TEACHING LOGIC TO LINGUISTS: THE LOGICAL APPROACH TO GRAMMAR

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Natural Language Grammar can be viewed as a formal system in many aspects. The traditional way of presenting grammar to students as a set of morphosyntactic rules in order to speak a language correctly can be substituted profitably by formal models that explain the interfaces between morphology, syntax and semantics and even pragmatics. These models are based in most cases in logical models. There are many grammatical theories that can be named logical grammars or formal grammars that represent these models.

Historically, these formal theories about natural language have been developed by logicians, mathematicians or linguists interested in computational aspects of linguistics. Nevertheless, they are also conceived in many aspects as good models of linguistic knowledge and competence. We are introducing in this paper certain concepts and methods, originally taken from logic, as they are used in real linguistic courses taught by the author in the University of Seville.

1. Predication theory and grammatical categories

Many aspects of actual theories about language and grammar cannot be understood unless they are seen as a historical consequence of the ancient Greek theories about the predicative sentence. Medieval speculative grammar and theoretical rational grammars are based on the Aristotelian distinction on the relations between subject and predicate in asertoric sentences. On the other hand, they are also based on the concept of category, firstly used in a technical manner by Aristotle and adopted in its grammatical sense by stoics and alexandrines.

This branch of linguistic thought in the Modern Age, in opposition to philology and the concept of grammar as the art of speaking, was considered by Chomsky as an antecedent of generative grammar. The students of linguistics must know these antecedents as a concrete application of Aristotelian Logic. For this, we introduce them in Classical Predicate Logic by means of linguistic reflection on categories and meaning in a set-theoretical way.

The predicative structures of enunciative sentences are presented as first order predicate logic formulas. Once these formulas have been introduced as the logical form of propositions behind sentences, we put them together with syntactic structures using certain grammatical theories like Dik's Functional Grammar, for instance (Dik 1997).

2. Generative, formal and logical grammars

A Grammar can be defined as a sort of device used for deciding about grammaticality of sentences. This device can be defined as an axiomatic system with a unique axiom and a set of inference rules of the form $\varphi \rightarrow \psi$, where φ and ψ are symbol chains taken from previously defined vocabularies. The grammatical (well-formed) sentences of a language are the theorems that are provable in this axiomatic system. This is, for example, the formal foundation of a Transformational Generative Grammar (Chomsky 1957, 1965).

We introduce the students in syntax as an inference system, so they must know the basis of logical propositional calculus. The formal properties of grammar so conceived are a very important matter to understand modern syntax theory in the generative framework; for example, Government and Binding theory (GB) (Chomsky 1981) or Minimalism (Chomsky 1995), as well as previous generative theories like Transformational Grammar.

On the other hand, we define formal grammars (in opposition to those grammatical theories mainly interested in competence and language acquisition) as grammatical models of language performance, implementable as computational models of natural language. Some formal grammars are introduced as Head-driven Phrase Structure Grammar (HPSG) (Pollard & Sag 1994) or Lexical Functional Grammar (LFG) (Bresnan 1982). The interest focus is on their formal properties as models of certain linguistic phenomena to be treated computationally.

Formal grammars can be considered logical grammars in a wide sense of this term, because of their formal properties and their treatment of the relation between syntax and semantics. But there is a set of grammatical models that are known specifically as logical grammars. These theories are, mainly, Categorial Grammars (CG) and Type Logical Grammars (TLG).

CGs are based on the ideas of the Polish logician Kazimierz Ajdukiewicz, who proposed in the 30's a categorial analysis of language based on two main basic categories: **n** for names and those linguistic expressions denoting individuals, and **s** for sentences and those linguistic expressions denoting propositions (Ajdukiewicz 1935). The functional application or composition of these two basic categories defines the categories of the other expressions of language and their combinatorial properties. CG was used in the 50's by Bar-Hillel in the emergent field of Machine Translation (Bar-Hillel 1950), but was abandoned almost until the 70's when Richard Montague recovered the idea of a grammatical model based on semantic categories for natural language. His works founded what we know as Montague Grammar (MG) (Montague 1974).

