

UNIVERSALITY AND INDIVIDUALITY: THE INTERACTION OF NOUN PHRASE DETERMINERS IN COPULAR CLAUSES

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Abstract

This paper presents an implemented theory for quantifying noun phrases in clauses containing copular verbs (e.g., 'be' and 'become'). Proceeding from recent theoretical work by Jackendoff [1983], this computational theory recognizes the dependence of the quantification decision on the definiteness, indefiniteness, or classness of both the subject and object of copular verbs in English. Jackendoff's intuition about the quantificational interdependence of subject and object has been imported from his broader cognitive theory and reformulated within a constraint propagation framework. Extensions reported here include the addition of more active determiners, the expansion of determiner categories, and the treatment of displaced objects. A further finding is that quantificational constraints may propagate across some clausal boundaries. The algorithm is used by the RELATUS Natural Language Understanding System during a phase of analysis that posts constraints to produce a 'constraint tree.' This phase comes after creation of syntactic deep structure and before sentential reference in a semantic-network model. Incorporation of the quantification algorithm in a larger system that parses sentences and builds semantic models from them makes RELATUS able to acquire taxonomic and identity information from text.

Introduction

The quantification of noun phrases, determining their universality or individuality, is critical for the automatic acquisition of taxonomic and identity information from natural language sentences. Automatic acquisition can convert ordinary texts into sources of taxonomic and identity information for use by learning and reasoning programs in artificial intelligence. Such information can also find use in efforts to develop selection restrictions from lexical sources. Of course, proper quantification of noun phrases also plays a key

role in computer programs that endeavor to understand natural language.

The theory for computing the quantificational status of noun phrases for the case of copular verbs (e.g., 'be' and 'become') was inspired by recent theoretical work of Jackendoff [1983]. Jackendoff noted that quantification of noun phrases for copular verbs depends jointly on the determiners of both the subject NP and the object NP [1983, 90-91, 96].¹ His intuition has been reformulated, augmented, and implemented in the RELATUS Natural Language Understanding System.²

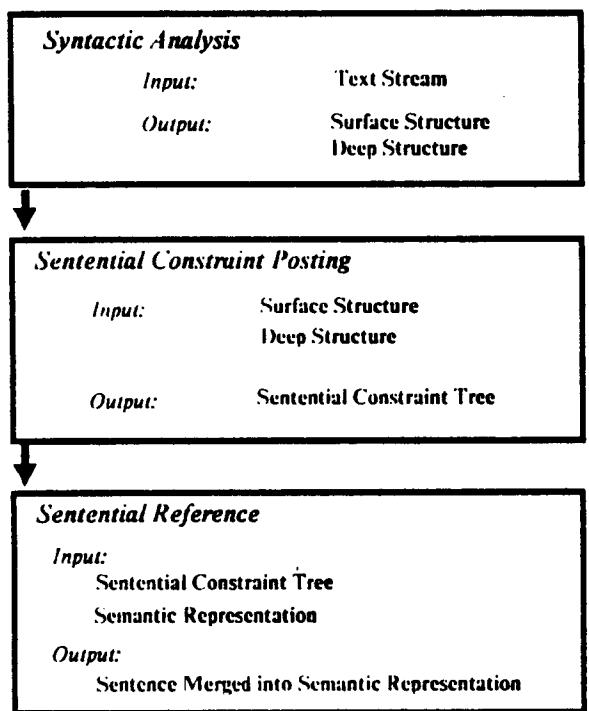
The implemented quantification theory is used by RELATUS as it incrementally builds a semantic model. This method recovers class and identity information from ordinary English sentences. Although the semantic model must be occasionally queried to resolve quantificational ambiguities, the method is primarily syntactic and does not require reasoning. The computational simplicity and broad coverage of the theory allow successful quantification of noun phrases in most copular clauses. Work is in progress to extend the analysis to partitives and thereby yield a comprehensive analysis. While this approach does not treat such difficult issues as belief contexts and metaphorical usages, it does address most literal cases. Since the quantification

1. I will use "object NP" to refer to what is frequently called a "predicate object."

2. The experimental RELATUS Natural Language Understanding System represents the combined efforts of Gavan Duffy and the author. Gavan Duffy is responsible for the parser, the categorial disambiguator [Duffy, 1985b], the lexicon and lexicon utilities. The author is responsible for the representation system, the reference system, the component that maps deep structure to semantics, the quantification system, the inversion system, and the question-answering component.

theory is deployed in a natural language system that parses sentences and builds a semantic model from them, RELATUS becomes, among other things, a system for acquiring class structure information from ordinary English texts.

