[]
\end{array}
\]

This means that negation functions in local context as a verb modifier and takes scope at a sentence to give a sentence. Now, one obtains the following denotation of *John does not own a car*:

\[
\frac{S \mid S}{DP}
\]

\[
\begin{array}{c}
\text{John} \\
[[]] \\
j
\end{array}
\]

\[
\frac{S \mid S}{DP}
\]

\[
\begin{array}{c}
\text{not} \\
\neg[[]] \\
[]
\end{array}
\]

\[
\frac{S \mid S}{own}
\]

\[
\begin{array}{c}
\text{a car} \\
\neg[[]] \\
[]
\end{array}
\]

\[
\frac{S \mid S}{\exists x. \text{car}(x) \land [x]}
\]

\[
\frac{S \mid S}{own}
\]

\[
\begin{array}{c}
\text{x} \\
\neg[[]] \\
[]
\end{array}
\]

\[
\frac{S \mid S}{S}
\]

\[
\begin{array}{c}
\text{John not own a car} \\
\neg([\exists x. \text{car}(x) \land [x]]) \\
\neg([\exists x. \text{car}(x) \land own \land x \land j])
\end{array}
\]

which means that there is no car that John owns, a fair approximation of the denotation of the intended meaning.

If we do not restrict the possible scope of negation, continuing the discourse with the sentence “*It is red*”, could result in the following wrong derivation:
which means that it can refer back to a car. In fact, if we do not restrict the possible scope of negation, any following sentence may be wrongly interpreted inside the scope of negation. Thus, one needs to force the scope closing of not immediately after the interpretation of its minimal clause, by applying Lower. This also closes the scope of any other DP inside the scope of negation, so it becomes impossible for it to bind (transmit its value to) subsequent anaphoric expressions. Thus, the interpretation followed by “It is red” crashes. This also has the pleasant effect of allowing the subject of the sentence to bind subsequent anaphora. To exemplify, we give the derivations of “John does not own a car. *It is red" and “A student did not knocked. He entered”:

\[
\begin{align*}
S|\text{DP} & \Rightarrow S \\
\text{John not own a car} & \Rightarrow S(S/S) \\
(\exists x. \text{car}(x) \land \text{own } x ) & \Rightarrow \lambda y. [ \text{is red } y ] \\
\Rightarrow & \text{John not own a car. It is red } \\
\Rightarrow & \neg ((\exists x. \text{car}(x) \land \lambda y. [ \text{own } x ] \land \text{is red } y )) \\
\end{align*}
\]

To obtain the above derivation, as soon as the verb phrase under negation was interpreted, we closed the scope of negation by applying Lower, then we lifted the denotation of not knocked to match the levels of a student.

Negation takes wide scope over other possible scope takers in the verb phrase it negates (like a man or every man in direct object position). The interpretation of “John does not own a car” in which the existential quantifier takes wide scope over the negation (there is a car that John does not own) is impossible in natural language, possibly because it is pragmatically ruled out by the fact that it is too uninformative. The right (preferred)
interpretation is obviously the one in which negation takes scope over the existential quantifier.

There are nevertheless lexical entries like definite descriptions (such as John, the men, the man who entered) that, when in direct object position of a negated verb phrase, may take wide scope over negation and thus bind subsequent anaphora. For instance, here it is the derivation of “Mary does not like John. He is rude”:

\[
\begin{array}{c}
S|S \\
\hline
S|S \\
\hline
S|S \\
\hline
S|S \\
\hline
S|S
\end{array}
\]

\[
\begin{array}{c}
\text{Mary} \\
\hline
\text{not} \\
\hline
\text{like} \\
\hline
\text{John}
\end{array}
\]

\[
\begin{array}{c}
\llbracket \\
\hline
\llbracket \\
\hline
\llbracket \\
\hline
\llbracket
\end{array}
\]

\[
\begin{array}{c}
\text{like} \\
\hline
\text{J}
\end{array}
\]

\[
\begin{array}{c}
S|DP \Rightarrow S \\
\hline
S|S \\
\hline
S
\end{array}
\]

\[
\begin{array}{c}
\text{Mary not like John Lower} \\
\hline
\text{Mary not like John}
\end{array}
\]

\[
\begin{array}{c}
\llbracket \\
\hline
\llbracket \\
\hline
\llbracket \\
\hline
\llbracket
\end{array}
\]

\[
\begin{array}{c}
\text{like J m} \\
\hline
\text{like J m}
\end{array}
\]

\[
\begin{array}{c}
S|DP \Rightarrow S \\
\hline
S|S \\
\hline
S|S \\
\hline
S|S
\end{array}
\]

\[
\begin{array}{c}
\text{Mary not like John} \\
\hline
\text{He is rude Lower} \\
\llbracket \\
\hline
\llbracket \\
\hline
\llbracket \\
\hline
\llbracket
\end{array}
\]

\[
\begin{array}{c}
\text{Mary not like John. He is rude} \\
\hline
\lambda y. \neg (\text{like J m} \land \text{is rude J})
\end{array}
\]

To conclude, allowing arbitrary type shifting will result in overgenerating interpretations impossible in natural language. To filter out these impossible (wrong) interpretations, we need to understand the scope behaviour of each scope-taking lexical entry: its maximal scope limits and the scope precedence preferences w.r.t. other lexical entries situated inside its syntactic scope. This means that getting right the scope of all lexical entries in a discourse automatically yields the right discourse truth conditions. For instance, in the case of negation, its maximal scope limits are its clause boundaries. The scope precedence preferences of negation w.r.t. some other relevant lexical entries are not > indefinites, not > every, not < definite descriptions, not < any.

4.5. Conditionals

In natural languages there are lexical entries like if (then), suppose or assume that introduce a conditional relation between a suppositional part and a hypothetically asserted part (usually called the antecedent and the consequent). At the sentence level, Barker and Shan (2008) give the following lexical entry for if:
Crucially, in the semantic value, the outer negation is above the line, where it can take scope over the entire conditional. The conjunction and the inner negation are below the line, where they can distinguish the antecedent from the consequent.

At the discourse level, as opposed to negation, the scope of the consequent may extend over the sentence boundaries. For example, in “If John owns a book on semantics, he uses it. He also recommends it”, the consequent stretches over the second sentence. The general mechanism of how a language user perceives the logical and rhetorical structure of a discourse is still poorly understood and very far from being solved. Nevertheless, it is certain that a language user knows exactly where the scope of a consequent begins and where it ends. In order to model this kind of conditionals with no a priori delimited scope of the consequent, we give the following lexical entry for if:

\[
\frac{S|S}{\lambda \rho \lambda q. p \land \neg q}
\]

\[
\frac{S|S}{\frac{S|\neg S}{S}}
\]

\[
\frac{\neg [\cdot]}{if}
\]

The gap in the upper layer of the semantic level delimits the scope of the entire conditional; \( p \) is the antecedent (supposing that the scope of the antecedent is fixed) and the gap of the second layer represents the scope of the consequent. We give here the derivation for the above discourse (ignoring also for simplicity, although it has an obvious contribution in signalling the extension of the consequent). Note that the upper four layers in the syntactic and semantic layer are used to transmit values from the DP binders John and a book on semantics to the four subsequent anaphoric pronouns he, it, he, it. Remember that distinct scope-taking levels correspond to different binders: a binder and the pronoun it binds must take effect at the same layer in the compositional tower.
This interpretation is a fair approximation of the upper discourse meaning. Observe that after applying the first time Lower, the scope of the consequent “He uses it. He recommends it” closes; this has the effect of closing the scope of every expression inside the consequent, making impossible the transmission of values to possible subsequent anaphoric expressions (for instance like in “If John owns a book on semantics, he uses it. He also recommends it” / *It is red*).

The same strategy may be applied to account for cases where the antecedent stretches over several sentences, in discourses such as: Suppose....And suppose....Then....
4.6. Quantifiers

The puzzling scope behaviour of quantificational determiners is far from being settled, in spite of the abundant research in the area. The most well-known and largely accepted view of natural language quantification is the generalized quantifiers view (Montague 1970, Barwise and Cooper 1981, Larson and Segal 1995, Keenan 2002, Martin van den Berg 1996, Brasoveanu 2007). The generalized quantifier type $\langle\langle e,t\rangle,t\rangle,t\rangle$ is exactly the type of quantificational determiners in continuation-based semantics. This is by no means a coincidence, generalized quantifiers approach only continuizes the noun phrase meanings rather than continuizing uniformly throughout the grammar as it is done in continuation-based semantics.

A tradition going back at least to Evans (1977) and May (1977) says that the scope of all quantifiers is clause bounded. An E-type (or donkey) pronoun is a pronoun that lies outside the restrictor of a quantifier or outside the antecedent of a conditional, yet co-varies with some quantificational element inside it, usually an indefinite. Here there are some of the famous donkey sentences examples:

“If a farmer owns a donkey, he beats it.”

“Every farmer who owns a donkey beats it.”

Evans (1977) made it standard to assume that the indefinite a donkey cannot take scope over the pronoun it, and therefore cannot bind it, at least not in the ordinary sense of binding. To the contrary, as Barker and Shan (2008) put forward, the relationship between a donkey and it in the above examples seems like binding because it is just binding. In what follows, we adopt the idea that the binding can only occur inside the scope of the binder (all binding is in-scope binding). We account for a wide range of linguistic data involving quantification and anaphora binding.

4.6.1. Singular quantifiers

We use the term singular quantificational determiners to refer to quantificational determiners that take as arguments singular common nouns, such as a, every, any, each or no. We will not commit ourselves to the hypothesis that the scope of all quantifiers is clause bounded. The important assumption here is that the binding can only occur inside the scope of the binder (all binding is in-scope binding). Indefinites are notorious for their binding capabilities outside their minimal clause, as opposed to the quantificational determiners every, any or no. Thus, one may say that the quantificational determiner a (that combines in English with a common noun to form an indefinite) can take scope outside its minimal clause, whereas every, any and no cannot.

Shan & Barker (2008) propose the following lexical entry for every:

\[
\begin{array}{c}
\text{S}|\text{S} \\
\text{S}|\text{S} \\
\text{DP} / \text{N} \\
\text{every} \\
\neg \exists x. [ ] \\
\lambda P, P(x) \land \neg [ ]
\end{array}
\]

Here, the authors apply the idea of distinguishing between the entire scope of a quantifier, its restrictor scope and its nuclear scope. The gap in the top layer of the semantic component of every indicates the entire scope of the quantifier. The variable $P$ is the restrictor and the negated gap delimits the nuclear scope.
As Barker and Shan (2008) rightfully note, there is no obvious semantic reason why *every* cannot extend its scope outside its minimal clause. They presume it must be a syntactic reason. We assume there are two different meanings of *every*, exemplified by the two examples:

“Every man came. *He whistled*” (distributional meaning)

“Every man loves a woman. He gives her flowers to prove it to her” (generic, universal meaning)

The use of *every* from the first example means “all men came”, whereas the second meaning is generic and may be paraphrased as “for any way of choosing a particular man,…”. We leave implicit here the mechanism for deciding which meaning is intended in a particular case.

The stipulation that *every* is polymorphic (it has two different meanings) is supported cross-linguistically by the fact that in the two examples above, *every* translates in Romanian by two different quantificational determiners: the distributional ‘*fiecare*’ and the generic ‘*oricare*’, respectively and not vice-versa.

The use of logically equivalent form in terms of existential quantifier and negation is just a matter of convenience (to have only existential quantification and negation in logical forms); we could have just as well used the lexical entry for *every* in explicit terms of universal quantification like:

\[
\begin{align*}
S[S] & \\
S[S] & DP/N \\
& every \\
& \forall x. \, [ ] \\
\lambda P. & P(x) \rightarrow [ ] \\
& x
\end{align*}
\]

The generic use of *every* may be modeled by choice functions; we propose the following lexical entry for the generic use of *every*:

\[
\begin{align*}
S[S] & \\
S[S] & DP/N \\
& every \\
& \neg \exists f. \, [ ] \\
\lambda P. & \neg [ ] \\
& f(P)
\end{align*}
\]

where \( f \) is a function that takes a property and returns a constant (an individual), thus of type \(<<e,t>,e>\). It is necessary to consider only those functions that map each (non-empty) set to a member of that set. This and other technical details can be found in (Egli 1995). As we have assumed that a binder can bind an anaphoric expression only inside its scope, it is natural to say that in such cases the nuclear scope of choice-function *every* extends to the following sentence. The singular pronoun refers back to the particular man \( f(man) \), thus a constant. Here is the interpretation of the upper example:
The lexical entry for plural common nouns will be introduced in the Plural Quantifiers section. So, for now, we do not pause to explain the semantics of flowers used here.
This interpretation is intuitive enough, because a paraphrase for the upper discourse is “for every way of choosing a man there is a woman this man loves and there are some flowers this man gives to the woman”.

We can give the related quantificational determiner any a similar lexical entry; the interpretative difference between every and any is made (in line with Quine and Geach among others) by the scope behavior of the two quantificational determiners. Any prefers to take wide scope, whereas every prefers to take narrow scope. The most common use of any is in negative sentences (any is a negative polarity item) and questions. Examine for instance the two sentences:

“John does not know every poem.”

“John does not know any poem.”

The difference in meaning between the two sentences is given by the scope preferences of the two quantificational determiners.
which means that there is at least one poem that John does not know, a fair approximation of the intended meaning.
which means that there is no poem that John knows, also a fare approximation of the intended meaning.

When used in negative context, due to the fact that any semantically implies nonexistence, it cannot take scope outside its minimal clause, exactly like not and no. For instance, consider: “John does not know any poem. *It is nice.”

We have to ensure the scope closing in the usual way, by applying Lower Rule immediately after the interpretation of its minimal clause. It cannot be argued that it is the negation which prevents further referring to any poem, because any takes wide scope over negation.

Notice that there is a third intermediate possibility of scope taking, with negation taking scope at the second level of the compositional tower:

\[
\begin{align*}
S & \rightarrow \frac{S|S}{S|S} \\
S & \rightarrow \frac{\neg[S]}{\neg[S]} \\
S & \rightarrow \frac{\neg[(S) / (S)]}{\neg[(S) / (S)]} \\
S & \rightarrow \frac{\neg[(S) / (S)] / S}{\neg[(S) / (S)] / S} \\
S & \rightarrow \frac{\neg[(S) / (S)] / S}{\neg[(S) / (S)] / S}
\end{align*}
\]

\[
\begin{align*}
\neg \exists x. [(\neg poem(x) \land \neg know x) J] \\
\equiv John not know any poem \\
\neg \exists x. [(\neg poem(x) \land \neg know x) J] \\
\equiv John does not know any poem
\end{align*}
\]

This interpretation is impossible in natural language. Thus, one may say that any obligatory takes wide scope over negation not only with its general (first level) scope, but also with its nuclear scope.

The quantificational determiner each is very similar to every. There has been said that each is “more distributional” than every. Specifically, all the occurrences of each may be replaced by occurrences of every, without losing the grammaticality, but not the other way around. Every requires some distributivity, while each requires a total form of distributivity (where there is a significant individual difference between the objects over which each distributes). Arguably, it seems that events or situations or possible worlds are involved in distinguishing the semantics of every and each.

Another interesting quantificational determiner is no, for which we propose the following lexical entry:

\[
\begin{align*}
S & \rightarrow \frac{\neg \exists x. [P(x) \land [J]]}{\neg \exists x. [P(x) \land [J]]}
\end{align*}
\]
To exemplify, the sentence “No man came” has the following derivation:

\[
\lambda P. \exists x. (Px \land [:]) \quad \text{man} \quad \text{came} = \quad \neg \exists x. (\text{man} \times \land [:]) \quad \text{x} \quad \text{came} \quad \neg \exists x. (\text{man} \times \land [:]) \\
\]

As in the case of not, we have to force the closing of no’s minimal clause, by applying Lower immediately after the interpretation of that clause, in order to disallow subsequent anaphoric reference as in “No man came. *He whistled”.

It is worth mentioning that when a quantificational determiner such as a, every, any or no appears in a DP having direct object position, no type mismatch occurs and the quantificational determiner is smoothly interpreted in situ without any further stipulations, as opposed to other theories in which such a type mismatch has to be fixed (for example by quantifier raising rule in QR theory). For instance, here is the derivation of “John saw no man”:

\[
\lambda P. \exists x. (Px \land [:]) \quad \text{j} \quad \text{saw} = \quad \neg \exists x. (\text{man} \times \land [:]) \quad \text{x} \\
\quad = \quad \text{John saw no man} \quad \text{Lower} \quad \neg \exists x. (\text{man} \times \land [:]) \\
\quad \neg \exists x. (\text{man} \times \land [:]) \\
\]

### 4.6.2. Plural quantifiers

There is a vast literature on representing plurals. We will only refer to four of the most influential existing approaches: the proposals of Scha (1981), Link (1983), Roberts (1987) and of Verkuyl and van der Does (1991).

Plural quantificational determiners take as arguments plural common nouns. Plural quantificational determiners (among other constructions such as coordinated DPs or singular DPs), introduce plural referring variables. From a technical point of view, a plural referring variable notated with upper letters (X, Y, Z...) is a set of entities.

We will give lexical entries for the plural quantificational determiners some (not to be confused with its singular counterpart), all and most, in the continuation semantics framework. Some and most need special care when the plural variable they introduce binds some subsequent anaphora, due to the so-called maximality constraint. While Some kids came (with no other subsequent anaphor that refers to the kids that came) means that there is a set of any cardinal of kids that came, the discourse “Some kids came. They played” means that there is a maximal set of kids who came and that maximal set played. So, there is a maximality operator that blocks further transmission of arbitrary sets, much like the
negation blocks transmission of values of indefinites in direct object position to subsequent anaphora. The two uses of *some* have different truth-conditions. When *some* is used in the first, weak sense, we take it to have the following lexical entry:

\[
\frac{S|S}{Dpt/Na}\   \frac{\exists X. (|X| \geq 1 \land P(X) \land [\_])}{some}\    \lambda P. \frac{X}{X} 
\]

Then, we have to force the scope closing of the variable \(X\) in the usual way by applying Lower, in order to forbid it to bind subsequent anaphora (transmit a non-maximal value).

When used in the second, maximal sense, that exports a maximal set to bind a subsequent anaphora (such as *they*), we take *some* to have the alternative lexical entry:

\[
\frac{S|S}{Dpt/Na}\   \frac{\exists X. (|X| \geq 1 \land [\_]X)}{some}\    \lambda P. \frac{X = \text{argmax}_Y \{|Y: P(Y) \land [\_]|Y\}}{X} 
\]

Note that we could have not used in this case the regular Bind rule, because of the intervening level that contains argmax. This level blocks the transmission of variable \(Y\) and only lets the maximal variable \(X\) to bind subsequent anaphora.