TLG (Morrill 1994) falls into the semiotic conception of natural language grammar. The semiotic perspective of MG is opposed to Chomsky's mentalist perspective. In fact, this opposition is in the base of the difference between a real formal logical grammar for natural language and the chomskyan conception of a generative grammar in the present (GB, Minimalism). The aim of TLG is generalising CG to a categorial logic. For this, TLG presents a refinement of Logical Grammar (Logical Syntax and Model-theoretic semantics) in which 'logical' applies not just to logical semantics, but also to logical types directing derivation. The bases of Type Logical Grammar are Montague Grammar (a montagovian fragment for English), the Theory of Types, a Gentzen Sequent Logic, Lambek Calculus (associative and non-associative), Multimodal Systems and Labelled Deduction.

3. Semantics and discourse

Formal and logical grammars have much more to do with the relation between syntax and semantics than Generative Grammar has. Therefore we use them in order to introduce the students of linguistics in semantics. The framework we use is Categorial Grammar and, specifically, Montague Grammar.

MG and λ-calculus permit us to study the syntax and semantics of Noun Phrase: the denotation of proper names and common nouns, plurals, mass nouns, generic nouns, the semantics of adjectives and determiners, etc. We present to the students the theory of Generalised Quantifiers and discuss its relevance for grammar.

On the other hand, MG and Intensional Logic are used to deal with sentence semantics. We explain possible worlds semantics and extend First Order Predicate Logic with modal and temporal operators. So we have an Intensional Grammar in the montagovian sense that can be used to treat with propositional attitudes, subordination, interrogative and imperative sentences, etc. We introduce, as well, situation and event semantics as alternative models for sentence semantics.

Once MG is presented as a tool for semantic analysis of natural language, we describe those phenomena that cannot be treated satisfactorily into this framework. These phenomena can be represented by anaphora and non referential expressions, inference, presuppositions and, in general, all those processes of semantic enrichment of discourse. This means we must deal with dynamics in semantics, what impel us to define new models for discourse. The first one to be introduced is Discourse Representation Theory (DRT).

DRT (Kamp 1981, Kamp & Reyle 1993) was born in the 80's to explain certain problems of discourse interpretation far away of MG scope. This problem of dynamic interpretation of discourse has also been treated in (van Benthem 1991). And even other authors (Groenendijk & Stockhof 1990, 1991) have proposed a dynamic treatment of Predicate Logic enriched with a typed language, lambda abstraction and Montague Semantics. This is what we call Dynamic Montague Grammar, a framework based on MG but capable to deal with dynamics.

The main differences between DRT and MG are that DRT is more flexible to interpret discourse relations, but the Principle of Compositionality, that holds in MG, does not hold in DRT. This explains why MG is more elegant when dealing with quantification and co-ordination phenomena, for instance, than DRT. Therefore, we would like to combine the dynamics of DRT with the compositionality of MG. This is the aim of certain works published in the 90's as (Muskens 1996). DRT logic is reducible to a First Order Predicate Logic and Muskens combines with it a Classical Type Theory Logic based on Church's lambda calculus instead of Montague's Intensional Logic.

But this is not the only way to have boxes (DRSs) and lambdas in the same logic. The categorial application to natural language of Labelled Deductive Systems (LDS) is another one. LDS are a general framework for logic and Logic Programming, developed by Dov Gabbay (Gabbay 1996). The aim of LDS is to supply a unified framework for the principal logical theories used in Logic Programming: Relevance Logic, Modal Logic, Linear Logic, Temporal Logic, etc.

The British linguist Ruth Kempson and Dov Gabbay have collaborated to implement a Categorial Grammar based in Montague Grammar in LDS to treat diverse aspects of Natural Language, namely: anaphora, tense and time, structural dependencies and logical inference (Gabbay & Kempson 1992, 1996). MG implemented in LDS offers a tool for analysing what Gabbay and Kempson call "semantic enrichment". In semantic enrichment, different syntactic and semantic aspects are involved, as well as pragmatic ones as the influence of context and situation in the interpretation of natural language utterances. In this sense, LDS is a MG-based alternative to situation semantics or possible world semantics.

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