Fig. 1. Sentence Processing in RELATUS



The quantification algorithm is embedded in a sentential constraint-posting process [Duffy and Mallery, 1984] shown in figure 1. Sentential constraint-posting creates a *constraint tree* that corresponds to roughly what transformational grammarians call *logical form*. The constraint tree is used to perform intersentential reference (merging successive sentences into a single semantic-network model) [Mallery, 1985]. The input to constraint-posting phase is both surface structure and deep structure canonicalized by a transformational parser [Duffy, 1985a]. In a depth-first, bottom up walk of the deep structure, constraints describing grammatical relations are posted on non-terminal parse-graph nodes.³ When verbs in major clauses (*i.e.*, clauses other than relative clauses or clausal adjuncts) are reached, they

supervise the quantification of noun phrases they command. If these verbs are copular verbs, the copular interconstraint algorithm is applied. In other cases, another experimental algorithm performs quantification by drawing on logical relations from surface structure. The result of this process is the sentential constraint tree. It is a hierarchical description of grammatical and logical relations that is suitable input for the reference system. By sequentially referencing the sentences of a text, a semantic model of the text is incrementally constructed.

The Copular Interconstraint Algorithm

Within a constraint-posting framework, the basic task of NP quantification is to decide whether to post a constraint marking the NP as an individual or a universal. Since the task involves knowing the specific subject and object of a copular verb, it is delegated to a higher constituent, the verb.⁴ This delegation is motivated by the *principle of local decision-making* which holds that decisions should be located where all required information is both available and proximate. In this case, only the verb knows the identities of both noun phrases due to the hierarchical structure of grammatical relations. Thus, when a verb posts its own referential constraints, it also directs the quantification of NPs that it dominates (*e.g.*, its subject and object).

This procedure was reformulated in a constraint propagation [Waltz, 1975] framework because features of a single constituent cannot be determined independently of other constituents in the sentential derivation. Since quantificational constraint propagates in both directions, this process is a type of *constituent interconstraint*. Fortunately, the possible states of NPs are only three: definite, indefinite, and class. Because the number of possible NP states is small (3) and the number of variables is also small (2), a simple table-lookup algorithm ‘compiles’ subject and object quantifications for all possible configurations of NP definiteness.⁵

3. At present, the RELATUS system builds sentential constraints using the canonical grammatical relations of the sentence, the quantification status of noun phrases, and the truth values of verbs. Work is in progress to incorporate temporal constraints on verbs, temporal adjectives, and various types of context markers.

4. The RELATUS parser uses non-standard parse graphs. A ‘kern’ corresponds to a clause while a ‘verbal’ is something like a verb phrase except that the kern tells it what its subject, object, and modifiers are at constraint-posting time. For further details, see Duffy [1985a].

Fig. 2. Determiner Categories

Determiner/Parameters	NP Classification
The	Definite
This/These	Definite
That/Those	Definite
<i>No det & singular proper noun.</i>	Definite
<i>No det & possessively modified.</i>	Definite
A	Indefinite
An	Indefinite
Another	Indefinite
Some	Indefinite
<i>No det & plural.</i>	Indefinite
All	Class
Any	Class
Every	Class
No	Class

The actual task of determining the quantificational status of the NPs decomposes into three steps.

(1) The definiteness of the noun phrases is ascertained by examining the determiners and several other parameters. The algorithm is summarized by figure 2. Another algorithm described by figure 3 is used for determinerless plural NPs.

(2) The quantificational status of the subject and object is determined by looking each case up in the table depicted by figure 4. Potentially ambiguous cases (marked with an asterisk) may require referencing the noun phrase in the semantic model to resolve the ambiguity. Example sentences for the cases in figure 4 are found in figure 5.

(3) The verb-phrase node informs each NP of its quantification (the results of step 2), and they in

5. The conversion of constraint propagation into a table lookup approach is possible in this special case because there are only two variables, the subject and the object. In the general case, the size of the table is exponential in the number of variables.

turn post corresponding constraints on themselves.