For the same reasons, we similarly treat the quantificational determiner *most*, for which we propose the following two alternative lexical entries, one for the weak sense, and one for binding sense, respectively:

\[
\frac{S|S}{Dpt/Na}\   \frac{\exists X. P(X) \land [\_] \land 2|X| \geq \{|x:Px|\}}{most}\    \lambda P. \frac{X}{X} 
\]

\[
\frac{S|S}{Dpt/Na}\   \frac{\exists X. 2|X| \geq \{|x:Px|\}}{most}\    \lambda P. \frac{X = \text{argmax}_Y \{|Y: P(Y) \land [\_]|Y\}}{X} 
\]

For the quantificational determiner *all*, the maximality condition has limited scope only over the restrictor \(P\), thus we can give it a single lexical entry:

\[
\frac{S|S}{Dpt/Na}\   \frac{\exists X. (X = \text{argmax}_Y \{|Y: P(Y)|\}) \land [\_])}{all}\    \lambda P. \frac{X}{X} 
\]

It has been argued that *all* is not a quantificational determiner proper, but more like a modifier. It may be for that reason that it behaves differently compared to genuine quantificational determiners.
We turn now to the problem of compositionally obtaining the meaning of bare plurals. Bare plurals are plurals without overt article. Sentences with bare plurals can have existential (“John gave Mary flowers”) and universal or generic (“Flowers are beautiful”) readings. We propose that the existential reading is accounted for in this framework by a silent quantificational determiner that has the same semantics as some (i.e. the two weak and maximal senses). The universal reading is accounted for by a similar silent quantificational determiner, having the semantics of all:

\[
\frac{S[S]}{DP_{pl}} / N_{pl}^{pl} \quad \phi \\
\lambda P, \exists X. (X = arg\max Y [Y \cdot P(Y)]) \wedge [\ ]
\]

We take predicate to be distributive or collective (see Distributivity chapter), so they are responsible for deriving the right truth-conditions (in “John gave Mary flowers”, gave is used in its collective sense for its second argument; in “Flowers are beautiful”, is beautiful is used in its distributive sense in its first argument.)

Cardinal determiners have two built-in meaning components: an existential component and a cardinality one. We propose the following two alternative lexical entries for card, one for the meaning there are card Ps…, the other for the meaning there are exactly card Ps…:

\[
\frac{S[S]}{DP_{pl}} / N_{pl}^{pl} \quad \text{card} \\
\lambda P, \exists X. |X| = \text{card} \wedge P(X) \wedge [\ ]
\]

and

\[
\frac{S[S]}{DP_{pl}} / N_{pl}^{pl} \quad \text{card} \\
\lambda P, \exists X. [X] = \text{card}
\]

The semantic ambiguity between the two lexical entries of a cardinal card is determined by whether the scope of the following context (continuation) lies inside the scope of the cardinality (as in the second entry) or not (as in the first entry).

Both these (weak and strong) meanings of the cardinals may bind subsequent anaphora (as opposed to the case of some that can bind only with its maximal meaning). For the weak meaning, we can just use the regular Bind rule, whereas for the strong meaning (exactly card), one cannot use Bind because that would bring the continuation into the scope of argmax, altering the truth conditions. Thus, we have to force the scope closing of argmax immediately after the interpretation of the cardinal’s minimal clause by applying Lower. To allow the strong meaning of card to bind, we have to give it jet another lexical entry:

\[
\frac{S[DP_{pl} \triangleright S]}{DP_{pl}} / N_{pl}^{pl} \quad \text{card} \\
\lambda P, \exists X. [X] = \text{card}
\]

These representations are not completely satisfying because the lexical ambiguity of plural quantificational determiners generates an explosion of ambiguous representation of
the discourse in which the determiners are used. We leave the problem of finding a more general solution for a unitar representation of the plural quantificational determiners *some, most* and cardinals for further research.

### 4.6.2.1. Distributive vs. Collective Readings

We will consider two of the most influential existing strategies to deal with plurals and their associated ambiguities (collective, distributive or cumulative readings): Scha (1981) and Link (1983, 1991). Scha and Link locate the source for the ambiguity of plural sentences differently. According to Scha the ambiguity between collective, distributive and possibly other readings is located in the plural noun phrase or more precisely in the determiner. According to Link, noun phrases are unambiguous and the readings should be generated within the verb phrase. A third strategy proposes that readings of complex sentences are a result of the whole structure or as Roberts (1987, p. 100) puts it: “Distributivity is a property of predications, combinations of a subject and a predicate. The readings can be triggered by different elements of a sentence; there is a functional interplay between the different categories.”

We will take *predicates*, not nouns to be distributive, collective, or ambiguous. We will not commit ourselves to whether the distributivity comes as a feature from the lexical semantics, or it is entailed from the world knowledge and the sense of the predicate itself (Roberts 1987).

Here are some examples:

- “Sue and Mary are pregnant.” (*be pregnant* is a distributive predicate)
- “John and Bill moved the piano.” (*moved* is an ambiguous (between distributive and collective) predicate)
- “The students gathered in the square.” (*gathered* is a collective predicate)

As a general rule, we posit that a distributive predicate $P_{\text{dist}}$ is true of a plural referring variable $X={x_1, x_2, \ldots x_n}$ iff $P_{\text{dist}}(x_1) \land P_{\text{dist}}(x_2) \land \ldots \land P_{\text{dist}}(x_n)$. And a collective predicate $P_{\text{coll}}$ is true of a plural referring variable $X={x_1, x_2, \ldots x_n}$ iff $P_{\text{coll}}(x_1 \land x_2 \ldots \land x_n)$. Note that a predicate may have multiple arguments (subject and direct object, for instance). So a predicate may be distributive or collective in each of the arguments.

### 4.6.2.2. Coordination: Conjunction and Disjunction

Barker (2002) proposes the following lexical entry for *or*:

\[ (A\ S)_{or} /A \]

\[ \lambda R . \lambda L . (\lambda k . (k(L) \lor k(R)) (\lambda x . [ ])) / x \]

The lexical entry for *or* is polymorphic: $A$ can be any category, such as $DP$, $DP \ S$ (verb phrases), $DP \ DP$ (adjectives) or $S$ (sentence). Partee and Rooth (1983) are the first to suggest allowing phrases like John or Bill to introduce new variables.

We point that disjunction may introduce only singular variables, as we can see from the following examples:

- “John owns a donkey or a goat. He beats it/* them.”
- “John or Bill called. He/* They hang up.”

We straightforwardly extend Shan and Barker’s (2008) semantic representation for disjunction to conjunction:
Note that \textit{and} is also polymorphic. Thus it may account for discourses like: \textit{“John drinks and talks. He does this for hours”} where \textit{this} is anaphoric to plural events, provided only we modify the binding rule to allow categories other then \textit{DP} (like \textit{DPs}) to bind subsequent pronouns. Note also that conjoined \textit{DP}s have the power to introduce variables that may be further referred by plural pronouns, a power disjoint \textit{DP}s do not have. To illustrate this, consider the following examples:

\begin{quote}
\textit{“John owns a donkey and a goat. He beats it/them.”} \\
\textit{“John and Bill called. He/They hang up.”}
\end{quote}

4.6.2.3. Plural pronominal anaphora

Ideally, singular and plural pronominal anaphora should behave similarly and be parallel phenomena. Unfortunately, at a closer look, there are striking differences between the anaphoric properties of singular and plural pronouns. On the one hand, only singular \textit{DP}s have the power to introduce singular variables that could bind subsequent singular pronominal anaphora. On the other, plural variables may be introduced not only by plural \textit{DP}s, but also by:

- Two or more singular \textit{DP}s, coordinated (“\textit{John and Mary came. They whistled}”) or not (“\textit{John took Mary to Acapulco. They had a lousy time}”),
- Quantificational singular \textit{DP}s (“\textit{Every man came. They whistled}” or “\textit{A kid climbed every tree. They were full of energy}”).

We first treat the simplest case, that of plural entities introduction by plural \textit{DP}s (analogous to singular entity introduction). Plural \textit{DP}s are formed of plural quantificational determiners such as \textit{some}, \textit{all} or \textit{most} and a plural common noun required as argument by the determiner. We take singular common nouns to be functions (properties) of individual variables \(x\), while plural common nouns expect a plural individual variable \(X\). Thus, for such (non-specific) antecedents of \textit{they}, we may use the following lexical entry:

\[
\frac{DP^{pl} \models \text{S|S}}{\text{they}}
\]

Here is the derivation for \textit{“Some kids came. They played”}:

\[
\frac{S|DP^{pl} \models \text{S}}{S|S \models DP^{pl}/N^{pl}} \quad \frac{DP^{pl} \models \text{S|DP^{pl} \models S}}{\exists X. |X| \geq 1 \land [\ ]X}
\]

\[
\frac{DP^{pl} \models \text{S|DP^{pl} \models S}}{\lambda X. \alpha \max_{Y}[Y : P(Y) \land [\ ]]} \quad \frac{DP^{pl} \models \text{S|DP^{pl} \models S}}{\lambda X. \alpha \max_{Y}[Y : P(Y) \land [\ ]]} \quad \frac{DP^{pl} \models \text{S|DP^{pl} \models S}}{\lambda X. \alpha \max_{Y}[Y : P(Y) \land [\ ]]} \quad \frac{DP^{pl} \models \text{S|DP^{pl} \models S}}{\lambda X. \alpha \max_{Y}[Y : P(Y) \land [\ ]]}
\]
which amounts to saying that there is a plural entity \( X \) of cardinality at least one, formed of all the kids that came and that plural entity \( X \) played.

For “Most kids came. They played”, the derivation is:

\[
\frac{S \mid D_{\text{pl}} \,
\Rightarrow \, S}{S \mid D_{\text{pl}} \,
\Rightarrow \, S}
\]

\[
\text{some kids came}
\]

\[
\exists X. |X| \geq 1 \land \{X\}
\]

\[
X = \arg \max_Y \{\{Y: \text{kids}(Y) \land \text{came } Y\}\}
\]

\[
\frac{S \mid D_{\text{pl}} \,
\Rightarrow \, S}{S \mid D_{\text{pl}} \,
\Rightarrow \, S}
\]

\[
\text{some kids came}
\]

\[
\exists X. |X| \geq 1 \land \{X\}
\]

\[
X = \arg \max_Y \{\{Y: \text{kids}(Y) \land \text{came } Y\}\}
\]

\[
\frac{S \mid D_{\text{pl}} \,
\Rightarrow \, S}{S \mid D_{\text{pl}} \,
\Rightarrow \, S}
\]

\[
\text{they played}
\]

\[
\lambda Z. \{Z\}
\]

\[
\text{played } Z
\]

\[
\frac{S \mid S \,
\Rightarrow \, S}{S \mid S \,
\Rightarrow \, S}
\]

\[
\text{some kids came. they played}
\]

\[
\exists X. |X| \geq 1 \land \lambda Z. \{Z\}
\]

\[
X = \arg \max_Y \{\{Y: \text{kids}(Y) \land \text{came } Y\} \land \text{played } Z\}
\]

\[
\frac{S \mid S \,
\Rightarrow \, S}{S \mid S \,
\Rightarrow \, S}
\]

\[
\text{some kids came. they played}
\]

\[
\exists X. |X| \geq 1 \land \lambda Z. \{X\}
\]

\[
X = \arg \max_Y \{\{Y: \text{kids}(Y) \land \text{came } Y\} \land \text{played } Z\}
\]

\[
\frac{S \mid S \,
\Rightarrow \, S}{S \mid S \,
\Rightarrow \, S}
\]

\[
\text{some kids came. they played}
\]

\[
\exists X. |X| \geq 1 \land \lambda Z. \{X\}
\]

\[
X = \arg \max_Y \{\{Y: \text{kids}(Y) \land \text{came } Y\} \land \text{played } X\}
\]
which amounts to saying that there is a plural entity $X$ of cardinality more than half of the cardinality of the set of all kids, and this entity $X$ is the set of all the kids that came and that entity $X$ played.

The derivation for “All kids came. They played” is:

\[
\frac{S|D^p \Rightarrow S}{S|D^p \Rightarrow S} \quad \frac{S \backslash (S/S)}{S} \quad \frac{S \backslash (S/S)}{S} \quad \frac{S \backslash (S/S)}{S} \quad \frac{S \backslash (S/S)}{S}
\]

\[
\text{most kids came} \quad \exists X. 2|X| \geq |\{x: Px]\} \wedge \lambda Z. [\lambda X \exists Y \text{ kids}(Y) \wedge \text{came } Y]\wedge \text{played } Z
\]

\[
\frac{S|S}{S} \quad \frac{S|D^p \Rightarrow S}{S|D^p \Rightarrow S} \quad \frac{S|D^p \Rightarrow S}{S|D^p \Rightarrow S} \quad \frac{S|D^p \Rightarrow S}{S|D^p \Rightarrow S}
\]

\[
\text{most kids came} \quad \exists X. 2|X| \geq |\{x: Px]\} \wedge \lambda Z. [\lambda X \exists Y \text{ kids}(Y) \wedge \text{came } Y]\wedge \text{played } Z
\]

\[
\frac{S}{S} \quad \frac{S}{S} \quad \frac{S}{S} \quad \frac{S}{S} \quad \frac{S}{S} \quad \frac{S}{S} \quad \frac{S}{S} \quad \frac{S}{S}
\]

\[
\exists X. (X = \arg \max Y \text{ kids}(Y)) \wedge \lambda X \exists Y \text{ kids}(Y) \wedge \text{came } Y\wedge \text{played } Z
\]

\[
\exists X. (X = \arg \max Y \text{ kids}(Y)) \wedge \lambda X \exists Y \text{ kids}(Y) \wedge \text{came } Y\wedge \text{played } Z
\]
which amounts to saying that there is a plural entity formed of all the kids and that entity came and played.

As for the plural anaphora introduced by cardinal determiners, consider the following two examples:

“Five men walk in the park. They watch the birds” (preferred reading: there are some context relevant five men and they walk in the park and they watch the birds; there could be other not contextually important men walking and watching);

“Five men walk in the park and watch the birds” (preferred reading: there are exactly five men who are in the park and watch the birds).

Evans (1977) gave this sort of examples and others (such as the donkey-sentences) to assert that there are two types of pronouns: bound-pronouns (as in the second example) and E-type pronouns (as in the first one). He assumes that quantifiers cannot extend their scope over clause boundaries. We already argued that this is not the case (in line with Barker and Shan (2008)) at least for indefinites. Cardinals are also good examples of quantificational determiners that may extend their scope over their minimal clause limits. For the above examples, what happens is that both are semantically ambiguous between two readings which correspond to the two scope-distinct lexical entries for the cardinal determiner five. Pragmatic reasons dictate the preferred reading in each case. We give the derivations of these preferred readings (and skip the not preferred ones, though semantically possible), ignoring the full interpretation of walk in the park and of watch the birds:

\[
\begin{align*}
S &\vdash S \\
D_{\text{pl}} &\vdash S \\
\text{five men} &\vdash S \\
\exists X. |X| = 5 \land \text{men}(X) \land [ ]X &\vdash \text{walk in the park} \\
&\vdash S \\
\exists X. |X| = 5 \land \text{men}(X) \land [ ]X &\vdash \text{walk in the park} \\
\end{align*}
\]

\[
\begin{align*}
D_{\text{pl}} &\vdash S \\
\text{five men walk in the park} &\vdash S \\
\exists X. |X| = 5 \land \text{men}(X) \land [ ]X &\vdash \text{walk in the park} \\
&\vdash S \\
\exists X. |X| = 5 \land \text{men}(X) \land [ ]X &\vdash \text{walk in the park} \\
\end{align*}
\]

\[
\begin{align*}
S &\vdash S \\
\text{they watch the birds} &\vdash S \\
\lambda Y. [ ] &\vdash \text{watch the birds} \\
&\vdash S \\
\exists X. |X| = 5 \land \text{men}(X) \land \lambda Y. [ ]X &\vdash \text{walk in the park} \land \text{watch the birds} \\
\end{align*}
\]
\[ \begin{align*}
\text{which means that is a set of cardinality five composed of men who walk in the park and watch the birds.} \\
\arg\max_x \{X : \text{men}(X) \land [\ ]\} = 5
\end{align*} \]

which means there are exactly five men in the park who watch the birds.

We turn now to the case of introducing plural entities by coordination (conjunction or disjunction). The lexical entry for conjunction obviously gives right truth conditions and offers an antecedent for subsequent anaphora, as in, for example: “John and Mary came. They whistled”. In such cases, where more than one specific antecedent is present in the discourse, the lexical entry for they needs to search left for two (or three, or another number) DPs, for instance:
The last equality is due to the fact that we take the predicate *whistled* to be distributive (as opposed to collective).
What about referring to determiner phrases that are not in a coordination relation (by conjunction) like: “John met Mary. They smiled”? The mechanism of transmitting more than one value of the antecedent to the plural anaphoric pronoun they is the same:
Again, the predicate \textit{smiled} is taken to be distributive.

Note that reversing the order of Binding and Lifting for the two DPs gives the denotation $\text{met } m \land \text{smiled } (m \land j)$. As usual, the layers act like indices; a superior level takes scope at inferior levels and left expressions take scope at right expressions, to account for left-to-right natural language order of processing.

An open problem still remains: how to block "\textit{John or Bill called. *They hang up}"? The third case, the case of introducing plural entities by singular DPs is the most difficult. We will stipulate that a singular DP may bind a plural entity (introduced by a pronoun or a definite) if and only if it is logically a plural, that is:

1. Either the singular DP is bound by universal quantifier,
2. Or the singular DP is embedded inside an expression in which it co-varies with a variable bound by the universal quantifier (the so-called structural dependency).

Consider the following example, in which the DP \textit{every man} is universally quantified: "\textit{Every man came. They whistled}". We give it the following derivation:

$$
\begin{align*}
\frac{\frac{\frac{\frac{\frac{\text{John met Mary. they smiled}}{\lambda y. [\text{smiled}]}}{\lambda x. [\text{met} \ j \land \text{smiled}(x) \land \text{smiled}(y)}}}{\text{met } m \land \text{smiled } (m \land j)}}{\lambda y. [\text{smiled}]}{\lambda x. [\text{met} \ j \land \text{smiled}]}{\text{John met Mary. they smiled}}}{\text{Lower twice}}
\end{align*}
$$
To exemplify the case in which the binding DP is embedded inside an expression in which it co-varies with a variable bound by the universal, consider the following examples:

“A kid climbed every tree.” followed by
“He was full of energy.” or
“They were full of energy.”

Note that the first sentence has two distinct readings, one in which a takes scope over every and one in which every takes scope over a. If the first sentence is continued by the second, then the only possible reading in natural language becomes that with a taking scope over every. If the first sentence is continued by the third, then the only possible reading in natural language becomes that with every taking scope over a. Ignoring the tense, for simplicity, the interpretations where every takes narrow scope is:

\[
\begin{align*}
\text{every man came. they whistled} & \quad \Rightarrow \\
\rightarrow \exists x. [\, ] & \\
\text{man}(x) \wedge \neg(\lambda y. [\, ]x) & \\
came x \wedge \text{whistled } Y & \\
\end{align*}
\]

\[
\begin{align*}
\text{every man came. they whistled} = \\
\rightarrow \exists x. [\text{man}(x) \wedge \neg(\lambda y. [\text{came } x \wedge \text{whistled } Y])x] & \\
\end{align*}
\]
Note that it is impossible that a plural pronoun (such as they) be bound by a kid in this interpretation, because the variable x is bound simply by the existential quantifier.

