Categories, Constructions, and Dependency Relations

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1 Introduction

It is perhaps a geographical coincidence that one can draw a more or less straight line connecting Brno, Prague, Amsterdam and Edinburgh. But there are even more interesting connections to be made.

Edinburgh has been an important center of developments in categorial grammar ever since the 1980's, side by side with Amsterdam where categorial grammar was (re-)married to Montague grammar to give rise to type-logical grammar; Prague has been a focal point of dependency grammar and information structure ever since the beginning of -already- last century, and Brno is the place where the spirit of transparent intensional logic (TIL) is kept high.

It seems that these approaches - dependency grammar, transparent intensional logic, and type-logical grammars - all can be considered to point to the following conception:

> *The linguistically realized meaning of a sentence relates the use of words in the sentence as an* expression *to the* construction *of the sentence's (linguistic) meaning out of meanings of the individual words.*

The aim of this paper is to explore how these thre approaches could possibly be combined. The advantages of a symbiosis of dependency grammar, TIL, and categorial grammar or categorial type logics can be briefly characterized as follows. Categorial type logics provide us with very powerful (formal *and* computational) means to describe intricate phenomena of surface structure, and using these logics to construct a dependency-based perspective on natural language grammar (DGL, [8]) enables us to model phenomena that arguably cannot be explained using a phrase-structure based approach. Furthermore, by using TIL we can tap into a considerable amount of research in formal semantics, whereas for TIL, DGL might provide the possibility for more fine-grained grammatical modeling.

2 Three strands

Dependency grammar, in its form as developed by Sgall et al [19], describes linguistic meaning using dependency relations and the head/dependent distinction. Thus, linguistic meaning as a *representation* elucidates in a direct way who modifies what, and in what semantically relevant way. Sgall et al describe various types of dependency relations that can hold between heads and dependents (see also Petkevič's [18] for a succinct overview). For the representation it is assumed that each dependent always has only one head (i.e. we are dealing with trees), and that each relation between a head and a dependent is classified as a *single* dependency relation.[1] Sgall et al, following Panevová's [16], describe (and distinguish) dependency relations in terms of syntactic behavior.

Categorial grammar, particularly in its extended form as *categorial type logics* combining resource-sensitive proof systems with a typed λ-calculus (cf. work by Hepple [6], Moortgat [11], Morrill [12], and Oehrle [13, 14]), gives rise to the above conception through the establishment of a Curry-Howard correspondence between proof formulas and λ-terms. A proof is not (just) a normative judgment - by virtue of the Curry-Howard correspondence, we build a representation of the sentence's linguistic meaning *in parallel* to establishing a syntactic structure, given the sentence's outer form. It is interesting and important to note that the λ-term representing linguistic meaning thus arrived at is -without exception- considered to be the *only* representation of the sentence. Syntactic structure in the Chomskyan sense is a useful but dispensible means to obtain our goal of relating the sentence's outer form to its (conceivable) linguistic meaning - a point that, we would argue, closely corresponds to the stress [19] lays on representing a sentence in terms of its linguistic meaning.

Finally, Tichý's transparent intensional logic as discussed by Materna in [9], describes meaning in terms of type-logical "constructions" that show how a meaning is constructed out of its components. A linguistic expression corresponds to a construction, which in turn can be evaluated to an object. An important characteristic is the distinction between constructions as representations of meaning, and the objects they can be associated to. Because we represent meaning as a *construction*, and not as an object, various semantical pitfalls are avoided. Moreover, the type logic is defined on a ramified hierarchy, meaning we can talk not just *in terms of* constructions, but also *about* constructions (without needing a metalanguage). That enables us to give -for example- a fairly straightforward logical account of propositional attitudes.

Available literature has pointed out various parallels between the above lines of thought. Categorial grammar and dependency grammar are closely related, as for example Bar-Hillel and Bach frequently pointed out. Montague Grammar and TIL have at occasion been compared, the latter often being argued for as preferable over the former - see for example Materna's [9]. And finally, TIL has been used in a couple of papers to provide a logical interpretation of core aspects of the representations used in Sgall et al's [19] - see for example [10, 22].

Below we explore how we could try to weave these three lines of thought together. As the starting point for our exploration we take Dependency Grammar Logic (or DGL for short), as introduced in [7] and described in detail in [8].

[1] Observe that this is an *assumption* - cf. Dowty's discussion on the closely related thematic relations or θ-roles in [4].

DGL is a categorial type logic that models dependency grammar, based on the intuitions behind the framework described by Sgall et al.[2]

3 Dependency Grammar Logic

DGL aims at describing the relation between a surface form and an (underlying) linguistic meaning that can be considered as being expressed by the outer form. The important questions there are of course, *how* form can be *indicative* of linguistic meaning, and what we consider to be the ingredients of linguistic meaning that can be expressed by form.

Following [19], the *structure* of linguistic meaning is phrased in terms of heads being modified by dependents, along particular dependency relations. When establishing the relation between surface form and linguistic meaning, we thus have to discern words (or wordgroups) as dependents and heads, making out what dependent modifies which head and along which type of relation. As Jakobson, Mathesius, and other authors in the Prague School have discussed at length (cf. [17, 23]), *case* can assist us in that job (whereby we understand "case" to cover the various ways in which morphological case is realized across languages - cf. e.g. [3], Chapter 2).

However, there are more aspects of form that are indicative of the underlying meaning of a sentence. For verbs, this concerns for example modality, tense and aspect. Steedman presents in [20] an elaborate model of tense and aspect (a model which DGL incorporates), explaining how tense and aspect give rise to *presuppositions* regarding relations holding between the meaning of the sentence and the context. These relations need not have to do primarily with temporality as such. Steedman advances the point that the relations are more generally concerned with aspects of causality and goal-directed action.