Fig. 3. Categories for Determiner-less NPs

Characteristic of NP	NP Classification
Singular Proper Noun	Definite
Plural	Indefinite
Possessively Modified	Definite
Animate Pronouns	Definite

In his discussion, Jackendoff [1983: 77-106, esp. 88-91, 94-106] only categorizes determiners according to the distinction between definite and indefinite. I have added *classness* to his scheme in order to cope with such determiners as 'all', 'any' and 'every'. While Jackendoff's examples use only the determiners 'a', 'an', and 'the', I have found interpretations for additional determiners which are summarized in figure 2. Jackendoff considers proper nouns to be definite and the same is done here, except in certain cases of plural proper nouns which are interpreted as the plural indefinite (see S21 in figure 5). The addition of the class categorization calls for the class determiners in the bottom of figure 2.

The determiner, 'no', is treated as the negation of 'all.' Thus, the NP is quantified as a class and the copula negated. While S10 and S18 in figure 5 are valid, S19 is not. There are restrictions on where 'no' can appear. It cannot modify both the subject and object. Nor can it modify the object when the subject is indefinite (S19) or a universal (S20), but it can when the subject is definite (S18). These restrictions seem generally valid for literal cases even though some idiomatic and metaphorical constructions may violate them.

Various cases of determiner-less NPs are handled by the algorithm that determines NP definiteness. Those cases are listed in figure 3. The indefinite category may be incompletely handled because the theory does not yet encompass partitives -- indefinite NPs that partition collections of individuals or universals. Thus, determiner-less NPs with plural head nouns are not analyzed for partitive readings.

Fig. 4. Universe of Interconstraint Categorizations

Case	Sentence	Determiner Classification		Noun Phrase Quantification	
		Subject	Object	Subject	Object
C1	S1, S2	Indefinite	Indefinite	Class	Class
C2	S3	Indefinite	Class	Class	Class
C3	S4	Indefinite	Definite	Class	Class
C4	S5, S6, S7	Definite	Definite	Individual*	Individual*
C5	S8, S9	Definite	Indefinite	Individual*	Class
C6	S11	Definite	Class	Individual	Class +
C7	S12	Class	Definite	Class	Class
C8	S13	Class	Class	Class	Class +
C9	S10, S14	Class	Indefinite	Class	Class

* Indicates the possibility of quantificational ambiguity.

+ Indicates that grammatical sentences must have displaced objects.

Partitive determiners may engender two readings. The NPs they modify can be read as either collections of individuals or universals. Some partitive determiners such as 'some,' 'each,' 'most,' 'few,' or 'many' are used to make statements about subsets of a collection. With the exception of 'some,' these are missing from figure 2 pending research about how to determine their quantification. 'Some' is interpreted just as an indefinite because of its high frequency. The determiners 'all,' 'any,' and 'every,' were included because they refer to the entirety of a collection. None of the partitive determiners, even the ones currently used to determine classness, will be adequately handled until completion of continuing work on the syntactic parse graphs and the interaction characteristics of partitives.

Sometimes copular verbs take adjectives in the object position, leaving no apparent object. Some of these adjectives have a *displaced object* as in S2, S11, S13, S15 and S16 in figure 5. Were there actually no object, the quantification of the subject would be determined in isolation (using a different algorithm). When the adjective has an object, that object is used to perform the NP interconstraint with the subject. Cases C6 and C8 are impossible (S22 and S24) unless the sentences have displaced objects (S11 and S13). However, this is not the case for C6 where a copular verb is modal and has a partitive determiner on its object. This suggests that partitive readings of class determiners may make these cases acceptable and that displaced objects simply make such a reading easier.