When every takes wide scope, it does so both with its general scope and its nuclear scope:

\[
\begin{align*}
S|DP & \Rightarrow S \\
S & \Rightarrow S|DP \\
& a \text{ kid climbed every tree} \\
\exists x. \text{kid}(x) \land \neg \exists y. [. | x] \\
\text{tree}(y) \land \neg [\text{climbed } y x] \\
\hline
S & \Rightarrow S|S \\
\text{he was full of energy} & \neg \exists y. [.] \\
\lambda z. [.] \\
\hline
S & \Rightarrow S|S \\
\text{was full of energy } z & \lambda p \lambda q. p \land q \\
\hline
S & \Rightarrow S|S \\
\text{a kid climbed every tree}. he was full of energy & \exists x. \text{kid}(x) \land \neg \exists y. \lambda z. [.] x \\
\text{tree}(y) \land \neg [\text{climbed } y x] \land \text{was full of energy } z \\
\hline
S & \Rightarrow S|S \\
\text{a kid climbed every tree}. he be full of energy & \exists x. \text{kid}(x) \land \neg \exists y. \lambda z. [\text{tree}(y) \land \neg [\text{climbed } y x] \land \text{be full of energy } z ] x \\
\text{a kid climbed every tree}. he be full of energy & \exists x. \text{kid}(x) \land \neg \exists y. \text{tree}(y) \land \neg [\text{climbed } y x] \land \text{be full of energy } x \\
\hline
\text{a kid climbed every tree} & \exists x. \text{kid}(x) \land \neg \exists y. \text{tree}(y) \land \neg [\text{climbed } y x] \land \text{be full of energy } z \\
\exists x. \text{kid}(x) \land \neg \exists y. \lambda z. [.] x \\
\text{climbed } y x
\end{align*}
\]
In this interpretation, the singular DP *a kid* is embedded inside an expression in which it co-varies (*climbed* *y* *x*) with a variable bound by the universal (*every tree*), so it is logically a plural, thus it may bind only a plural pronoun, in this discourse, the pronoun *they*. It is worth mentioning that this analysis accounts for structural dependencies in (Brasoveanu 2007). To give the interpretation of “John bought a gift for every girl in his class and asked their deskmates to wrap them.”, he argues in favour of using sets of assignment functions to obtain all the pairs gift-girl.

Note that, similar to the case of wide-scope *any*, there is a third intermediate scope-taking possibility, which gives an impossible interpretation for natural language and supports the hypothesis that *every* takes wide scope obligatory with both general and nuclear scope:

It is interesting to note that, although *no* has no power to introduce singular variables, there are arguably cases of plural variables that refer back to something that was introduced by *no*:

“No man came. They were ill”

It may be said that they refers to the noun *man* and not to the DP *no man*, or that they refers to the complement set of the DP *no man*. Either way, no suitable lexicalized antecedent is available in the discourse for *they* to refer back to. It could be argued that *no* (and other quantifiers) introduces both their variable (set of variable) and the complement set (w.r.t some context given set). We will have no more to say about these cases here.

4.6.3. Conclusions

We showed how singular and plural quantifiers can be represented in continuation semantics framework. We discussed the scope behaviour of singular quantifiers. We
accounted for some aspects of plural dynamic semantics such as plural anaphora, conjunction and disjunction, distributivity or the maximality condition.

4.7. Handling Hierarchical Discourse Structure

While at the sentence level the combination of elements proceeds via syntactic rules, at the discourse level the combination of sentences proceeds via rules imposed by rhetorical relations between sentences. This parallelism functions at semantic level too: syntax determines how the meaning of words should be put together to provide the meaning of the whole sentence; analogously, the meaning of the sentences and the way they are combined via rhetorical relations determines the meaning of the discourse.

Rhetorical relation theory is introduced in Mann and Thompson (1986). We will refer to (Asher and Lascarides 2003) for more recent and extensive theory that combines the dynamic semantic (DRT style) with discourse structure via rhetorical relations. We only mention here the way of choosing a distinct rhetorical relation: \( R \) is a relation iff there is evidence that it affects truth-conditions of the sentences it connects, which cannot be explained by other means. For instance, Asher and Lascarides (2003) give the following rhetorical relations:

- Coordinating relations (the two constituents they relate have the same importance in the discourse): Narration, Background, etc.
- Subordinating relations (the second constituent is not essential for the discourse and it may be dropped): Elaboration, Explication, Result.
- Structural: Contrast, Parallel.

We will be concerned here neither by formulating explicit rules to combine sentences via rhetorical relation, nor to give an exhaustive treatment of the phenomena (see Asher and Lascarides 2003). Instead, we will give enough details to make plausible the use of continuations for modeling hierarchical discourse structure. Specifically, we will treat some side effects of rhetorical relations, such as the constraints that hierarchical structure (induced by subordinating rhetorical relations) imposes on the interpretation of pronominal anaphora.

There are two types of side effects: local and global. In the case of local effects, the rhetorical relation between a sentence \( A \) and a sentence \( B \) constrains the interpretation of pronouns that occur in \( B \) (Kehler 2002). In the case of global effects, the relation between \( A \) and \( B \) (be it a clause, a sentence, a phrase or a chunk of discourse) constrains the interpretation of pronouns that occur in some subsequent clause \( C \). This is known as the Right Frontier Constraint (RFC) (Polanyi 1985): “the antecedent of a pronoun in the current sentence must be introduced by the previous utterance or one that dominates it in the discourse structure”. To exemplify the RFC, we give an example from (Asher and Lascarides 2003):

\[
\begin{align*}
  & \text{John had a great evening.} \\
  & \text{He had a great meal.} \\
  & \text{He ate salmon.} \\
  & \text{He devoured cheese.} \\
  & \text{He then won a dance competition.} \\
  & \ast \text{It was a beautiful pink.}
\end{align*}
\]

This discourse has the following structure:
Elaboration is a subordination relation, thus introduces a new (subordinating) level represented on the vertical. Narration is a coordinating relation, thus the two components remain on the same (horizontal) level. The impossibility that it refers back to salmon is accounted for by the Right Frontier Constraint: the antecedent salmon is not in the previous sentence or upper in the structure of discourse, thus it is inaccessible for subsequent reference.

To account for RFC, we will formulate a naïve interpretation for the relation of subordination (be it Explanation, Elaboration, etc.). It is naïve in two respects: first, it ignores other rhetorical relation-specific aspects of interpretation; second, we will only consider the point separator between sentences, that leaves implicit the exact rhetorical relation between the sentences it relates and, which is by no means the only one that introduce rhetorical relations: consider for instance explicit lexical entries like but, also, on the one hand, on the other, so, because, when, while, nevertheless, etc. When dot introduces a new subordinated piece of discourse, we take its lexical entry to be:

$$S \sigma S \sigma$$

At the syntax level, subordinating point takes two components of type \( S \) (the first one is the previous discourse) and gives a component of type \( S \sigma S \). At the semantic level, the subordinating point introduces a new level on which it places the previous discourse and a gap; the gap is just a place holder for the subordinated future discourse. When the subordinated discourse ends, one returns upper in the discourse structure by applying Lower, which plugs all subordinated discourses into the gap and collapses the two levels introduced by subordinating point. In doing so, the scope of all DPs that could have possibly offered to bind a subsequent pronoun also closes, making further reference to them impossible. This accounts for RFC and thus for the impossibility that the pronoun it refers back to antecedent salmon in the upper example.

4.8. **Ellipsis**

Since ellipsis acts as an anaphora (it picks out a previously introduced constituent), we expect it to function in discourse similarly to other anaphora (definite descriptions or pronouns). Thus, ellipsis looks left for an expression to bind (transmit its value to) it.
Depending on their category, there are several types of ellipses, for instance noun phrase ellipses or verb phrase ellipses. We will only sketch here the treatment of nominal ellipses. The other types may be treated similarly.

In English, Noun Phrase ellipsis is only possible for plurals. The problem is exactly what gets elided. Consider the two examples of cross-sentential nominal ellipsis (Cornilescu 2010):

“Some men entered. Some (men) remained out.”

“Same men entered. Most (of the men who entered) sat down.”

In the first case, what gets elided is the common noun men previously introduced as the restrictor of the first quantificational determiner some. In the second case, what gets elided is the whole plural referent previously introduced, i.e., the intersection of the restrictor and nuclear scope of the quantificational determiner some. While in the first example the quantificational determiner some should take as argument a plural common noun (men) at the ellipsis site, in the second example, the quantificational determiner most requires as argument at ellipsis site a determiner phrase preceded by of (of the man who came). This syntactic difference implies a semantic difference. We will first treat the (syntactically simpler) case of plural quantificational determiners that take as arguments a common noun (without preposition of). We assume that what gets elided is the plural common noun previously introduced as the restriction of a DP antecedent. Observe that, although there is a mathematical difference between a set (plural individual) and a predicate, one may always consider a set as a predicate true of all the objects in the set and false of all the others. Our proposal is that on the one hand, the plural common noun introduced as the restriction of a DP antecedent offers to bind the ellipsis site and on the other, the ellipsis site is filled with a silent lexical entry that functions in local context as a plural common noun and takes scope at a sentence to make a sentence that looks left for a plural common noun (a binder):

\[
\frac{N^{pl} \triangleright S}{N^{pl}} \phi \\
\frac{\lambda Q. [\ ]}{Q}
\]

We extend the Bind rule accordingly, to allow other categories than DPs to bind (transmit its value), in this case \(N^{pi}\):

\[
\frac{A|B}{N^{pi} \triangleright N^{pi}}
\]

expression \(\triangleright\) expression

\[
\frac{f([\ ])}{x}
\]

expression

Here it is the derivation of “Some men entered. Some (men) remained out”:

3 In Romanian, singular NPE is possible, but only because unarticulated singular nouns (such as masina-car) denote a kind in Romanian. For instance:

I”on wants car red. Maria wants [car|e] yellow.

It is easy to extend our theory to treat in a similar manner this kind of ellipsis in Romanian, by allowing singularNs to bind anellipsis site.
a fare approximation of the intended meaning: there is a set $X$ of men who entered and there is a set $Y$ of man who remained out.

The more (syntactically) complex case which involves the preposition $of$ may be treated similarly, but with an important difference: in “most of the men who entered”, the quantificational determiner takes a $DP$ as an argument, and not a plural common noun as in “some men”. Thus, quantificational determiners should have two distinct lexical entries, one for the case without the preposition $of$, that requires a plural common noun as an argument and one for the case with the preposition $of$, that requires a plural $DP$ as an argument. We give here the lexical entry for the of-variant for the quantificational determiner most, that we need to derive our ellipsis example:

$$\lambda Y. \forall X. X \subset Y \land 2|X| \geq |Y| \land \left[ \left[ \right. \right]$$

The void lexical entry for a $DP$ is:
Here is the derivation for “Same men entered. Most (of the men who entered) sat
down”:

\[
\frac{\text{\textit{DP}$_{pl}$} \Rightarrow S | S}{\text{\textit{DP}$_{pl}$} \Rightarrow S | S / \text{\textit{DP}$_{pl}$}} \\
\frac{\text{\textit{mostof}}}{} \\
\frac{\lambda Q. [\cdot]}{} \\
\frac{Q}{\exists Z. Z \subseteq Y \land 2|Z| \geq |Y| \land [\cdot]}}{\text{s}a\text{t d}a\text{wn}}
\]

\[
\frac{\text{\textit{DP}$_{pl}$} \Rightarrow S | S}{\text{\textit{DP}$_{pl}$} \Rightarrow S | S / \text{\textit{DP}$_{pl}$}} \\
\frac{\text{\textit{mostof}}}{} \\
\frac{\lambda Q. [\cdot]}{} \\
\frac{Q}{\exists Z. Z \subseteq Q \land 2|Z| \geq |Q| \land \text{s}a\text{t d}a\text{wn} Z}
\]

\[
\frac{S | \text{\textit{DP}$_{pl}$} \Rightarrow S}{S \frac{\text{\textit{some men entered}}}{\exists X. |X| \geq 1 \land [\cdot] X}} \\
\frac{X = \text{argmax}[(Y: \text{\textit{men}} Y \land \text{\textit{entered}} Y)]}{S | \text{\textit{sat down}}}}{S | \text{\textit{sat dawn}} Z}
\]

\[
\frac{S | \text{\textit{DP}$_{pl}$} \Rightarrow S}{S \frac{\text{\textit{some men entered.\textit{mostof} sat down}}}{\exists X. |X| \geq 1 \land \lambda Q. [\cdot] X}} \\
\frac{X = \text{argmax}[(Y: \text{\textit{men}} Y \land \text{\textit{entered}} Y)] \land \exists Z. Z \subseteq Q \land 2|Z| \geq |Q| \land \text{\textit{sat dawn}} Z}}{S | \text{\textit{sat dawn}} Z}
\]

which means that there is a maximal set \(X\) of all men who entered and there is a subset \(Z\) of \(X\) of cardinality more than half of the cardinality of \(X\) and \(Z\) sat down.

### 4.9. Accommodation

Anaphoric expressions may not always find a suitable antecedent in the previous discourse, (a situation described as “it came out of the blue”). Nevertheless, they are
perfectly understood and acceptable, because the reference of that expression is (pragmatically) particularly salient. They are said to be “accommodated”. For instance, there are plenty of legal uses of definites like the door or his mother that lack a previously introduced antecedent in discourse. For example, the sentence “The door closed” is not usually preceded by “There is a door”. In order to account for these facts, we may allow the definite article the to introduce variables that do not look left for a binder to transmit a value to them. Hence, we give to the definite article the, two alternative lexical entries, one for its regular use and one for its accommodated use:

\[
\frac{DP^{pl} \Rightarrow S|S/N}{DP\ 
\text{the}\ \lambda P.\ P(y)\Lambda[\ ]\ /y} \quad \text{and} \quad \frac{S|S}{DP/N\ 
\text{the}\ \lambda P.\ \exists y.\ P(y)\Lambda[\ ]\ /y}
\]

The plural version of the definite article, receives a similar treatment: one lexical entry for its anaphoric use (like in “Some kids came. The kids played”), and one for its accommodated use (like in “The doors are opened”):

\[
\frac{DP^{pl} \Rightarrow S|S/N^{pl}}{DP^{pl}\ 
\text{the}\ \lambda y.\ P(y)\Lambda[\ ]\ /y} \quad \text{and} \quad \frac{S|S}{DP^{pl}/N^{pl}\ 
\text{the}\ \lambda y.\ P(y)\Lambda[\ ]\ /y}
\]

Another related phenomena is cataphora, i.e. pronominal anaphora that precedes the DP it refers to, like in: “If he comes, John brings wine”. Note that cataphora only occurs at sentential level. At the expense of dramatically raising the number of possible derivations, we could allow pronouns to look right for binders and binders to look left for expressions to bind. The much higher cost is explained by the natural left to right order of natural language processing which cataphora brakes. Another solution is given in (de Groote 2010), where the author chooses to change the role of the definite phrase and pronoun: the pronoun introduces an underspecified referent that binds the subsequent definite phrase.

4.10. Focus

A treatment of focus within the continuation semantics framework was sketched in Barker (2004). He uses the operators fcontrol and run to account for the semantics of focus. Instead, we give focus a continuation based interpretation with no such operators, treating focus in much the same uniform way in which we previously treated other linguistic phenomena. Moreover, we account in this framework for the phenomena of free-focus and bound-focus anaphora.

Most (probably all) languages provide some way of marking some constituent in a sentence as having extra prominence. In spoken English, this is typically accomplished in part by a local maximum in the fundamental frequency (the lowest frequency at which the vocal folds are vibrating). By convention, the location of such a `pitch accent' is indicated typographically by setting the most affected word in capital letters:

a. “JOHN saw Mary.”
b. “John SAW Mary.”
c. “John saw MARY.”
There is a distinct but elusive difference in meaning among these sentences that depends on the location of the pitch accent. In each case, it remains true that John saw Mary, but which piece of information is being emphasized differs. In traditional terms, the constituent containing the pitch accents is said to be ‘in focus’, which means (very roughly) that it carries the new information provided by the sentence. These observations can be sharpened by noting that the location of the pitch accent correlates with the use of only the precise piece of information requested by a question.

a. Who saw Mary?
b. What did John do to Mary?
c. Who did John see?

We will give the focus maker (operator) $F$ the following denotation:

$$
\begin{align*}
\text{S|S} & \xrightarrow{A/\text{F}} \\
\lambda x. & \quad (\lambda k. k(x) \land \forall y. (y = x \lor \neg (k(y))))(\lambda z. []) \\
\end{align*}
$$

The type is polymorphic: $A$ may be any category. The variable $z$ is just a means to distribute the context of the focused word to its positive contribution (i.e. it is true what is said about that constituent) and to the negative part (no other relevant choice of constituents of the same type makes the statement true). For instance, here there are the derivations of the upper three examples:

$$
\begin{align*}
\text{S|S} & \xrightarrow{\text{DP}} \\
\lambda x. & \quad (\lambda k. k(x) \land \forall y. (y = x \lor \neg (k(y))))(\lambda z. [[]]) \\
\end{align*}
$$

Jackendoff (1972) noted:

1. **John only gave his DAUGHTER a new bicycle.**
2. **JOHN only gave his daughter a new bicycle.**

The apparent generalization is that only must have a focus within its scope. Focus also interacts in an interesting way with ellipsis, for instance as in:

**JOHN loves Mary. Not Sue.** (≠not Sue loves Mary).

**John loves MARY. Not Sue.** (≠not John loves Sue).

We leave these issues for further research in the continuation semantics framework.