Finally, there are aspects of form that are indicative of a sentence's *information structure*. These *structural indications of informativity* [7, 8] signify how the meaning of a particular word (or wordgroup) is dependent on the already established context, or how it will affect that context (cf. Sgall et al's topic-focus articulation). Examples of structural indications are word order and intonation, cf. for example [19, 21].

To recapitulate, we understand *form* here to be indicative of how the meanings of words and wordgroups relate to one another *structurally*, and how they relate to the preceding context or purport to affect the succeeding context. Dependency relations are "presupposition triggers" (in a loose sense of the word)[3],

[2] Needless to say, space limits us in how far we can take our exploration. For that reason, we will focus on pointing out the possibilities rather than discussing formal details. Where possible we will refer to places where such details are available.

[3] Without any formal characterization of what a presupposition is, we can only use the idea of presupposition triggers here in the loose sense. Whether a dependency relation will trigger a genuine presupposition in the sense as used in formal semantics or a weaker form, i.e. an allegation, will be dependent on information structure - cf. the discussion in [19]. Note that in [8] I characterize dependency relations primarily

just as tense and aspect signify underlying presuppositions about e.g. causal relations. Finally, form can be indicative of information structure.

Together this leads (in DGL) to an understanding of linguistic meaning as a structure indicating how meanings of words are related using dependency-relations, and how these meanings and their relations *project* presuppositions (and possibly, allegations) about refering to the preceding context, affecting the succeeding context, and presupposed temporal/causal/etc. relations. (See [8] for a detailed discussion.) The important point here is that, in keeping with for example [19] and dynamic approaches like Oehrle's [15], we do not *evaluate* the presuppositions against the larger context. Linguistic meaning only projects how, as far as the form has indicated it, the sentence "aims to" relate to the larger context. Whether it does (i.e. is felicitous) or not, is left for subsequent discourse interpretation.

In a sense this appears to correspond to TIL's distinction between constructions and object - whereby DGL's linguistic meaning would correspond to the former, and the interpretation established by discourse interpretation could be considered to be like the latter.

To be able to represent linguistic meaning, DGL uses *hybrid logics* [2,1]. Traditionally, typed λ-calculi are used to represent "semantics" in categorial grammar, cf. e.g. [12,14]. As the above discussion already indicates, though, our linguistic meaning potentially contains a rich variety of information about modality, temporality, causality, reference, etc. For this purpose, DGL abandons the fairly monolithic traditional approach in favor for a system of modal logic that is capable of capturing the kind of ontological richness we need.

4 Weaving the three strands together

In DGL, the underlying machinery for carrying out derivations establishing the relation between form and meaning is phrased as a resource-sensitive proof theory [11]. Traditionally, categorial type logics relate form and meaning through a Curry-Howard correspondence, established as follows. First, as Oehrle describes in detail in [14], the meanings of words are given in a (e,t)-typed λ-calculus. These definitions are translated into syntactic categories specifying the syntactic behavior corresponding to the underlying meaning. Oehrle describes the translation as an isomorphism - in particular, there is an isomorphic relation between the number (and type) of arguments a verbal predicate takes and the corresponding syntactic functional category. Besides an isomorphism at the level of lexical meaning, there is also an isomorphism (or at least, a close correspondence) at the level of derivations. Fashioned after the original Curry-Howard isomorphism, each step in a proof (operating on a category) is reflected in the meaning. Thus,

from this 'semantic' viewpoint, and conceive of syntactic behavior as derivated from that. On the contrary, Sgall et al characterize dependency relations (strictly) in terms of their syntactic behavior, without noting the influence that distinguishing different relations might have on a sentence's interpretation-in-context.

when we use natural deduction, composition (or elimination) corresponds to application at the level of meaning, and introduction corresponds to abstraction.

It is easy to see why this has lead various authors to claim that surface syntax is thus an artefact: this is a direct consequence of the correspondence between lexically assigned categories and meanings, and maintaining the correspondence between categories and meanings in a derivation.

Because DGL does not use a typed λ-calculus but a (many sorted or hybrd) modal logic, a correspondence is established in a slightly different fashion; namely, using a *linking theory*. The purpose of the linking theory is to relate dependency relations, specified in a predicate's valency frame, with a surface category. Naturally, it is for an important part based on the Praguian ideas about abstract case, how abstract case realizes dependency relations, and how different languages can realize case. The need for a more involved linking theory (rather than saying that "e's map to N's") arises from the fact that we have a richer representation of meanings. At the same time, we broadly maintain the ideas expressed in Oehrle's [14] regarding the relation between categorial functions and predicate structure[4].

The way that we proceed in DGL to establish a relation between form and meaning is very different from Hadacz's proposal involving TIL. Hadacz discusses in [5] a so-called *translation procedure* translating forms into TIL-constructions. Contrary to DGL, syntactic composition appears to play little or no role in the translation procedure (possibly because Hadacz' model is based on a fragment of Czech that has a completely free word order). We would like to argue that this makes the approach too restricted to be generally applicable: For example, any phenomenon involving word order will be hard to model, like case realized through word order (cf. [3]), information structure, or restrictions on otherwise flexible word order (like clitic placement in Czech). Hadacz' model simply misses an explicit syntactic component.

At the same time, it is not difficult to imagine how we can overcome this problem, in almost exactly the same way as done in DGL. Like in DGL we could establish a Curry-Howard correspondence - this time between (primitive) objects and constructions in TIL on the one hand, and syntactic categories on the other hand.

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[4] With some notable exceptions, as I noted in [7].

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