Displaced subjects appear as the NPs to which "relative pronouns" bind in relative clauses or appositives. S15 provides an example of interconstraint across a relative clause. There, 'a philosopher' is the displaced subject of the displaced object, 'an Ionian stoic.' Interestingly, 'a philosopher' is also a displaced object with respect to 'Mary.' Recall that constraint posting proceeds from the bottom of the parse graph up the hierarchy of grammatical relations with quantification following along and being governed by major verbs. In S15, quantification interconstraint is first applied to 'a philosopher' and 'an Ionian stoic' by the copula of the relative clause. Then, it is applied to 'Mary' and 'a philosopher' by the major copula. Since the first NP interconstraint fixes 'a philosopher' as a universal, that result is then carried over into the interconstraint with 'Mary.' In both S15 and S16, the quantificational constraint propagates across clausal boundaries because both clause share the same NP as an object and a subject. Cases such as these should not lead to inconsistent quantifications. Instead, they should agree, attesting to the soundness of the algorithm.

Jackendoff [1983: 97] argues that cases C4 and C5 in figure 4 are semantically ambiguous. This ambiguity seems only to hold for the determiner 'the' and is resolved by a simple reference of the NP in the semantic representation.⁶ If the ambiguous NP has no referent in the current discourse focus [Grosz, 1977], then the NP must be a universal. If there is a referent, it is either a universal or an individual, and the same

Fig. 5. Sentences Exhibiting Copular Interconstraint

- (S1) $i \succ c$ $i \succ c$
A dog is not a reptile. (*Generic categorization* [Jackendoff, 1983: 95])
- (S2) $i \succ c$ $i \succ c$
An antelope is not similar to a fish.
- (S3) $i \succ c$ $c \succ c$
A priest is similar to all religious figures.
- (S4) $i \succ c$ $d \succ c$
Parallelism is not the panacea of combinatorial explosion.
- (S5) $d \succ i$ $d \succ i$
Clark-Kent is the man who was given the martini by Mary.
- (S6) $d \succ i$, $d \succ c$ $d \succ i$, $d \succ c$
Clark-Kent is Superman. (*Identity* [Jackendoff, 1983: 95])
- (S7) $d \succ i$ $i \succ c$
The tiger is the fiercest beast of the jungle.
- (S8) $d \succ i$, $d \succ c$ $i \succ c$
Clark-Kent is a friendly super-hero. (*Ordinary categorization* [Jackendoff, 1983: 95])
- (S9) $c \succ c$ $i \succ c$
The tiger is a frightening beast. [Jackendoff, 1983: 97]
- (S10) $d \succ i$ $c \succ c$
No mammal is a reptile.
- (S11) $c \succ c$ $c \succ c$
George was similar to every professor in the school.
- (S12) $c \succ c$ $d \succ c$
All sycophants are the heart-throb of vanity.
- (S13) $c \succ c$ $c \succ c$
Every man is similar to any biped.
- (S14) $c \succ c$ $i \succ c$
All men are fallible creatures.
- (S15) $d \succ i$ $i \succ c$ $i \succ c$
Mary is similar to a philosopher who is close to an Ionian stoic.
- (S16) $d \succ i$ $d \succ i$ $i \succ c$
Mary is similar to the philosopher who is close to an Ionian stoic.
- (S17) $d \succ i$ $d \succ i$
Clark-Kent is the man drinking the martini. [Jackendoff, 1983: 88-89]
- (S18) $d \succ i$ $c \succ c$
Joe is no reptile.
- (S19)* $i \succ$ $c \succ$
A mammal is no reptile.
- (S20)* $c \succ$ $c \succ$
Every mammal is no reptile.
- (S21) $i \succ c$ $i \succ c$
Bobs are as common as fruit flies.
- (S22)* $d \succ$ $c \succ$
The woman is all lawyers.
- (S23) $d \succ i$ $c \succ c$
The woman could be any lawyer.
- (S24)* $c \succ$ $c \succ$
All mammals are every warm-blooded creature.

<Definiteness: i , d , c > > <Quantification: i or c > indicates the analysis of the NP under it.

The definiteness categories: indefinite (i), definite (d), and class (c).

The quantification categories: individual (i), class (c).

* Indicates an ungrammatical sentence.

quantification should be chosen. Where both appear in the discourse focus, the individual reading is preferred. This is particularly important for C4 because the status of the subject is needed to predict that of object. In either case, both must have the same quantificational status.

The analysis of NP quantification in copular clauses is significantly simplified by the fact that there is no need to analyze quantifier scoping. This follows from the absence of a passive interpretation for copular verbs. They are specialized in conveying classificational information rather than expressing active changes of state. Since there is no agent and no object which is acted upon, passive constructions can have no meaningful interpretation. Interchanging the subject and the object either has no effect on identity statements or inverts the classification relationship in other cases. Thus, the semantic specialization of copular verbs in conveying links of class hierarchies simplifies aspects of their syntactic analysis.