---

4 The use of “only” enhances the focus semantics, making it more obvious. It appears that focus placement can affect grammaticality. Jackendoff (1972) noted:

1. John only gave his DAUGHTER a new bicycle.
2. JOHN only gave his daughter a new bicycle.

The apparent generalization is that only must have a focus within its scope. Focus also interacts in an interesting way with ellipsis, for instance as in:

**JOHN loves Mary. Not Sue.** (≠not Sue loves Mary).

**John loves MARY. Not Sue.** (≠not John loves Sue).

We leave these issues for further research in the continuation semantics framework.
\[ S = \begin{array}{l}
F \text{ John saw Mary} \\
\lambda z. \text{saw } m \ z(j) \land \forall y. (y = j \lor \neg(\lambda z. \text{saw } m \ z(y)))
\end{array} \]

\[ S = \begin{array}{l}
F \text{ John saw Mary} \\
\text{saw } m \ j \land \forall y. (y = j \lor \neg(\text{saw } m \ y))
\end{array} \]

\[
\frac{\frac{\frac{\frac{\frac{S}{DP}}{\lambda x. (\lambda k. k(x) \land \forall y. (y = x \lor \neg(k(y))))(\lambda z. [\ ])}{z}}{m}}{\text{saw}}}{\text{F}}
\]

\[ S = \begin{array}{l}
\text{John F saw Mary} \\
(\lambda k. (\text{saw } (\text{saw } \land \forall y. (y = \text{saw} \lor \neg(k(y))))(\lambda z. [\ ])) z m j
\end{array} \]

\[ S = \begin{array}{l}
\text{John F saw Mary} \\
\lambda z. m \ j(\text{saw}) \land \forall y. (y = \text{saw} \lor \neg(\lambda z. m \ j(y))
\end{array} \]

\[ S = \begin{array}{l}
\text{John F saw Mary} \\
\text{saw } m \ j \land \forall y. (y = \text{saw} \lor \neg(y \ m j)
\end{array} \]
There is no point in using continuations if the context of the focused word is as simple as it is in the upper examples. But the context may be arbitrary complex, for example like "Mary tried to dance with F(JOHN)."
"Mary tried to F(DANCE) with John."

There is a problem with this interpretation: the universal quantifier in the upper denotation quantifies over absolutely every semantic objects of the focused expression’s type. But this is a too strong interpretation. The standard assumption is that the quantification over alternatives is context dependent. The quantifier should only quantify over the contextually relevant objects. For instance, "F(John) saw Mary", does not mean that absolutely nobody saw Mary (except John), but that no people from the relevant context saw Mary. We assume that what ought to count as a contextually-relevant object is a pragmatic issue and not a semantic one.

Now, we give an account in this framework of the notions of free-focus and bound-focus anaphora. The sentence “F(John) thinks he is smart” is ambiguous between the following two meanings:

1. John is the only individual y who thinks John (j) is smart.
2. John is the only individual y who thinks y is smart.

The first reading is called free-focus and the second bound-focus. We give the two derivations that show how one obtains the two different meanings:

\[
\begin{align*}
S|S &
\quad \frac{\begin{array}{c}
S|S \\
\frac{S|S}{DP / DP} \\
F \\
\lambda x. (\lambda k(x) \land \forall y. (y = x \lor \neg (k(y))))(\lambda z.[]) \\
\end{array}}{\text{Lower}} \\
\end{align*}
\]

\[
\begin{align*}
S &
\quad \frac{\begin{array}{c}
S|S \\
\frac{DP \triangleright S}{DP} \\
\text{John} \\
\lambda x. (\lambda k(x) \land \forall y. (y = x \lor \neg (k(y))))(\lambda z.[]) \\
\end{array}}{\text{Upper}} \\
\end{align*}
\]
\[
\frac{S|DP \triangleright S}{\text{think he is smart}}
\]
\[
\frac{DP \triangleright S|S}{\text{think he is smart}}
\]

\[
\frac{S|S}{DP}
\]

\[
\frac{S|S}{DP \triangleright S}
\]

\[
\frac{DP \triangleright S|S}{S|S}
\]

\[
F \ \text{John} \ \lambda t.[\ ]
\]

\[
(\lambda k. k(j) \land \forall y. (y = j \lor \neg(k(y))))(\lambda z.[\ ])
\]

\[
\text{think he is smart}
\]

\[
\text{think is smart t}
\]

\[
\frac{S|S}{S|S}
\]

\[
\frac{S|S}{DP \triangleright S}
\]

\[
\frac{DP \triangleright S|S}{S|S}
\]

\[
\text{think he is smart}
\]

\[
\text{think is smart t}
\]

\[
\frac{\lambda t.[\ ]}{DP \triangleright S}
\]

\[
\frac{DP \triangleright S|S}{S|S}
\]

\[
\text{think he is smart}
\]

\[
\text{think is smart t}
\]

\[
\frac{\lambda t.[\ ]}{DP \triangleright S}
\]

\[
\frac{DP \triangleright S|S}{S|S}
\]

\[
\text{think he is smart}
\]

\[
\text{think is smart t}
\]

\[
\frac{\lambda t.[\ ]}{DP \triangleright S}
\]

\[
\frac{DP \triangleright S|S}{S|S}
\]

\[
\text{think he is smart}
\]

\[
\text{think is smart t}
\]
Let’s look at the two interpretations again:

1. John is the only individual y who thinks John (j) is smart:

   \[ \text{think (is smart \ j)} \quad \forall y. \ (y = j \lor \neg (k(y))) \] 

2. John is the only individual y who thinks y is smart:

   \[ \text{think (is smart \ y)} \quad \forall y. \ (y = j \lor \neg (k(y))) \] 

The only difference in meaning is given by the presence of j as the argument of is smart in the first interpretation and by the presence of y as the argument of is smart in the second interpretation. Again, the two different interpretations are obtained just by choosing different levels on which the anaphoric pronoun (he) takes scope: outside or inside the focus. Not surprisingly, the mechanism of scope taking based on continuations needs no extra stipulation to account for free-focus and bound-focus anaphora.

### 4.11. Eventualities

We explore in this chapter the possibilities of representing the semantics of events (in the sense of Bach (1981, 1986)) in the continuation semantics framework (as presented in (Barker and Shan 2008)). The focus of this chapter is on providing an analysis for quantification over events and for anaphora to events in continuation semantics framework. We give specific lexical entries for the adverbial (eventuality) quantifiers always and never and for a silent adverbial quantifier we consider responsible for the meaning of expressions with no overt adverbial quantifiers. We provide here enough details to make plausible the interpretation of events in continuation semantics framework.

We point out that quantificational adverbs usually have an implicit restriction, (i.e. the contextually relevant events), as opposed to the nominal quantifiers (such as every, any, no, each, some, etc) where the restrictor is the noun phrase. This restriction is a set of events that cannot be completely specified or enumerated. Nevertheless, the human mind has no problem to operate with this kind of vagueness. Also, we argue that the Scope Domain Principle (SDP) (adapted from Landman 2000, cf. Parsons 1987), which says that
the eventuality quantifier always takes lowest possible scope with respect to other quantifiers, is too strong. Instead, we propose that the scope behaviour of eventuality quantifiers is ambiguous and it is a discourse matter to decide which reading is preferred. We point out that eventualities semantics needs no extra stipulations to be accounted for in this framework. This is again due to the fact that the continuation based semantics provides a unified account of scope-taking. We also highlight the importance of further research on relevant aspects (such as thematic roles, modality, tense, aspect or distributivity) without which a complete account of event semantics cannot be possible.

4.11.1. Previous work

In the above formalism we only allowed quantification over and anaphora to (singular or plural) entities (of type $e$). But natural language expressions may also quantify over and refer to eventualities (events, processes and states) or situations. We will use the term eventualities in the sense of Bach (1981, 1986), who proposed the following division of ‘eventualities’ into states, processes and events (following Vendler (1957/1967), Kenny (1963), Mourelatos (1978, 1981) and Carlson (1981)):

**EVENTUALITY TYPES**

- **STATE**
  - non-state

- **PROCESS**
  - (activity)
  - achievement

- **EVENT**
  - accomplishment

Although this categorization has important grammaticality implications, we will not use here the distinction between these types of eventualities, considering only the most general type: the eventualities themselves. We will be interested in giving a semantics that copes with reference to such objects. For instance, consider direct reference to events, e.g. event nominalizations (*the fall of the Berlin Wall*), quantification over eventualities, (*John kissed Mary twice*, or *John always sings*) or anaphoric pronominal reference to eventualities across sentence boundaries, (*“John kissed Mary. She liked it. / That was nice of him”*).

It is worth mentioning here that the notion of event is often used sloppily to mean eventuality, or situation, or sometimes even possible world. Roughly speaking, the difference between those notions is as follow: event is a particular case of eventuality; an eventuality is a situation with a minimality condition included; a situation is a partial possible world. In this work, we have chosen to use the eventuality for simplicity reasons. The semantic types are complex enough anyway, without adding the complexity of situation semantics or of possible worlds. Enriching the class of semantic types may as well be a topic for further research.

Beaver and Condoravdi (2007) point that, in Davidsonian Event Semantics (Davidson 1967, Parsons 1990, Link 1998, Landman 2000, among others), the analysis of quantification is problematic: “either quantifiers are treated externally to the event system and quantified in (cf. Landman 2000), or else the definitions of the quantifiers must be greatly (and non-uniformly) complicated (cf. Krifka 1989)”. Lucas Champollion (2010) advocates for a straightforward analysis of quantification in neo-Davidsonian Event Semantics based on standard type-shifting very much resembling continuations.
4.11.2. The semantics of adverbial quantifiers

In our approach, the eventuality’s ontological status will be that of “basic entity” of special type $E$, along with individual entity of type $e$ and truth value of type $t$. We will dub the corresponding category $S_E$ (of type $E$). We will consider predicates (verbs) as functions that take an eventuality as an extra argument. The only thing we might want to be careful about is the order in which a verb takes its arguments: it first takes the (indirect) direct object (if any), then the event variable and, finally, the subject. Thus, a transitive verb for instance will have the form: $\forall y. \lambda e. \lambda x. \text{verb } y e x$ . This order of applying the arguments is meant to mimic the default surface word order in English (“John always/never reads a book”). The notational difference between individual variables and eventuality variables will be that the former will be notated as usual with $x,y,z,...$ and the latter with $e, e', e'' ,...$

Adverbial quantifiers quantify over sets of events/situations (Heim 1990, de Swart 1993, v. Fintel 1994). They do that either overtly (never, always, twice, mostly, usually, often), or covertly by a silent existential adverbial quantifier. We propose that its lexical entry may have the following alternative forms:

$$
\frac{S[S]}{S_E} \quad \frac{S[S]}{S_E} \\
\phi_{ev} \quad \phi_{ev} \\
\exists e. \text{RelevEvent}(e) \land [ ] \quad \forall e. \text{RelevEvent}(e) \rightarrow [ ] \\
e \quad e
$$

The existential silent quantifier is generally used with past tense in constructions such as “John came”. The universal silent quantifier is generally used with present tense in generic constructions such as “John smokes” or “Birds fly”. Although the linguistic notions of time, modality and aspect are of great help in disambiguating existential versus universal event quantification in sentences that lack an overt adverbial quantifier, the ambiguity cannot be resolved always only on such bases. Certain vagueness is implicit in sentences with covert adverbial quantifiers. For instance, in languages with no continuous aspect, a sentence such as “John smokes” may mean that John always smokes or that there is a smoking event of John at the speech time.

We give always the following logically equivalent lexical entries:

$$
\frac{S[S]}{S_E} \quad \frac{S[S]}{S_E} \\
\text{always} \quad \text{always} \\
\forall e. \text{RelevEvent}(e) \rightarrow [ ] \quad \neg \exists e. \text{RelevEvent}(e) \land \neg [ ] \\
e \quad e
$$

We also give the following lexical entry to the adverbial quantifier never:

$$
\frac{S[S]}{S_E} \quad \frac{S[S]}{S_E} \\
\text{never} \quad \text{never} \\
\neg \exists e. \text{RelevEvent}(e) \land [ ] \\
e
$$

Observe that quantificational adverbs usually have an implicit restriction, (i.e. the contextually relevant events), as opposed to the nominal quantifiers (such as every, any, no, each, some, etc) where the restrictor is the noun phrase. Sometimes the restrictor is
overtly manifested by means of if or when clauses, as in “If the door is open, John came”. However, most of the time, the restrictor is implicit. In this case, RelevEvent is a set of events that cannot be completely specified or enumerated. Nevertheless, the human mind has no problem to operate with this kind of vagueness. The implementation of the event semantics presented in this work needs a way of representing the imprecision of the RelevEvent restriction. We leave this issue to further research.

Note also that variable e over eventualities from the above lexical entries is not to be confused with the semantic type e of entities.

In this framework, “John came” receives the following interpretation which makes use of the existential silent quantifier:

\[
\begin{align*}
S | S & \quad S | S \\
\frac{DP}{John} & \quad \frac{\phi_{ev}}{e} \\
\frac{[\_]}{\exists e. \text{RelevEvent}(e) \land [\_]} & \quad \frac{\_}{\exists e. \text{RelevEvent}(e) \land [\_]}
\end{align*}
\]

which amounts to saying that there is a contextually relevant eventuality e of coming which is true of John.

Similarly, “John smokes” receives the following interpretation, this time using the universal silent quantifier:

\[
\begin{align*}
S | S & \quad S | S \\
\frac{DP}{John} & \quad \frac{\phi_{ev}}{e} \\
\frac{[\_]}{\forall e. \text{RelevEvent}(e) \rightarrow [\_]} & \quad \frac{\_}{\forall e. \text{RelevEvent}(e) \rightarrow [\_]} \\
\end{align*}
\]

4.11.3. Anaphora to eventuality

To account for eventuality anaphora, we should allow the eventuality category \( S_e \) to bind, by adding the following binding rule:

\[
\begin{align*}
A | [\_] & \quad A | E \Rightarrow B \\
\frac{S_E}{expression} & \quad \frac{S_E}{expression} \\
\frac{f([\_]x)}{x} & \quad \frac{f([\_]x)}{x}
\end{align*}
\]

We also give the following lexical entry for the pronoun that:
In this framework, the interpretation of a discourse with eventuality anaphora such as “John came. That was a surprise” is derived as it follows (ignoring the existential force of a surprise, for simplicity):

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\text{Bind} \quad \exists e. \text{RelevEvent}(e) \land \left[ \right] e
\]

\[
\exists e. \text{RelevEvent}(e) \land \left[ \right] e
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\text{That} \quad \exists e''. \text{RelevEvent}(e'') \land \left[ \right] e''
\]

\[
\exists e''. \text{RelevEvent}(e'') \land \left[ \right] e''
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\text{was a surprise} \quad \text{was a surprise} \quad \text{was a surprise}
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\lambda e'.[ ] \quad \exists e''. \text{RelevEvent}(e'') \land \left[ \right] e''
\]

\[
\exists e''. \text{RelevEvent}(e'') \land \left[ \right] e''
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\text{John came} \quad \exists e. \text{RelevEvent}(e) \land \left[ \right] e \quad \lambda p q, p \land q
\]

\[
\exists e. \text{RelevEvent}(e) \land \left[ \right] e \quad \lambda p q, p \land q
\]

\[
\text{came e j} \quad \text{was a surprise} \quad \text{came e j} \quad \text{was a surprise}
\]

\[
\text{John came. That was a surprise}
\]

\[
\exists e. \text{RelevEvent}(e) \land \left[ \right] e \quad \exists e''. \text{RelevEvent}(e'') \land \left[ \right] e''
\]

\[
\exists e. \text{RelevEvent}(e) \land \left[ \right] e \quad \exists e''. \text{RelevEvent}(e'') \land \left[ \right] e''
\]

\[
\text{came e j} \land \text{was a surprise} \quad \text{came e j} \land \text{was a surprise}
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\exists e. \text{RelevEvent}(e) \land \left[ \lambda e'. \left( \exists e''. \text{RelevEvent}(e'') \land \left[ \right] e'' \right) \right] e
\]

\[
\exists e. \text{RelevEvent}(e) \land \exists e''. \text{RelevEvent}(e'') \land \left[ \text{came e j} \land \text{was a surprise} \right] e''
\]

\[
\exists e. \text{RelevEvent}(e) \land \exists e''. \text{RelevEvent}(e'') \land \text{came e j} \land \text{was a surprise}
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\text{John came. That was a surprise}
\]

\[
\exists e. \text{RelevEvent}(e) \land \exists e''. \text{RelevEvent}(e'') \land \text{came e j} \land \text{was a surprise}
\]

\[
\frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E} \quad \frac{S|S}{S_E}
\]

\[
\text{John came. That was a surprise}
\]

\[
\exists e. \text{RelevEvent}(e) \land \exists e''. \text{RelevEvent}(e'') \land \text{came e j} \land \text{was a surprise}
\]

\[
\text{which means that there is a coming event true of John and a surprising event true of John's coming.}
\]
Observe that the category of the verb *is a surprise* is here $S_E \setminus (S_E \setminus S)$, that is, the subject is of category $S_E$ (an eventuality). This appears to be a complication at first sight, because it means verbs may be polymorphic: *is a surprise* may also be of category $S_E \setminus (DP \setminus S)$ in discourses such as “The party was a surprise”. But it only means that verbs may take as arguments both regular DPs (of type $e$) and event nominalizations (of type $E$).

Up until now, the use of the restriction $RelevEvent(e)$ for the silent existential adverbial quantifier may have been awkward. However, its use becomes more transparent in deriving the interpretation of discourses with overt adverbial quantifiers such as “*John always sings*”:

\[
\begin{align*}
S[S] & \quad S[S] & \quad S[S] \\
\overline{DP} & \quad \overline{S_E} & \quad \overline{S_E \setminus (DP \setminus S)} \\
john & \quad always & \quad sing \\
\frac{}{e} & \quad \frac{}{\forall e. RelevEvent(e) \rightarrow [\ ]} & \quad \frac{}{\forall e. RelevEvent(e) \rightarrow sing e j} \\
\overline{S} & \quad \overline{S} \\
\overline{S} & \quad Lower & \quad S \\
\overline{\forall e. RelevEvent(e) \rightarrow [\ ]} & \quad \overline{\forall e. RelevEvent(e) \rightarrow sing e j} \\
\overline{sing e j} & \quad \overline{sing e j} \\
\end{align*}
\]

which means that for every event, if that event is a contextually relevant one (one in which John might sing, for instance), than that event is a singing by John.

4.11.4. Rejecting the scope domain principle

There has been argued that (adapted from Landman 2000, cf. Parsons 1987) the eventuality quantifier always takes lowest possible scope with respect to other quantifiers (Scope Domain Principle - SDP), based on examples of expressions containing other scope taking lexical entries that disallow the inverse scope interpretation (the one in which the eventuality quantifier takes wide scope over the other scope taking lexical entry). For instance, in examples such as “No dog barks”, “Spot does not bark” or “Every dog barks”, the direct scope interpretation is the only possible one:

\[
\begin{align*}
S[S] & \quad S[S] \\
\overline{DP} & \quad \overline{DP \setminus S} \\
\overline{No dog} & \quad \overline{bark} \\
\frac{}{\neg \exists x. (dog(x) \land [\ ])} & \quad \frac{}{\exists e. RelevEvent(e) \land [\ ]} \\
\overline{x} & \quad \overline{bark e} \\
\overline{S} & \quad \overline{S} \\
\overline{\neg \exists x. (dog(x) \land \exists e. RelevEvent(e) \land [\ ])} & \quad lower \\
\frac{}{\neg \exists x. (dog(x) \land \exists e. RelevEvent(e) \land [\ ])} & \quad \overline{bark e x} \\
\overline{No dog bark} & \quad \overline{bark e x} \\
\overline{\neg \exists x. (dog(x) \land \exists e. RelevEvent(e) \land [\ ])} & \quad \overline{bark e x} \\
\end{align*}
\]
meaning that there is no dog for which there is a barking event that is done by that dog.

Similarly, the interpretation of \textit{"Spot does not bark"} is:

\[
\frac{\text{Spot}}{S|S} \quad \frac{\text{not}}{\overline{\text{DP}S}} \quad \frac{\text{bark}}{\overline{\text{DP} \backslash S}} = \frac{\text{Spot not bark}}{S}
\]

\[
\frac{\text{Spot not bark}}{\overline{\text{Spot}}} \quad \frac{\text{bark}}{\overline{\text{e s}}}
\]

meaning that there is no relevant eventuality of barking by Spot.

The direct scope interpretation for \textit{"Every dog barks"} is:

\[
\frac{\text{every dog}}{S|S} \quad \frac{\text{barks}}{\overline{\text{DP}S}} = \frac{\text{every dog barks}}{S|S}
\]

\[
\frac{\text{every dog barks}}{\overline{\text{every dog}}} \quad \frac{\text{bark e}}{\overline{\text{x}}}
\]

meaning that there is no dog for which there is no event of barking.

We consider that it is premature to conclude that eventuality quantifiers always take lowest possible scope with respect to other quantifiers based only on this kind of examples. Rather, in these examples, the inverse scope is ruled out by factors such as the use of a particular aspect (perfect aspect, in this case). For instance, the inverse scope interpretation of \textit{"No dog barks"} is impossible because in natural language it would be realized using a different aspect (continue aspect): \textit{"No dog is barking"}, having the following derivation:

\[
\frac{\text{No dog}}{S|S} \quad \frac{\text{bark e}}{\overline{\text{x}}}
\]

meaning that there is a relevant event for which there is no dog that makes true that event of barking.
A stronger motive for rejecting SDP hypothesis is that there are cases where the preferred meaning is the one with wide eventuality quantifier scope, for instance as in “A diplomat always smiles”. Its direct scope interpretation (not preferred) is:

\[
\frac{\exists x. \text{diplomat}(x) \land \forall e. (\text{RelevEvent}(e) \rightarrow [])}{\text{smile } e}
\]

meaning that there is a certain diplomat who smiles in all relevant eventualities.

The inverse scope interpretation (preferred) is:

\[
\frac{\exists x. \text{diplomat}(x) \land \forall e. (\text{RelevEvent}(e) \rightarrow \text{smile } e x)}{S}
\]

meaning that in every relevant eventuality, a diplomat smiles.

### 4.11.5. Conclusions and further work

Our starting point was Barker and Shan’s (2008) continuation semantics. We shifted from quantifying over entities and truth values to quantifying over entities, truth values and eventualities. The key points of this chapter were accounting for quantification over events and for anaphora to events. We gave specific lexical entries for the adverbial quantifier always and never and a silent adverbial quantifier which we consider responsible for the meaning of expressions with no overt adverbial quantifiers. We pointed
out that the restrictor of the silent event quantifier is a set of events that cannot be completely specified or enumerated. Nevertheless, the human mind has no problem to operate with this kind of vagueness. We also argued that the Scope Domain Principle (adapted from Landman 2000, cf. Parsons 1987), which says that the eventuality quantifier always takes lowest possible scope with respect to other quantifiers, is too strong. Instead, we proposed that the scope behaviour of eventuality quantifiers is ambiguous and it is a discourse matter to decide which reading is preferred.

Event semantics needs no extra stipulations to be accounted for in this framework. This is due to the fact that the continuation based semantics provides a unified account of scope-taking. No other theory to our knowledge lets indefinites, other quantifiers, pronouns and other anaphors interact in a uniform system of scope taking, in which quantification and binding employ the same mechanism.

We only provided here enough details to make plausible the interpretation of events in continuation semantics framework, leaving for further research important issues such as:

- A complete specification of event semantics, that is obviously not possible without taking into consideration thematic roles, aspect, modality and tense.
- A way of representing the imprecision of the restriction RelevEvent, needed to implement the event semantics presented in this work.
- Multiple eventualities as in “All diplomats smile”; for instance, the interpretation:

\[
\frac{S|S}{DP} \quad \text{all diplomats} \\
\exists X. (X = \arg \max_X \{[X: \text{diplomat}(X)]\}) \land [\emptyset] \\
\frac{S|S}{S_E} \quad \phi_{ev} \\
\frac{S|S}{S_E} \quad \forall e. \text{RelevEvent}(e) \rightarrow [\emptyset] \\
\frac{S|S}{\text{smile } e} \\
\frac{\exists X. (X = \arg \max_X \{[X: \text{diplomat}(X)]\}) \land [\forall e. \text{RelevEvent}(e) \rightarrow [\emptyset]]}{\text{smile } e X} \\
\frac{S|S}{\text{smile } e X} \\
\frac{S}{\text{all diplomats smile}} \\
\exists X. (X = \arg \max_X \{[X: \text{diplomat}(X)]\}) \land \forall e. \text{RelevEvent}(e) \rightarrow \text{smile } e X
\]

is not a valid interpretation, because we need to distribute multiple events of smiling over the set of diplomats.

4.12. A mechanism to restrict the scope of clause-bounded quantifiers in continuation semantics

In the above work, we freely allowed type shifting to obtain the interpretation of natural language discourse. However, allowing arbitrary type shifting will result in overgenerating interpretations impossible in natural language. To filter out these impossible interpretations, we first need to understand the scope behaviour of each scope-taking lexical entry: its maximal scope limits and the scope precedence preferences w.r.t. other lexical entries. Second, we should force the scope closing of the quantifiers by applying a standard type shifter \(\text{Lower}\) (which is equivalent to identity function...
application), once their scope limits were reached. But the actual mechanism that ensures the scope closing was left underspecified in previous work on continuation semantics.

In what follows, we propose such a mechanism, designed to ensure that no lexical entry having the scope bounded to its minimal clause (such as not, no, every, each, any, etc) will ever take scope outside, thus automatically getting the right discourse truth conditions.

Remember our first proposal for the lexical entry of the negation:

\[
\frac{S \mid S}{(DP \setminus S) / (DP \setminus S)} \quad \text{not} \quad \frac{\neg [\ ]}{[\ ]}
\]

meaning that negation functions in local context as a verb modifier and takes scope at a sentence to give a sentence.

It is generally accepted that negation cannot take scope outside its minimal clause. But, if we do not restrict the possible scope of negation, any sentence following a negated one may be wrongly interpreted inside the scope of negation. In order to block such interpretations, we could adopt a similar strategy with the one proposed in Barker and Shan (2008): to force the scope closing of not immediately after the interpretation of its minimal clause, by applying Lower. This also closes the scope of any other DP inside the scope of negation, so it becomes impossible for it to bind (transmit its value to) subsequent anaphoric expressions. But this strategy leaves the actual mechanism that insures the scope closing unspecified. As Barker and Shan (2008, p.28) put it, when referring to the scope closing of quantificational determiner every, "Like most leading accounts of donkey anaphora (including Elbourne 2005), we provide no formal mechanism here that bounds the scope-taking of universals.". In what follows, we propose such a mechanism within the continuation semantics framework. The mechanism is designed to ensure that no lexical entries having the scope bounded to their minimal clause (such as not, no, every, each, any, etc) will ever take scope outside.

We introduce (Dinu 2011.c) a new category for clauses: C, of the same semantic type as the category S, namely t. C is the minimal discourse unit, whereas S is composed from at least one such unit. We constrain by definition the lexical entries with clause-bounded scope to take scope only at clauses. For instance, here there are the lexical entries for not, no and every:

\[
\frac{C \mid C}{(DP \setminus C) / (DP \setminus C)} \quad \text{not} \quad \frac{\neg [\ ]}{[\ ]}
\]

\[
\frac{C \mid C}{DP \setminus N} \quad \text{no} \quad \frac{\lambda P. \neg \exists x. (P(x) \land [\ ])}{x}
\]

\[
\frac{C \mid C}{DP \setminus N} \quad \text{every} \quad \frac{\forall x. [\ ]}{\lambda P. P(x) \rightarrow [\ ]}
\]
After the full interpretation of the minimal clause which they appear in, the category $C$ has to be converted to category $S$. Specifically, one can use the following silent lexical entry:

$$
S/C
\phi
\lambda p. p([])
$$

This step ensures that clauses (of category $C$) can be further processed as pieces of discourse (of category $S$), because all discourse connectors (such as the dot or if) are allowed to take only expressions of category $S$ as arguments.

We modify the Lower rule such that category $C$ may also be lowered similarly to category $S$:

$$
\frac{A(C)}{C} \quad \frac{expression}{expression} \quad \frac{f[i]}{f[x]}
$$

With this clause-restricting mechanism, the derivation of “John does not own a car” becomes:

$$
\frac{\text{John}}{\text{not}} \quad \frac{\text{not}}{\text{own}} \quad \frac{\exists x. \text{car}(x) \land []}{x}
$$

Now that the scope of negation is closed, it is obviously impossible for it to stretch over the following discourse. We only have to change the category $C$ into $S$ in order to connect it to the discourse:

$$
S/C
\phi
\lambda p. p([]) \quad \text{John not own a car}
\lambda p. p([-\exists x. \text{car}(x) \land \text{own} x f])
$$

What about the binding capabilities of the expressions in a clause whose scope has been closed? The subject, for instance, should be able to bind subsequent anaphora. It can do so by lifting over the negation and being available to bind from that position:
It is conceivable that an indefinite in direct object position may also rise from its minimal negated clause to give the inverse scope interpretation. This interpretation may sometimes be ruled out on pragmatic grounds as being too uninformative (for instance, there is a car that John does not own is not a valid interpretation for “John does not own a car”) or may be the preferred interpretation (there is a certain colleague Mary does not like is the preferred interpretation of “Mary does not like a colleague”). Also, there are lexical entries such as negative polarity items (for instance, any) or definite descriptions (such as John, the man, the man who entered) that, when in direct object position of a negated verb phrase, take wide scope over negation and thus bind subsequent anaphora. For instance, here it is the derivation of “Mary does not like John. He is rude”: 
The scope behaviour of the quantificational determiners *every* and *any* may be accounted for in a similar manner. Consider for instance the following examples:

"John does not know every poem. *It is nice."

"John does not know any poem. *It is nice."

The interpretative difference between *every* and *any* is made (in line with Quine and Geach among others) by the scope behaviour of the two quantificational determiners. *Any* prefers to take wide scope, whereas *every* rather takes narrow scope:

\[
\begin{array}{cccc}
S|S & S|S & S|S & S|DP \Rightarrow S \\
C|C & C|C & C|C & C|C \\
DP & DP \backslash C & DP \backslash C & DP \\
Mary & not & like & John = \\
[ ] & [ ] & [ ] & [ ]j \\
m & \neg m & [ ] & [ ]j \\
& like & [ ] & \neg \text{like } j \text{m} \\
\end{array}
\]
which means that there is (at least) one poem that John does not know, a fare approximation of the intended meaning. In this context, the interpretation of “It is nice” crashes, because it cannot find a suitable antecedent into the preceding discourse. It would have been useless for poem to offer to bind in the first place, because not takes scope over it and negation has to close its scope before its minimal clause is interpreted in discourse.

The interpretation of the quantificational determiner any proceeds similarly:
which means that there is no poem that John knows, a fare approximation of the intended meaning. It cannot be argued that it is the negation which prevents further referring to any poem, because any takes wide scope over negation. Obviously, the same mechanism prevents poem to bind subsequent anaphora both in the case of every and of any.

Notice that there is a third intermediate possibility of scope taking, with negation taking scope at the second level of the compositional tower:

\[
\frac{C | C}{\text{John not know any poem}} \quad \frac{\neg \exists x. [\text{poem}(x) \land \neg[\text{know} \times j]]}{\text{John does not know any poem}}
\]

\[
\frac{\neg \exists x. [\text{poem}(x) \land \neg[\text{know} \times j]]}{\text{John does not know any poem}}
\]

\[
\frac{S}{\text{John does not know any poem}}
\]

\[
\frac{\neg \exists x. \neg [\text{poem}(x) \land [\text{know} \times j]]}{\text{John does not know any poem}}
\]

\[
\frac{\neg \exists x. \neg [\text{poem}(x) \land [\text{know} \times j]]}{\text{John does not know any poem}}
\]

\[
\text{This interpretation is impossible in natural language. Thus, it may be said that any, like every, obligatory takes wide scope over negation not only with its general (first level) scope, but also with its nuclear scope.}
\]

4.13. Conclusions

We gave in this work an explicit formal account of discourse semantics that extends Barker and Shan’s (2008) (sentential) semantics based on continuations. We shifted from sentential level to discourse level. In this framework we accounted for side effects like pronominal (singular or plural) anaphora, quantifier scope, focus, ellipsis, accommodation and quantification over eventualities. All of these linguistic phenomena needed no extra stipulations to be accounted for in this framework. This is due to the fact that the continuation based semantics provides a unified account of scope-taking. No other theory to our knowledge lets indefinites, other quantifiers, pronouns and other anaphors interact in a uniform system of scope taking, in which quantification and binding employ the same
mechanism. Thus, once we get the scope of the lexical entries right for a particular discourse, we automatically get the right truth conditions and interpretation for that piece of discourse.

The accessibility mechanism from Discourse Representation Theory is here regulated by deciding where each lexical entry takes scope.

A word about variable renaming is in order here: throughout the examples in this section we have conveniently chosen the names of the variables, as to be distinct. Because there are no free variables in the theory, there is no danger of accidentally binding a free variable. As for the bound variable, the simple rule is that the current bound variable is renamed with a fresh variable name (cf Barendregt’s variable convention) so as all bound variable have distinct variable names.

4.14. Further work

Except for the issues left for further work in each of the subchapters of the first part, we leave for future research the following general directions:

- completing an algorithm that generates all possible interpretations for a given piece of discourse in continuation semantics framework;
- the possibility to express situation semantics using continuations;
- the comparison of our approach to anaphora to approaches of anaphora in algebraic linguistics.
5. Creating electronic resources for Romanian language

5.1. Building and annotating a generative lexicon for Romanian

We present in this section an on-going research (Dinu 2010.a, Dinu 2010.b): the construction and annotation of a Romanian Generative Lexicon (RoGL), along the lines of generative lexicon theory (Pustejovsky 2006), a type theory with rich selectional mechanisms. Lexical resources, especially semantically annotated are notoriously effort and time consuming. Thus, we try to use as much already done work as possible in our effort to build RoGL. We follow the specifications of CLIPS project for Italian language. The motivation is that we envisage the use of CLIPS in an attempt to automatically populate a Romanian GL. Such work has already been done in an effort to semi-automatically build a French generative lexicon, using CLIPS, a bilingual dictionary and specially designed algorithms.

We describe the architecture and the general methodology of RoGL construction. The system contains a corpus, an ontology of types, a graphical interface and a database from which we generate data in XML format. We give details of the graphical interface structure and functionality and of the annotation procedure.

5.1.1. Motivation

Currently, there are a number of ‘static’ machine readable dictionaries for Romanian, such as Romanian Lexical Data Bases of Inflected and Syllabic Forms (Barbu 2008), G.E.R.L. (Gavrila and Vertan 2005), Multext, etc. Such static approaches of lexical meaning are faced with two problems when assuming a fixed number of "bounded" word senses for lexical items:

- In the case of automated sense selection, the search process becomes computationally undesirable, particularly when it has to account for longer phrases made up of individually ambiguous words.
- The assumption that an exhaustive listing can be assigned to the different uses of a word lacks the explanatory power necessary for making generalizations and/or predictions about words used in a novel way.

Generative Lexicon (Pustejovsky 1995) is a type theory with richer selectional mechanisms (see for instance Proceedings of The first/second/third International Workshop on Generative Approaches to the Lexicon 2001/2003/2005), which overcomes these drawbacks. The structure of lexical items in language over the past ten years has focused on the development of type structures and typed feature structures (Levin and Rappaport 2005, Jackendoff 2002). Generative Lexicon adds to this general pattern the notion of predicate decomposition. Lexicons built according to this approach contain a considerable amount of information and provide a lexical representation covering all aspects of meaning. In a generative lexicon, a word sense is described according to four different levels of semantic representation that capture the componental aspect of its meaning, define the type of event it denotes, describe its semantic context and positions it with respect to other lexical meanings within the lexicon.

GLs had been already constructed for a number of natural languages. Brandeis Semantic Ontology (BSO) is a large generative lexicon ontology and lexical database for English. PAROLE – SIMPLE – CLIPS lexicon is a large Italian generative lexicon with phonological, syntactic and semantic layers. The specification of the type system used both in BSO and in CLIPS largely follows that proposed by the SIMPLE specification (Busa et al. 2001), which was adopted by the EU-sponsored SIMPLE project (Lenci et al. 2000).
Also, Ruimy et al. (2005) proposed a method for semi-automated construction of a generative lexicon for French from Italian CLIPS, using a bilingual dictionary and exploiting the French-Italian language similarity.

5.1.2. Theoretical prerequisites: Generative Lexicon Theory

A predicative expression (such as a verb) has both an argument list and a body. Consider four possible strategies for reconfiguring the arguments-body structure of a predicate:

1. Atomic decomposition (do nothing—the predicate selects only the syntactic arguments):
   \[ P(x_1, \ldots, x_n) \]

2. Parametric decomposition (add arguments):
   \[ P(x_1, \ldots, x_n) \rightarrow P(x_1, \ldots, x_n, x_{n+1}, \ldots, x_m) \]

3. Predicative decomposition (split the predicate into subpredicates):
   \[ P(x_1, \ldots, x_n) \rightarrow P_1(x_1, \ldots, x_n), P_2(x_1, \ldots, x_n), \ldots \]

4. Full predicative decomposition (add arguments and split the predicate):
   \[ P(x_1, \ldots, x_n) \rightarrow P_1(x_1, \ldots, x_n, x_{n+1}, \ldots, x_m), P_2(x_1, \ldots, x_n, x_{n+1}, \ldots, x_m), \ldots \]

The theory uses the full predicative decomposition, with an elegant way of transforming the subpredicates into richer argument typing: Argument Typing as Abstracting from the Predicate:

\[
\lambda x_2 \lambda x_1 [\Phi_1, \ldots, \Phi_{x_1}, \ldots, \Phi_{x_2}, \ldots, \Phi_k]
\]

\[
\lambda x_2 : \sigma \lambda x_1 : \tau [\Phi_1, \ldots, \Phi_k - \{\Phi_{x_1}, \Phi_{x_2}\}]
\]

For example, possible types for the verb *sleep* are:

<table>
<thead>
<tr>
<th>Approach</th>
<th>Type</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic</td>
<td>( e \rightarrow t )</td>
<td>( \lambda x [\text{sleep}(x)] )</td>
</tr>
<tr>
<td>Predicative</td>
<td>( e \rightarrow t )</td>
<td>( \lambda x [\text{animate}(x) \land \text{sleep}(x)] )</td>
</tr>
<tr>
<td>Enriched typing</td>
<td>( \text{anim} \rightarrow t )</td>
<td>( \lambda x : \text{anim} [\text{sleep}(x)] )</td>
</tr>
</tbody>
</table>

Under such an interpretation, the expression makes reference to a type lattice of expanded types (Copestake and Briscoe 1992, Pustejovsky and Boguraev 1993).