Fig. 6. Classification of Copular Links in RELATUS

Subject	Real Object	Link Classification
Individual	Universal	Ordinary Classification
Universal	Universal	Generic Classification
Individual	Individual	Identity Relation
<i>Either</i>	Adjective	Quality

A Glimpse At Semantics

Since RELATUS incrementally constructs a semantic model of the sentences it analyzes, the copular interconstraint algorithm allows a class structure to be automatically acquired. The way in which this information is represented in RELATUS exploits the encoding scheme underlying English usage of copular verbs. This encoding method allows four types of linking relations to be encoded using a single token, (i.e., 'be'). This encoding is summarized in figure 6. Since the types can be differentiated according to the quantification of the nodes linked, the unique representation of each link type does not require the introduction of *ad hoc* tokens. Ordinary and generic classification are used to construct the taxonomy. When two individuals are linked by a 'be'

6. Such a strategy has been followed for other types of ambiguous preposition and clause bindings [Hirst, 1981, 1984; Duffy, 1985b].

relation, identity between them is represented. Identity between two universals is represented with two generic classifications indicating that each universal is a subset of the other. For predicate adjectives, a special token (e.g., 'HQ; 'HAS-QUALITY') is used as the relation and the adjective as the object in order to represent a one-place property [Winston 1980, 1982]. This avoids confusion when a word token has uses both as an adjective and a noun. Because RELATUS incorporates a theory of *interpretive semantics*, where syntactic canonicalization is performed on input and semantic equivalence is determined only through reasoning over a syntactically canonical representation, this encoding system is particularly appropriate. Because no post-processing is needed to substitute distinct tokens for the different types of linking relations, this encoding also simplifies quantification of copular clauses, and therefore, the constraint posting process in general. The encoding method only requires a small constant increase in time for walking the created class structure. Thus, the potential gain in efficiency by using a more explicit encoding technique is marginal, and might be offset by other factors.

Conclusions

The copular interconstraint algorithm presented in this paper has been surprisingly robust in large text applications over the past year. Once the research on partitives is completed, the algorithm will cover an even larger proportion of copular verb cases. Work has been done on copular questions but is too complex for discussion here, largely due to pragmatic interactions. Conjunctions have been treated just like ordinary NPs, except that error checking ensures that all *sps* in conjunctions agree in definiteness. The idea of constraint propagation has been extended experimentally to non-copular verbs using a different propagation algorithm. The approach has been successful thus far. However, more research is required to analyze interactions between various quantification algorithms and to ascertain the propagation characteristics of different verbs, according to their senses and meanings. Quantifier scoping, algorithm interaction, and differential propagation are some of characteristics of general constituent interconstraint that make it more difficult. In general, propagation of quantificational constraints, seems a promising approach to previously recalcitrant problems. Even so, strong psychological claims must await further research and exhaustive analyses across languages.

Recent interest in developing lexicons to support computer understanding of natural language [Walker and Amsler, 1985] suggests the need for effective methods of augmenting our lexicographical knowledge using large corpora and unrestricted text. Selection restrictions are an important type of information to accumulate because they are needed not only to distinguish different senses of words but also to recognize metaphorical uses. Since accumulation of selection restrictions requires it, acquisition of taxonomic information is a priority. The copular interconstraint algorithm introduced in this paper provides a basis for acquiring large taxonomies from unrestricted texts. A filter can be used to quickly prune all non-copular sentences as well as difficult copular sentences involving belief, and perhaps, time contexts. The remaining sentences can be parsed, quantified and represented in a large semantic model.

This research would not only advance our knowledge of natural taxonomies and selection restrictions but it would also generate empirical data useful for those studying 'default logics' and stereotype hierarchies [Minsky, 1975; Keil, 1979; Reiter, 1980; Brachman, 1982; Etherington and Reiter, 1983]. One difficulty with this research program is that an uncertainty principle is at work: The taxonomy used to determine selection restrictions itself depends on recognition of metaphors through selection restrictions. Success in this lexicographical task will require the careful development of effective research strategies.

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