Thus, generative Lexicon Theory employs the “Fail Early” Strategy of Selection, where argument typing can be viewed as pretest for performing the action in the predicate. If the argument condition (i.e., its type) is not satisfied, the predicate either: fails to be interpreted, or coerces its argument according to a given set of strategies. Composition is taken care of by means of typing and selection mechanisms (compositional rules applied to typed arguments).

Lexical Data Structures in GL:

1. Lexical typing structure: giving an explicit type for a word positioned within a type system for the language;
2. Argument structure: specifying the number and nature of the arguments to a predicate;
3. Event structure: defining the event type of the expression and any subeventual structure;
4. Qualia structure: a structural differentiation of the predicative force for a lexical item.

Argument and Body in GL:

\[
\begin{array}{c}
\text{Environ} \\
\text{AS} \\
\text{ES} \\
\text{Body}
\end{array}
\]

\[
\begin{array}{c}
\lambda x_n \ldots \lambda x_1 \lambda e_m \ldots \lambda e_1 \\
[Q_1 \land Q_2 \land Q_3 \land Q_4; C]
\end{array}
\]

where \(AS\): Argument Structure, \(ES\): Event Structure, \(Q\): Qualia Structure, \(C\): Constraints.

Qualia Structure:
5. Formal: the basic category which distinguishes it within a larger domain;
6. Constitutive: the relation between an object and its constituent parts;
7. Telic: its purpose and function, if any;
8. Agentive: factors involved in its origin or “bringing it about”.

A prototypical lexical entry for GL is given in fig. 1.

![Figure 1. Prototipical lexical entry in GL](image)

The Type Composition Language of GL:
1. \(e\) is the type of entities; \(t\) is the type of truth values (\(\sigma\) and \(\tau\), range over simple types and subtypes from the ontology of \(e\));
2. If \(\sigma\) and \(\tau\) are types, then so is \(\sigma \rightarrow \tau\);
3. If \(\sigma\) and \(\tau\) are types, then so is \(\sigma \bullet \tau\);
4. If \(\sigma\) and \(\tau\) are types, then so is \(\sigma \circ Q \tau\), for \(Q = \text{const}(C)\), telic(\(T\)), or agentive(\(A\)).

Compositional Rules:
1. Type Selection: Exact match of the type.
2. Type Accommodation: The type is inherited.
3. Type Coercion: Type selected must be satisfied.

The domain of individuals (type \(e\)) is separated into three distinct type levels:
1. Natural Types: atomic concepts of formal, constitutive and agentive;
2. Artifactual Types: Adds concepts of telic;
3. Complex Types: Cartesian types formed from both Natural and Artifactual types.

5.1.3. Why choosing CLIPS architecture for RoGL

Creating a generative lexicon from scratch for any language is a challenging task, due to complex semantic information structure, multidimensional type ontology, time...
consuming annotation etc. Thus, in our effort to build a Romanian Generative Lexicon along the above theoretic lines, we made use of previous work both on Romanian static lexicons, and on existing generative lexicons for other languages such as Italian CLIPS or English BSO.

Our system follows closely the specifications of CLIPS project for Italian language. The reason for doing so is that we envision the possibility to semi-automatically populate RoGL using the massive Italian generative lexicon CLIPS and a quality bilingual dictionary.

The idea is not original: such a research exists for French, exploiting the French-Italian language similarity, with encouraging results (Ruimy et al 2005). The authors proposed a method based on two complementary strategies (cognate suffixes and sense indicators) for relating French word senses to the corresponding CLIPS semantic units. The cognate strategy proposed is guided by the following two hypotheses:

- morphologically constructed words usually have sense(s) that are largely predictable from their structure;
- Italian suffixed items have one (or more) equivalent(s) – constructed with the corresponding French suffix – that cover(s) all the senses of the Italian word.

If an Italian CLIPS word has, in the bilingual dictionary, the same translation for all its senses, this unique French equivalent will share with the Italian word all the SIMPLE-CLIPS semantic entries.

We may employ the same strategy to obtain Romanian semantically annotated units from their Italian counterpart. The fact that Romanian is in the same group of Romance languages creates the morpho-syntactic premises to obtain similar results.

The cognates approach is rather easy to implement (and yields expected higher recall then sense indicator method), based, for example, on cognateness of suffixes from Romanian and Italian (such as –ie, -zione; -te, -tà). For the other words and for those constructed words that have more than one translation, the cognate method results inadequate and the sense indicator method takes over. The sense indicator method is more demanding, but has a higher precision. A specific algorithm for Romanian - Italian needs to be designed and implemented.

5.1.4. Architecture and Implementation of RoGL

Creating a generative lexicon for any language is a challenging task, due to complex semantic information structure, multidimensional type ontology, time consuming annotation etc. Our system follows the specifications of CLIPS project for Italian language. It contains a corpus, an ontology of semantic types, a graphical interface and a database from which we generate data in XML format (figure 2).
The annotation is to be done web-based, via a graphical interface, to avoid compatibility problems. The interface and the data base where the annotated lexical entries will be stored and processed are hosted on the server of Faculty of Mathematics and Informatics, University of Bucharest: http://ro-gl.fmi.unibuc.ro. Each annotator receives a username and a password from the project coordinator in order to protect already introduced data and also to protect against introducing erroneous data.

The type ontology we choose is very similar with the CLIPS ontology. It has a top node, with types Telic, Agentive, Constitutive and Entity, as daughters. The types Telic, Agentive and Constitutive are intended to be assigned as types only for lexical units that can be exclusively characterized by one of them. Type Entity has as subtypes Concrete_entity, Abstract_entity, Property, Representation, and Event. In all, the ontology has 144 types and can be further refined in a subsequent phase of RoGL, if the annotation process supplies evidences for such a necessity.

The first task the annotator has to deal with is to choose one of the meanings of the lexical unit. The annotator sees a phrase with the target word highlighted. To help the annotator, a gloss comprising the possible meanings from an electronic dictionary pops up. Here we are interested in regular polysemy (such as bank: institution or chair), not the different meaning levels of the same lexeme (such as book: the physical object or the information), aspect which is to be described later by specifying the semantic type of the lexical item as complex. We will record in the data base different entries for different senses of a polysemic lexical entry.

The semantic type of the lexical unit is first chosen from a list of 17 types. Only if the annotator cannot find the right type to assign to the lexical unit, he may consult the complete ontology (144 types). Thus, the complexity of annotation task remains tractable: the annotator does not have to bother with the inheritance structure or with over 100 types to choose from. The 17 initial types are the ones in Brandeis Shallow Ontology (table 1), a shallow hierarchy of types selected for their prevalence in manually identified selection context patterns. They were slightly modified to mach our ontology and we expect to modify them again to fit our Romanian data, once we have our own annotations statistics. It is important to notice that the same lexical unit is presented several times to the annotator in a different context (phrase). For the same disambiguated meaning, the annotator may enhance the existing annotation, adding for example another type for the lexical unit (see the dot operator for complex types).
### Table 1: Type System for Annotation

<table>
<thead>
<tr>
<th>Top Types</th>
<th>Abstract Entity Subtypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>abstract entity</td>
<td>attitude</td>
</tr>
<tr>
<td>human</td>
<td>emotion</td>
</tr>
<tr>
<td>animate</td>
<td>property</td>
</tr>
<tr>
<td>organization</td>
<td>obligation</td>
</tr>
<tr>
<td>physical object</td>
<td>rule</td>
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<tr>
<td>artifact</td>
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<tr>
<td>event</td>
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<tr>
<td>proposition</td>
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<tr>
<td>information</td>
<td></td>
</tr>
<tr>
<td>sensation</td>
<td></td>
</tr>
<tr>
<td>location</td>
<td></td>
</tr>
<tr>
<td>time period</td>
<td></td>
</tr>
</tbody>
</table>

The annotator selects a part of speech from a list of pos such as: intransitive verb, transitive verb, ditransitive verb, unpredicative noun, predicative noun (such as deverbals, for example collective simple nouns such as grup, nouns denoting a relation such as mama, a quantity such as sticla, a part such as bucata, a unit of measurement such as metru, a property such as frumusete) and adjective. Depending on the particular pos selected for a lexical unit, its predicative structure modifies. Accordingly, once one of the pos tags was selected, our graphical interface automatically creates a template matching argument structure with no arguments, with Arg0, with Arg0 and Arg1, or with Arg0, Arg1 and Arg2.

The event type is selected from a drop down list comprising process, state and activity.

The Qualia Structure in RoGL follows the CLIPS extended qualia structure (figure 3): each of the four qualia relations has a dropdown list of extended relations which the annotator has to choose from. The choice may be obligatory, optional or multiple.

Then, the annotator has to provide the words which are in the specified relation with the current word. Here a distinction is to be made between existing words (already introduced in the data base) and words not yet introduced. For existing words, a link between each of them and the current word is automatically created. For the others, a procedure of verification for the data base has to be run at some time intervals, in order to check and update the existing links, so that words in the lexicon become maximally connected. Figure 4 depicts a fragment of the graphical interface for annotating the qualia structure.

The Predicative Representation describes the semantic scenario the considered word sense is involved in and characterizes its participants in terms of thematic roles and semantic constraints. We make use again of the expertise of the CLIPS developers in adopting an adequate predicative representation for RoGL. In SIPLEMPLE project, the predecessor of CLIPS project, only the predicative lexical units (units that subcategorize syntactic arguments) receive a predicative representation: for example, a word like constructor (which is not the head of a syntactic phrase) is not linked with the predicate to construct. In CLIPS (and also in RoGL), the non-predicative lexical units may be linked (when the annotator decides) to a predicative lexical unit, thus constructor is linked by an AgentNominalization type of link to the predicative lexical unit to construct, so it fills the ARG0 of this predicate. The type of link Master is to be chosen between a predicative unit and its predicative structure (reprezentation). Thus, in the ideal case, a semantic frame
such as *to construct* (the predicate), *construction* (pacient or process nominalization) and *constructor* (agent nominalization) will end up being connected (with the proper semantic type of link) in the data base.

**Figure 3.** First tasks of the annotation process.

**Figure 4.** Fragment of qualia structure annotation.
The annotator has to choose the lexical predicate the semantic unit relates to and the type of link between them (master, event, process or state nominalization, adjective nominalization, agent nominalization, patient nominalization, instrument nominalization, other nominalization). In the data base, we store the predicates separately from the semantic units.

For example, the predicate a construi (to build) is linked to USem constructie (construction - building) by a patient nominalization link, to USem construire (construction - process) by a process nominalization link, to USem constructor (constructor) by an agent nominalization link and to USem construi (to build) by a master link.

The argument structure annotation consists of choosing for each argument its type from the ontology (the semantic constraints of the semantic unit) and their thematic roles from the thematic roles list: Protoagent (arg0 of kill), Protopatient (arg1 of kill), SecondParticipant (arg2 of give), StateOfAffair (arg2 of ask), location (arg2 of put), Direction (arg2 of move), Origin (arg1 of move), Kinship (arg0 of father), HeadQuantified (arg0 of bottle).

Figure 7 depicts a fragment of the annotation process for a predicate.
To implement the generative structure and the composition rules, we have chosen a functional programming language of the Lisp family, namely Haskell. The choice of functional programming is not accidental. With Haskell, the step from formal definition to program is particularly easy. Most current work on computational semantics uses Prolog, a language based on predicate logic and designed for knowledge engineering. Unlike the logic programming paradigm, the functional programming paradigm allows for logical purity. Functional programming can yield implementations that are remarkably faithful to formal definitions. In fact, Haskell is so faithful to its origins that it is purely functional, i.e. functions in Haskell do not have any side effects. (However, there is a way to perform computations with side effects, like change of state, in a purely functional fashion).

Our choice was also determined by the fact that reducing expressions in lambda calculus (obviously needed in a GL implementation), evaluating a program (i.e. function) in Haskell, and composing the meaning of a natural language sentence are, in a way, all the same thing.

The Haskell homepage http://www.haskell.org was very useful. The definitive reference for the language is (Peyton 2003). Textbooks on functional programming in Haskell are (Bird 1998) and (Hutton 2007).
5.1.5. Further work

The most important work which still needs to be done is to annotate more lexical entries. The manual annotation, although standardized and mediated by the graphical interface is notoriously time consuming especially for complex information such as those required by a generative lexicon. We plan to automate the process to some extent, taking advantage of the existing work for Italian. Thus, the CLIPS large and complex generative lexicon may be used in an attempt to automatically populate a Romanian GL. A feasibility study is necessary to assess the potential coverage of such a method. However, the final annotation, we believe, is to be done manually.

5.2. Building and exploiting Romanian corpora for the study of Differential Object Marking

5.2.1. Motivation

The motivation for this work is that in Romanian the uses of the accusative marker “pe” with the direct object in combination or not with clitics involve mechanisms which are not fully understood and seeming messy for the non-native speaker: sometimes the accusative marker is obligatory, sometimes it is optional and even forbidden at times. The Differential Object Marking parameter draws a line between languages such as Spanish, Romanian, Turkish, or Russian which show a propensity for overtly marking those objects which are considered to be ‘prominent’, i.e. high in animacy, definiteness or specificity and other languages, such as German, Dutch and English, where such a distinction between types of direct objects is not at stake (they rely mostly on word order to mark the direct object). Thus, this research tackles a specific linguistic difference among those languages. It presents a systematic account for these linguistic phenomena based on empirical evidence present in corpora. Such an account may be used in subsequent studies to improve statistical methods with targeted linguistic knowledge.

5.2.2. The corpus

In order to find empirical evidences for the way DOM with accusative marker “pe” is interpreted in Romanian, we semi-automatically constructed a corpus of Romanian phrases (Dinu and Tigau 2010). The construction of the corpus was straightforward: we only included the phrases containing the word “pe” from a given set. The only problem was to manually detect and delete from the corpus the occurrences of “pe” which lexicalized the homonym preposition meaning on. By doing so, we obtained 960 relevant examples from present day Romanian: 560 of these were automatically extracted from publically available news paper on the internet; the other 400 examples (both positive and negative) were synthetically created, due to the fact that we needed to test the behaviour of the direct object within various structures and under various conditions, which made such sequences rare in the literature.

We manually annotated the direct objects from the corpus with semantically interpretable features we suspected, based on previous studies, are relevant for DOM, such as [±animate], [±definite],[ ±human].

We also assembled a corpus containing 779 examples from XVI-th and the XVII-th century texts (approx. 1000 pages of old texts were perused), in order to study the temporal evolution of DOM in Romanian. In what the XVith century is concerned, we used Catehismul lui Coresi (1559) (Coresi’s Cathexism), Pravila lui Coresi (1570) (Coresi’s Code of Laws) as well as various prefaces and epilogues to texts dating from the XVI-th century: Coresi: Tetraevangel (1561) (The Four gospels), Coresi: Tîlcul evangheliilor (1564) (Explainig the Gospels), Coresi: Molitvenic(1564) (The Prayer Book), Coresi: Psâltire Romînească (1570) (The Romanian Psalm Book), Coresi: Psâltire Slavo-Romînă (1570) (The Slavic-Romanian Psalm Book), Coresi: Evanghelie cu
invățătură (Gospel with Advice), Palia de la Orăștie (1582) (The Old Testament from Orăștie). To these texts we have added a number of documents, testaments, official and private letters. The texts dating from the XVII century were basically chronicles – we had a wider choice of texts as we moved along the centuries. We have studied the following works: Istoria Ţării Româneşti de la octombrie 1688 până la martie 1718 (The History of Ţara Românească from October 1688 until March 1718), Istoriiile domnilor Ţării Româneşti. Domnia lui Costandin – voď Brâncoveanu (Radu Popescu) (The Lives of the Rulers of Ţara Românească. The reign of Costandin Brâncoveanu (Radu Popescu)), Istoria ţării româneşti de când au descălecat pravoslavnicii creştini (Letopiseţul Cantacuzîno)(The History of Ţara Românească since the Advent of the Christian Orthodox Believers)(The Cantacuzino Chronicle), Letopiseţul Ţării Moldovei (Ion Neculce) (The Chronicle of Moldavia by Ion Neculce).

From this old Romanian corpus we noticed that prepositional PE came to be more extensively employed in the XVII-th century texts and by the XVIII-th century it had already become the syntactic norm. It seems that the Accusative was systematically associated with P(R)E irrespective of the morphological and semantic class the direct object belonged to. This is in line with the results arrived at by Heusinger & Onea (2008) who observe that the XIX-th century was the epiphenomenon in what the employment of DOM is concerned. This evolution was then reversed around the XIX-th –XX-th centuries so that the use of PE today is more restrained than it was two centuries ago, but more relaxed if we were to compare it to the XVI-th century.

5.2.3. Previous accounts of DOM in Romanian

We started our analysis of DOM in Romanian, considering a range of former accounts of the prepositional PE such as the studies of Aissen (2003), Cornilescu (2000) and Farkas and Heusinger (2003) in an attempt to isolate the exact contribution of the marker PE on various types of direct objects.

Apparently, DOM in Romanian is affected both by the scale of animacy and by the scale of definiteness (Aissen 2003), as it is largely restricted to animate–referring and specific objects i.e. it is obligatory for pronouns and proper names but optional for definites and specific indefinites. In order to solve this puzzle, Aissen crosses the two scales and comes up with a partial ranking, as depicted in figure 8.

![Figure 8. Partial ranking on animacy and definiteness](image)

Thus, as one can see above, pronouns referring to humans outrank (universally) all other types of expressions due to the following reasons: pronouns are the highest on the definiteness scale, outranking all other types of expressions just like the feature [+ human] which outranks everything on the animacy scale. However, there seems to be a problem when it comes to comparing animate pronouns and human determiner phrases (DPs) as the former outranks the latter in terms of the definiteness scale whereas the latter outranks the
former with respect to the animacy one. Aissen holds that in this case it is up to the grammar of a particular language to set the ranking.

In Romanian the definiteness scale seems to override the animacy one in that pronouns will always be overtly case marked as opposed to definite DPs whose case marking is optional.

Although Aissen’s analysis seems to account for several important general facts about Romanian e.g. why are personal pronouns overtly case-marked as opposed to non-specific indefinites, it does not account for the optionality of overtly case-marking definite DPs and specific indefinites, nor does it explain how the choice when it comes to elements ranked on the same level with the complex scale is made (e.g. human indefinites (optionally case-marked) as opposed to inanimate-referring proper names which are not overtly case-marked).

Cornilescu’s (2002) proposal is that PE is a means of expressing semantic gender - which distinguishes between non-neuter gender (personal gender) and neuter gender (non-personal gender). One advantage of such an account is that it would explain the optionality of PE in certain cases. Thus, while grammatical gender is necessarily marked on the noun’s morphology i.e. it is an obligatory feature, semantic gender on the other hand is only sometimes marked formally by PE, 'when it is particularly significant, because the intended referent is prominent. Thus, PE is optional even for nouns denoting person. Furthermore, Cornilescu points to the fact that semantic gender is related to individualization because individualized referents are granted “person” status. Thirdly, it appears that the presence of PE places constraints on the denotations of the overtly case-marked DPs. Thus, the DPs which get overtly case-marked always have an object-level reading and as for their specific denotations, these DPs always select only argumental denotations i.e. <e> (i.e. object) or <<e,t> (i.e. generalized quantifier). On the other hand, these DPs never have a property reading i.e. <e,t>, nor do they ever get a kind interpretation which is related to the property reading.

Our analysis is developed within the Discourse Representational Theory (DRT) as it is put forth by Kamp & Reyle (1993) and developed by Farkas & de Swart (2001) and Farkas (2002). DRT is a theoretical semantic-pragmatic framework with the aim of bridging sentence-level semantics and dynamic, discourse level aspects of semantic interpretation. Within this framework, the interpretation process involves updating the semantic representation with material that affects the truth conditional and the dynamic aspects of discourse. Thus, each new sentence is interpreted with respect to the contribution it makes to an already existing piece of (already) interpreted discourse. The interpretation conditions for sentences act as instructions for the updating the representation of the discourse. The most important tenets of this approach that we employed and along which all distinctions between DPs with respect to DOM were provided, were that each argumental DP contributes a discourse referent (or a value) and a condition on it.

The idea underlying our analysis and which we adopted from Farkas (2002) is that DPs differ one with respect to another on account of the value conditions they contribute. Also on account of the value conditions these DPs introduce, we developed the analysis of DOM in Romanian sentences. The core notion we employed in this respect was that of ‘determined reference’ which seems to be the underlying parameter organizing DPs along the definiteness scale provided by Aissen (2003). DPs with determined reference are obligatorily marked by PE. (The few exceptions will be accounted for). The animacy scale of Aissen (2003) remains an important factor when it comes to differentially marking the object DP and can sometimes override the parameter of determined reference.

5.2.4. Empirically grounded accounts of DOM in Romanian

We give here our findings based on corpus analysis, for the three classes of DPs: proper names and definite pronouns, definite descriptions, indefinite descriptions.

**Proper names and definite pronouns** differ from definite descriptions in that only the former but not the latter are obligatorily marked by means of PE. This difference was captured in terms of the conditions on how variables introduced by DPs are assigned
values. Thus, proper names and definite pronouns contribute equative conditions on the variable they introduce – in virtue of the equative value conditions these DPs contribute, the variables they introduce meet the determined reference requirement. Hence these DPs are obligatorily marked by PE. The only exception in this case is that [-animate] proper names are not marked by means of PE, nor is the relative pronoun ce ‘what’. Consider:

1. a. Deseori(vă)d*(pe)Ioana stand la fereastră. [+human]

   Often (her.cl.) see PE Ioana sitting at widow.
   ‘I often see Ioana sitting by the window.’

   b. Îl chem *(pe) Lăbuş dar s-a ascuns şi aşteaptă să-l găsesc. [-human, +animate]

   Him.cl. call.I PE Lăbuş but refl. has hidden and wait SĂ him.cl. find.I.
   ‘I called Lăbuş but he is hiding somewhere waiting for me to find him.’

   c. Am traversat (*pe) Parisul pe timp de noapte uitându-ne împrejur la tot pasul.

   Have we crossed (*PE) Paris during night looking refl. fearful around every step.
   ‘We crossed Paris during the night, fearfully peering around all the time.’

Thus, proper names acquire PE as a consequence of the interaction between two parameters: determined reference and the animacy scale. The former parameter requires the obligatory use of PE, hence all proper names should be marked in this respect. However, the latter parameter overrides the parameter of determined reference when it comes to [-animate] proper names because these DPs may not receive DOM.

2. a. Îi aşteptam *(pe) ei cu sufletul la gură, dar nu eram prea încântat că vor veni şi ele.

   The.cl. waited PE them (masculine) with soul at mouth but not were we too thrilled that will come and they. (feminine)
   ‘I could hardly wait for the boys’ coming but I was not too thrilled that the girls were coming too.’ (personal pronoun).

   b. Vă strigă pe dumneavoastră, domnule Dinică.

   You call PE you Mr. Dinică.
   ‘It is you that they call, Mr. Dinică.’ (pronoun of politeness)

   c. Babele stăteau toate roată pe lângă poartă doar s-a prinde vreo veste.

   Old ladies sat all around near the gate so as to catch any news.
   Altele, mai curajoase, stăteau la pândă pe după casă. *(pe) acestea din urmă le-am speriat de moarte.

   Others, more courageous sat in waiting behind the house. PE these latter them.cl. have.I frightened to death. (demonstrative pronoun)

Unlike definite pronouns and proper names, definite descriptions contribute a predicative condition on the variables they introduce. This condition does not fix the reference of the variable in question in the way equative conditions do therefore this difference with respect to the nature of the value conditions could be taken to account for the optionality of DOM with definite descriptions. Nevertheless, as pointed out by Farkas (2002), there are some cases of special definite descriptions which may acquire determined reference i.e. if the NP denotes a singleton set relative to the model or a contextually restricted set of entities According to Farkas (2002), this can be achieved in several ways: if the NP is a superlative (e.g. ‘the first man on the moon’), if it points to unique referents in relation to the model relative to which the discourse is interpreted (e.g. ‘the moon’).

Now, if these special types of definite DPs may acquire determined reference, our expectation with respect to their marking by means of PE was for DOM to be obligatory with such DPs. Our corpus analysis proved, however, that this is only partially true as only [+human, + determined reference] definite descriptions were obligatorily marked by means of PE. We needed therefore to weaken our initial hypothesis so as to correspond to the facts present in corpus.

3. a. L-am văzut *(pe) ultimul supraviețuitor de pe

   Him.cl. have.I seen PE last survivor on
   Titanic şi m-au impresionat foarte tare amintirile lui.
   Titanic and me.cl. have impressed very much memories his.
‘I have seen the last survivor from the Titanic and I was very impressed with his memories.’

b. Nu am văzut-o (pe) prima cățe care a ajuns pe lună, dar știu că o chema Laica.
‘I haven’t seen the first dog which reached the moon but I know her name was Laica.’

c. Nu-l stiu pe primul obiect gasit in piramida lui Keops dar trebuie sa fi fost foarte pretios.
‘I don’t know which was the first object they found in Keops’s pyramid but it must have been very precious.’

Thus, the parameter of determined reference still imposes obligatoriness of DOM on those DPs that have determined reference. Nevertheless, in the case of definitive descriptions, this parameter is overridden by the animacy scale of Aissen (2003). This accounts for both the obligatory nature of DOM with [+human, + determined reference] definite descriptions (normally DOM is optional with [+ human, - def] definite descriptions) and for the behavior of [- human, +/- animate, + determined reference] definite DPs. The results concerning the interaction between the two parameters are summarized below:

4. a. [+ determined reference] – obligatory DOM
   [+ human] – the highest on the animacy scale – preference for DOM
   Result: obligatory DOM

b. [+ determined reference] – obligatory DOM
   [- human, + animate] – lower on the animacy scale, optional DOM
   Result: optional DOM

c. [+ determined reference] – obligatory DOM
   [- human, -animate] – lowest on the animacy scale, no DOM
   Result: no DOM

As for the definite descriptions having indetermined reference, it proved from the corpus data that, in all these cases where definite DPs had a kind-generic interpretation, (hence they could not acquire determined reference), the use of DOM was prohibited. As it seems, the fact that these DPs could not acquire determined reference was reason enough to disallow the employment of DOM. Consider the example below containing kind denoting definite descriptions (‘fel’ kind, or ‘tip’ type) – these DPs may not acquire determined reference therefore we expect DOM to be at best optional (if not impossible). In fact, it proves impossible.

5. a. Mihai nu agreează tipul ăsta de fete.
   Mihai not like type.the this of girls.
   ‘Mihai does not like this type of girls.’

Furthermore, verbs like ‘a iubi’ (to love), ‘a uri’ (to hate), ‘a respecta’ (to respect), ‘a admira’ (to admire) range among those verbs which allow a ‘kind’ reading for the DP occupying their object position. As the examples below point out, PE-DPs (in the plural) are not allowed with these verbs. On the other hand, definite DPs in the plural that are not accompanied by PE can occur in the object position of these verbs and can receive a ‘kind’ reading as well.

6. a. Ion iubeste femeile.(generic)
   Ion loves women.the.

b. Ion le iubeste pe femei.(generic).
   ‘Ion loves women’.

Finally, we turned our attention to indefinite DPs and to their behaviour with respect to DOM. Since these DPs contribute a discourse referent and a predicative
condition on this value, we would not expect them to acquire determined reference, hence the lack of obligatoriness with DOM. However, following the lines of Farkas (2002) we linked the issue of variation in value assignments with indefinites comes with specificity. As it seems, when indefinites are specific (scopally specific or epistemically specific) they may be marked by means of PE as also pointed out by Carmen Dobrovie-Sorin (1994).

7. a. Fiecare parlamentar asculta un cetatean.
   Every member of parliament listened a citizen.
   ‘Every member of parliament listened to a citizen.
   
   b. Fiecare parlamentar îl asculta pe (anumit) un cetatean.
   Every member of parliament him.cl listened PE (certain) a citizen.
   ‘Every member of parliament listened to a citizen.’

Thus, sentence 7.a. above is ambiguous. It may have a quantificational reading i.e. when the variable introduced by the indefinite is within the scope of the universal quantifier (dependent indefinite i.e. the variable introduced by the indefinite is dependent on the variable introduced by the quantifier). On the other hand, the indefinite may also be outside the scope of the quantifier and point to a certain citizen. If one applies the preposition PE to the indefinite in this case, the interpretation is no longer ambiguous and the balance will be tilted in favour of a referential reading.

Nevertheless, the facts should not be taken at face value: all the examples we provided, the indefinite object was marked by PE but was also resumed by clitic pronoun in the same time. Therefore the specific reading the indefinite DP acquires in these examples may also be due to the presence of the clitic. Another problem which remains unsolved at this point is that concerning the optionality of DOM with these DPs. Thus, indefinite DPs may acquire a specific reading in the absence of DOM (the presence thereof however tilts the balance towards a clear-cut specific interpretation). This optionality may reside with the speaker who might play a bigger role in DOM assignment than foreseen so far. As it seems, further research is necessary in this respect.

Lastly, we extracted from the corpus some cases where the DOM was impossible: PE can never occur with mass nouns, bare plurals and incorporated DPs. This was a confirmation for the theoretical premises we had assumed: all these DPs fail to contribute a discourse referent let alone a condition on it.

We have requested the help of 42 native speakers of Romanian who kindly accepted to pass judgments and evaluate our synthetically created corpus of positive and negative 400 examples. Their judgments massively support our empirically grounded findings. The inter-subject agreement was high, i.e. r = 0.89.

5.2.5. Conclusions

In order to find empirical evidences for the way DOM with accusative marker “pe” is interpreted in Romanian, we semi-automatically constructed a corpus of Romanian phrases. We manually annotated the direct objects from the corpus with semantically interpretable features we suspected, based on previous studies, that are relevant for DOM, such as [±animate], [±definite], [±human]. Although the corpus is rather small, these annotations could make such a corpus attractive to be subsequently used to study other linguistic phenomena at semantic and pragmatic level.

Pronouns (Personal pronouns, pronouns of politeness, reflexive pronouns, possessive pronouns and demonstrative pronouns) are obligatorily marked by means of PE irrespective of the status of the referent on the animacy scale.

For proper names the use of PE is conditioned by the animacy scale which overrides the parameter of determined reference: it is obligatory with proper names pointing to [±human] Determiner Phrases and optional with [±animate] DPs, and ungrammatical with [-animate] proper names.

Definite descriptions are optionally marked by means of PE; the parameter of determined reference still imposes obligatoriness of DOM on those DPs that have determined reference. Nevertheless, in the case of definite descriptions, this parameter is overridden by the animacy scale. This accounts for both the obligatory nature of DOM
with [+human, + determined reference] definite descriptions (normally DOM is optional with [+human, -def] definite descriptions) and for the behaviour of [-human, +/- animate, + determined reference] definite DPs.

**Indefinite Description**: Only specific Indefinite Descriptions are optionally marked by means of PE. The others cannot be marked.

Based on the empirical evidence present in the corpus, we proposed a systematic account for DOM with accusative marker “pe” in terms of determined reference (cf. Farkas 2002) and the animacy scale (Aissen 2003). Thus, we argue that DOM is triggered both by the semantic nature of the object DP (in terms of how referentially stable it is) and by parameters such as ‘animacy’.

6. **On classifying coherent/incoherent short texts**

6.1. **A first experiment: classifying coherent/incoherent e-mail messages**

We propose a quantitative approach (Dinu 2010.c) to a relatively new problem: categorizing text as pragmatically correct or pragmatically incorrect (forcing the notion, we will refer to these categories as coherent and incoherent). The typical text categorization criterions comprise categorization by topic, by style (genre classification, authorship identification (Dinu et al. 2008)), by language (Dinu and Dinu 2005, Dinu and Dinu 2006), by expressed opinion (opinion mining, sentiment classification), etc. Very few approaches consider the problem of categorizing text by degree of coherence, as in (Miller 2003). One example of application of text categorization by its coherence is creating a spam filter for personal e-mail accounts able to cope with one of the new strategies adopted by spammers. This strategy consists of encoding the real message as picture (impossible to directly analyze and reject by the text oriented classical filters) and accompanying it by a text especially designed to surpass the filter. For human subjects, the text in the picture is easily comprehensible, as opposed to the accompanying text, which is only recognizable as either syntactically incorrect (collection of words), or semantically incorrect, or pragmatically incorrect i.e. incoherent (collection of proverbs or texts obtained by putting together phrases or paragraphs from different text). On the other hand, for classical spam filters, which usually relay on algorithms that use as features content words (based on the frequencies of the words commonly used in spam messages), the picture offers no information and the accompanying text may pass as valid (because it contains content word usually not present in spam messages). As a result, such messages are typically sent by the spam filter into the Inbox, instead of the Bulk folder. The role of this e-mail messages is double: to surpass the spam filter so that get to be read by the owner of the account and, second and more important, if they are manually labelled as spam messages, they untrain the classical spam filter due to their content words which do not usually appear in spam messages. Thus, after the spam filter sees enough such messages labelled as spams, it eventually cannot make any difference between spam and normal messages. An important question for automatically categorizing texts into coherent and incoherent is: are there features that can be extracted from these texts and be successfully used to categorize them? We propose a quantitative approach that relies on the use of ratios between morphological categories from the texts as discriminant features. We supposed that these ratios are not completely random in coherent text.

The goal of our experiment is to automatically classify e-mail messages into two classes: coherent messages, to go to Inbox and incoherent messages (good candidates for Bulk folder). We used a number of supervised machine learning techniques on a small
corpus of English e-mail messages and let the algorithms to extract important features from all the pos ratios; The results are encouraging: the best performing technique used in our experiment has a leave one out (l.o.o.) accuracy of 85.48%.

6.1.1. The corpus

We manually built a small English e-mail messages corpus comprising 110 messages: 55 negative (incoherent) and 55 positive (coherent). The 55 negative messages were manually selected from a large list of personal spam messages. There are three categories of specially designed text for surpassing the spam filter: syntactically incorrect, semantically incorrect and pragmatically incorrect. In this article we focus on the last category, so we only included into the 55 negative examples the pragmatically incorrect messages (most of them being collections of proverbs or phrases randomly chosen from different texts and assembled together). We reproduce one negative and one positive example in the Appendix. As positive messages we selected coherent messages from two sources: Enron corpus (http://www.cs.cmu.edu/enron/) and personal e-mail messages, trying not to have a too homogenous collection of e-mail messages. All 110 e-mail messages are genuine, with no human intervention into their text.

6.1.2. Categorization experiments and results

To produce the set of features, we tagged each text using the set of tags from Penn Tree Bank. We considered that this set of tags is too detailed; for the purpose of this experiment we do not need all tags, so we only took in consideration 12 representative parts of speech: we eliminated the punctuation tags and we mapped different subclasses of pos into a single unifying pos (for example all subclasses of adverbs were mapped into a single class: the adverbs, all singular and plural common nouns were mapped into a single class: common nouns, etc). We give in table 1 the mappings that we used:

<table>
<thead>
<tr>
<th>Pos</th>
<th>Label</th>
<th>Pos</th>
<th>Label</th>
<th>Pos</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>1</td>
<td>VBZ</td>
<td>3</td>
<td>RBS</td>
<td>7</td>
</tr>
<tr>
<td>NN</td>
<td>1</td>
<td>MD</td>
<td>4</td>
<td>PRP</td>
<td>8</td>
</tr>
<tr>
<td>NNS</td>
<td>1</td>
<td>PDT</td>
<td>5</td>
<td>PRPS</td>
<td>8</td>
</tr>
<tr>
<td>NNP</td>
<td>2</td>
<td>DT</td>
<td>5</td>
<td>CC</td>
<td>9</td>
</tr>
<tr>
<td>NNPS</td>
<td>2</td>
<td>JJ</td>
<td>6</td>
<td>CD</td>
<td>10</td>
</tr>
<tr>
<td>VB</td>
<td>3</td>
<td>JJR</td>
<td>6</td>
<td>IN</td>
<td>11</td>
</tr>
<tr>
<td>VBD</td>
<td>3</td>
<td>JJS</td>
<td>6</td>
<td>TO</td>
<td>11</td>
</tr>
<tr>
<td>VBG</td>
<td>3</td>
<td>RB</td>
<td>7</td>
<td>WDT</td>
<td>12</td>
</tr>
<tr>
<td>VBN</td>
<td>3</td>
<td>RBR</td>
<td>7</td>
<td>WP</td>
<td>12</td>
</tr>
<tr>
<td>VBP</td>
<td>3</td>
<td>RBS</td>
<td>7</td>
<td>WPS</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 1. Mapping pos subclasses into unifying classes.

For the task of tagging we used Maximal Entropy Part of Speech Tagger (Ratnaparkhi 1996) because it is free to use and because it has a high reported accuracy of 96.43%.

We computed pos frequencies for each text from the training set (both from the positive – coherent and from the negative - incoherent examples). We normalized them (divided all the frequencies to the total number of tagged words in each text), to neutralize the fact that the texts had different lengths. We then computed all possible 66 ratios
between all tags. We also added a small artificial quantity (equal to 0.001) to all the frequencies before computing the ratios, to guard against division by zero. These 66 values become the features on which we trained 3 out of 5 types of machines we employed (the other two needed no such pre-processing). Because of the relative small number of examples in our experiment, we used leave one out cross validation, which is considered an almost unbiased estimator of the generalization error. Leave one out technique consists of holding each example out, training on all the other examples and testing on all examples.

The first and the simplest technique we used was the linear regression (Duda et al. 2001), not for its accuracy as classifier, but because, being a linear method, allows us to analyze the importance of each feature and so determine some of the most prominent features for our experiment of categorizing coherent/incoherent texts.

For this experiment we used the pre-processed data as described above. Its l.o.o accuracy was of 68.18%, which we used further as baseline for next experiments.

We ordered the 66 features (pos ratios) in decreasing order of their coefficients computed by performing regression. The top 5 features that contribute the most to the discrimination of the texts are very interesting from a linguistic point of view:

- the ratio between modal auxiliary verbs and adverbs, representing 17.71% of all feature weights;
- the ratio between the pre-determiner (such as all, this, such, etc) and adverbs, representing 14.6% of all feature weights;
- the ratio between pre-determiner and conjunction, representing 9.92% of all feature weights;
- the ratio between common nouns and conjunctions, representing 7.37% of all feature weights;
- the ratio between modal verbs and conjunctions, representing 7.25% of all feature weights.

These top 5 features accounted for 56.85% of data variation. The first ratio may be explained by the inherent strong correlation between verbs and adverbs. The presence of conjunction in 3 out of the top 5 ratios confirms the natural intuition that conjunction is an important element w.r.t. the coherence of a text. Also, the presence of the pre-determiners in top 5 ratios may be related to the important role coreference plays in the coherence of texts.

As we said, we used the linear regression to analyze the importance of different features in the discrimination process and as baseline for state of the art machine learning techniques. We tested two kernel methods (ν support vector machine and Kernel Fisher discriminant), both with linear and polynomial kernel.

Kernel-based learning algorithms work by embedding the data into a feature space (a Hilbert space), and searching for linear relations in that space. The embedding is performed implicitly, that is by specifying the inner product between each pair of points rather than by giving their coordinates explicitly.

The kernel function captures the intuitive notion of similarity between objects in a specific domain and can be any function defined on the respective domain that is symmetric and positive definite.

Given an input set \( X \) (the space of examples), and an embedding vector space \( F \) (feature space), let \( \phi : X \to F \) be an embedding map called feature map.
A kernel is a function $k$, such that for all $x, z$ in $X$, $k(x, z) = \langle \phi(x), \phi(z) \rangle$, where $\langle \cdot, \cdot \rangle$ denotes the inner product in $F$.

In the case of binary classification problems, kernel-based learning algorithms look for a discriminant function, a function that assigns $+1$ to examples belonging to one class and $-1$ to examples belonging to the other class. This function will be a linear function in the space $F$, so it will have the form:

$$f(x) = \text{sign}(< w, \phi(x) > + b),$$

for some weight vector $w$. The kernel can be exploited whenever the weight vector can be expressed as a linear combination of the training points, $\sum_{i=1}^{n} \alpha_i \phi(x_i)$, implying that $f$ can be expressed as follows:

$$f(x) = \text{sign} \left( \sum_{i=1}^{n} \alpha_i k(x_i, x) + b \right).$$

Various kernel methods differ by the way in which they find the vector $w$ (or equivalently the vector $\alpha$). Support Vector Machines (SVM) try to find the vector $w$ that defines the hyperplane that maximally separates the images in $F$ of the training examples belonging to the two classes.

Kernel Fisher Discriminant (KFD) selects the $w$ that gives the direction on which the training examples should be projected such that to obtain a maximum separation between the means of the two classes scaled according to the variances of the two classes in that direction.

Details about SVM and KFD can be found in (Taylor and Cristianini 2004, Cristianini and Taylor 2000).

The $\nu$ support vector classifier with linear kernel ($k(x, y) = \langle x, y \rangle$) was trained, as in the case of regression, using the pre-processed 66 features, exactly the same features used for linear regression. The parameter $\nu$ was chosen out of nine tries, from 0.1 to 0.9, the best performance for the SVC being achieved for $\nu = 0.3$. The l.o.o. accuracy for the best performing $\nu$ parameter was 78.18%, with 10% higher than the baseline.

The Kernel Fisher discriminant with linear kernel was trained on preprocessed data as it was the case with the regression and $\nu$ support vector classifier. Its l.o.o. accuracy was 75.46 %, with 7.28 % higher than the baseline.

The flexibility of the kernel methods allow us to directly use the pos frequencies, without computing any pos ratios. That is, the polynomial kernel implicitly relies on the inner product of all features, so there is no further need to compute their ratios in advance.

The support vector machine with polynomial kernel was trained directly on the data, needing no computation of ratios. The kernel function we used is: $k(x, y) = (\langle x, y \rangle + 1)^2$. Its l.o.o. accuracy for the best performing $\nu = 0.4$ parameter was 81.81 %, with 13.63% higher than the baseline.

The Kernel Fisher discriminant with polynomial kernel was trained directly on the data, needing no ratios. Its l.o.o. accuracy was 85.46 %, with 17.28 % higher than the baseline. We summarized these results table 2.

<table>
<thead>
<tr>
<th>Learning method type</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression (baseline)</td>
<td>68.18%</td>
</tr>
<tr>
<td>linear Support Vector Classifier</td>
<td>78.18%</td>
</tr>
<tr>
<td>quadratic Support Vector Machine</td>
<td>81.81%</td>
</tr>
<tr>
<td>linear Kernel Fisher discriminant</td>
<td>75.46%</td>
</tr>
<tr>
<td>polynomial Kernel Fisher discriminant</td>
<td>85.46%</td>
</tr>
</tbody>
</table>

Table 2. Accuracy of the learning methods used in the experiment.
The best performance was achieved by the Kernel Fisher discriminant with polynomial kernel.

6.1.3. Conclusions and further work

The best l.o.o. accuracy we obtained, i.e. 85.48% is a good accuracy because there are inherent errors, transmitted from the part of speech tagger and perhaps from the subjective human classification into the two classes (coherent/incoherent text) used as the training set. Also using only the frequencies of the parts of speech in the texts disregards many other important features for text coherence.

It would be interesting to compare our quantitative approach to some qualitative techniques related to text coherence, such as latent semantic analysis (Dumais et al. 1988), lexical chains (Hirst and St.-Onge 1997), or textual coherence vs. textual cohesion approach (Marcus 1980). Also, it would be useful to train the machine to have an error as small as possible for positive examples (coherent texts sent into Bulk folder), even if the error for negative examples would be bigger (incoherent texts sent into Inbox).

6.1.4. Appendix

We reproduce here in order a positive example of a coherent e-mail message and a negative example of an incoherent e-mail message, respectively.

"I will be getting back to the website some time this week. Thank you for updating the info on the need analysis page. If you haven’t done it yet, please look at Paula’s page to check what remains to be done for your language. Remember that your deadline for sending me your final report forms as explained in Prague is Nov.15. I hope Mario can give you some details on how to go about filling in the various pages. Concerning the Wikipedia entry for Euromobil in all 9 languages, we agreed in Prague that it was indeed a good idea. I haven’t been able to deal with it yet, but I saved the revised PL text and I hope to have some time shortly to do it. I hope those of you who haven’t done it yet can do it also. Best, Jeannine”

" No one will ever think of looking for you in there. A job applicant challenged the interviewer to an arm wrestle. I am fascinated by fire. I did not object to the object. Your first-aid kit contains two pints of coffee with an I.V. hookup. And you can travel to any other part of the building without difficulty. Interviewee wore a alman, explaining that she could listen to the interviewer and the musicat the same time. You can outlast the Energizer bunny. Dancing around in a threatening manner until you have dispatched their predecessors. I know who is responsible for most of my troubles I have no difficulty in starting or holding mybowel movement. People get dizzy just watching you. Candidate said he never finished high school because he was kidnapped and kept in a closet in Mexico.”

6.2. A second experiment: classifying coherent/incoherent Romanian short texts

In this section we present and discuss a similar coherence experiment performed on a small corpus of Romanian text from a number of alternative high school manuals (Dinu 2008).

During the last 10 years, an abundance of alternative manuals for high school was
produced and distributed in Romania. Due to the large amount of material and to the
relative short time in which it was produced, the question of assessing the quality of this
material emerged; this process relied mostly of subjective human personal opinion, given
the lack of automatic tools for Romanian.

Debates and claims of poor quality of the alternative manuals resulted in a number
of examples of incomprehensible / incoherent paragraphs extracted from such manuals.
Our goal was to create an automatic tool which may be used as an indication of poor
quality of such texts.

We created a small corpus of representative texts from 6 Romanian alternative
manuals. We manually classified the chosen paragraphs from such manuals into two
categories: comprehensible/coherent text and incomprehensible/incoherent text. We then
used different machine learning techniques to automatically classify them in a supervised
manner.

There are many qualitative approaches related to coherence that could be applied to
English language. For example, segmented discourse representation theory (Lascarides
2007) is a theory of discourse interpretation which extends dynamic semantics by
introducing rhetorical relations into the logical form of discourses. A discourse is coherent
just in case: a) every proposition is rhetorically connected to another piece of discourse,
resulting in a single connected structure for the whole discourse; b) all anaphoric
expressions/relations can be resolved. Maximize Discourse Coherence is a guiding
principle. In the spirit of the requirement to maximize informativeness, discourses are
normally interpreted so as to maximize coherence. Other examples of qualitative
approaches related to coherence are latent semantic analysis (Dumais et al. 1988), lexical
chains (Hirst and St.-Onge 1997), centering theory (Beaver 2004), discourse representa-
tion theory (Kamp and Reyle 1993), veins theory (Cristea 2003), etc.

Nevertheless, because of the lack of appropriate tools for Romanian language, we
had to choose a quantitative approach for automatically categorizing short Romanian text
into coherent /comprehensible and incoherent /incomprehensible. An important question
for such categorization is: are there any features that can be extracted from these texts that
can be successfully used to categorize them? We propose a quantitative approach that
relies on the use of ratios between morphological categories from the texts as discriminant
features. We supposed that these ratios are not completely random in coherent text.

Our approach is rather simple, but the results are encouraging.

6.2.1. The corpus

We created a small corpus of texts from 6 Romanian alternative manuals with
different authors. We used 5 annotators to manually classify the chosen paragraphs from
such manuals into two categories: comprehensible /coherent text (the positive examples)
and incomprehensible /incoherent text (the negative examples). We selected 65 texts
(paragraphs) which were unanimously labelled by all the annotators as incoherent
/incomprehensible. We also selected 65 coherent / comprehensible texts from the manuals,
by the same method.

As some annotators observed, the yes or no decision was overly restrictive; they
could have gave a more fine grained answer such as very difficult to follow, easy to follow,
etc, but we decided to work with 2 class categorisation from reasons of simplicity. We
leave this for further work, as well as creating a larger corpus.

6.2.2. Categorization experiments and results
We used Balie system developed at Ottawa University http://balie.sourceforge.net/), which has a part of speech tagger for Romanian, named QTag. We only took in consideration 12 parts of speech. We eliminated the punctuation tags and we mapped different subclasses of pos into a single unifying pos (for example all subclasses of adverbs were mapped into a single class: the adverbs, all singular and plural common nouns were mapped into a single class: common nouns, etc). We manually corrected the tagging, because of the poor accuracy obtained by the parser and because the size of the corpus allowed us to do so. We computed the pos frequencies in each of the training set texts (both from the positive and from the negative examples). We normalized them (divided the frequencies to the total number of tagged words in each text), to neutralize the fact that the texts had different lengths. We then computed all possible 66 ratios between all 12 tags. In the process of computing these ratios we added a small artificial quantity (equal to 0.001) to both the numerator and the denominator, to guard against division by zero. These 66 values become the features on which we trained 3 out of 5 types of machines we employed (the other two needed no such pre-processing).

Because of the relatively small number of examples in our experiment, we used leave one out cross validation (l.o.o.) (Efron and Tibshirani 1997, Tsuda 2001), which is considered an almost unbiased estimator of the generalization error. Leave one out technique consists of holding each example out, training on all the other examples and testing on the hold out example.

We used was the linear regression (Duda et al. 2001, Chen et al. 2003, Schroeder et al. 1986), not for its accuracy as a classifier, but because, being a linear method, it allows us to analyze the importance of each feature and so determine some of the most prominent features for our experiment of text categorization. We also used this method as a base line for the other experiments.

For a training set: $S = (x_1, y_1), (x_2, y_2), ..., (x_l, y_l)$, the linear regression method consists in finding the real linear function (i.e finding the weights $w$)

$$g(x) = \sum_{i=1}^{l} w_i x_i$$

such that

$$\sum_{i=1}^{l} (y_i - g(x_i))^2$$

is minimized. If the matrix $X'X$ is invertible, then the solution is $w = (X'X)^{-1}X'y$. If not (the matrix $X'X$ is singular), then one uses the pseudo-inverse of the matrix $X'X$, thus finding the solution $w$ with the minimum norm. For this experiment we used the pre-processed data as described above. Its l.o.o. accuracy was of 67.48%, which we used further as baseline for next experiments.

We ordered the 66 features (pos ratios) in decreasing order of their coefficients computed by performing regression. Next, we tested two kernel methods (M"uller et al. 2001, Sch"olkopf and Smola 2002): ν support vector machine (Saunders et al. 1998) and Kernel Fisher discriminant (Mika et al. 1999, Mika et al. 2001), both with linear and polynomial kernel.

The ν support vector classifier with linear kernel ($k(x, y) = \langle x, y \rangle$) was trained, as in the case of regression, using the pre-processed 66 features, exactly the same features used for linear regression.

The parameter ν was chosen out of nine tries, from 0.1 to 0.9, the best performance for the SVC being achieved for ν = 0.4. The l.o.o. accuracy for the best performing ν parameter was 73.34%, with 5.86% higher then the baseline.
The Kernel Fisher discriminant with linear kernel was trained on pre-processed data as it was the case with the regression and ν support vector classifier. Its l.o.o. accuracy was 74.92%, with 7.44% higher than the baseline.

The flexibility of the kernel methods allows us to directly use the pos frequencies, without computing any pos ratios. That is, the polynomial kernel relies on the inner product of all features: it implicitly embeds the original feature vectors in a space that will contain as features all the monomial (up to the degree of the polynomial used) over the initial features. For a polynomial kernel of degree 2 for example, the implicit feature space will contain apart of pos frequencies, all the products between these frequencies, these products playing the same role as the ratios.

The support vector machine with polynomial kernel was trained directly on the data, needing no computation of ratios. The kernel function we used is:

\[ k(x, y) = (\langle x, y \rangle + 1)^2 \]

The l.o.o. accuracy of the support vector machine with polynomial kernel for the best performing ν = 0.4 parameter was 81.13%, with 13.65% higher than the baseline.

The Kernel Fisher discriminant with polynomial kernel was trained directly on the data, needing no ratios. Its l.o.o. accuracy was 85.12%, with 17.64% higher than the baseline.

All machine learning experiments were performed in Matlab, or using Matlab as interface (Chang and Lin 2001).

The best performance was achieved by the Kernel Fisher discriminant with polynomial kernel, with a l.o.o. accuracy of 85.12%.

6.2.3. Conclusions

The best l.o.o. accuracy we obtained, i.e. 85.12% is a good accuracy because using only the frequencies of the parts of speech in the texts disregards many other important features for text coherence, such as, for example, the order of phrases, coreferences resolution, rhetorical relations, etc.

Further work: the two class classification, in the case of Romanian alternative high school manuals, is a rather dramatic classification. It would be useful to design a tool that produces as output not just a yes/no answer, but a score or a probability that the input (text) is in one of the two categories, such that a human expert may have to judge only the texts with particular high probability to be in the class of incoherent texts.

7. Conclusions of the thesis and future work

The unifying topic of this thesis was the concept of discourse.

In the first part of the thesis we accounted for discourse related notions such as anaphora, quantifier scope, binding, singular and plural pronouns (conjunction and disjunction, distributivity and maximality condition included) ellipsis, accommodation, quantifying over eventualities (Dinu 2011.a, Dinu 2011.b). All of these phenomena needed no extra stipulations to be accounted for in continuation semantics framework. This is due to the fact that the continuation based semantics provides a unified account of scope-
taking. No other theory to our knowledge lets indefinites, other quantifiers, pronouns and other anaphors interact in a uniform system of scope taking, in which quantification and binding employ the same mechanism. We also proposed a mechanism (left underspecified in previous work on continuation semantics) which ensures that no lexical entry having the scope bounded to its minimal clause (such as \textit{not}, \textit{no}, \textit{every}, \textit{each}, \textit{any}, etc) will ever take scope outside (Dinu 2011.c).

The second part of this thesis presented the work on creating and analyzing electronic resources for Romanian language: a Romanian Generative Lexicon (Dinu 2010.a, Dinu 2010.b) and a corpus for the study of differential object marking in Romanian (Dinu and Tigau 2010). RoGL contains a corpus, an ontology of types, a graphical interface and a database from which we generate data in XML format. The interface and the database where the annotated lexical entries are stored and processed are hosted on the server of Faculty of Mathematics and Computer Science, University of Bucharest: http://ro-gl.fmi.unibuc.ro. To implement the generative structure and the composition rules, we have chosen the functional programming language Haskell. Our choice was determined by the fact that reducing expressions in lambda calculus (obviously needed in a GL implementation), evaluating a program (i.e. function) in Haskell, and composing the meaning of a natural language sentence are, in a way, all the same thing. The most important work which still needs to be done in RoGL framework is to annotate more lexical entries. The manual annotation, although standardized and mediated by the graphical interface is notoriously time consuming especially for complex information such as those required by a generative lexicon.

Building a Romanian corpus for the study of Differential Object Marking (DOM) was motivated by the fact that in Romanian the uses of the accusative marker “pe” with the direct object (in combination or not with clitics) involve mechanisms which are not fully understood and seeming messy for the non-native speaker: sometimes the accusative marker is obligatory, sometimes it is optional and even forbidden. This research provided a systematic account for these linguistic phenomena based on empirical evidence present in the corpora. Such an account may be used in subsequent studies to improve statistical methods with targeted linguistic knowledge.

The third part of the thesis comprised two experiments of classification by coherence/incoherence of short English and Romanian texts, respectively, using machine learning techniques (Dinu 2010.c, Dinu 2008). We proposed a quantitative approach that relies on the use of ratios between morphological categories from the texts as discriminant features, assuming that these ratios are not completely random in coherent text. We used a number of supervised machine learning techniques, letting the algorithms to extract important features from all the pos ratios.

In this thesis, we have analyzed the semantic content of distinct lexical entries, as well as of the discourse as a hole, using computer science tools and methods such as continuations and machine learning techniques.

We leave for future research challenging issues such as:

- Completing an algorithm that generates all possible interpretations for a given piece of discourse in continuation semantics framework;
- The possibility to express situation semantics in continuation framework;
- A complete specification of event semantics, that is obviously not possible without taking into consideration thematic roles, aspect, modality and tense.
- A way of representing the imprecision of the restriction RelevEvent, needed to implement the event semantics presented in this work.
- The comparison of our approach to anaphora to anaphora in algebraic linguistics.
8. References:


