

A Model for Contextualizing Natural Language Discourse

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Abstract

This paper describes a computational model of semantic processing in natural language discourse understanding based on the distribution of knowledge over multiple *spaces* as proposed by Fauconnier (1985), Dinsmore (1987a), Kamp (1980), Johnson-Laird (1985) and others. Among the claims made about such a partitioned representation of knowledge are the following: First, it promotes a more direct, more natural mapping from surface discourse sentence to internal representation. Second, it supports more efficient reasoning and retrieval processes over that internal representation. Finally, it provides an accurate account of many of the most recalcitrant problems in natural language discourse understanding. Among these are implicit information, presupposition, referential opacity, tense and aspect, and common-sense reasoning in complex domains.

The model identifies two fundamental levels of semantic processing: *contextualization*, in which an appropriate space for assimilating the information conveyed in a discourse sentence is located, and *construction*, in which the information is actually assimilated into that space. Contextualization allows the full semantics of the discourse to be realized implicitly in the internal representation. It also accounts for the use of moods, tenses, and various adverbials in discourse. The interaction of the contextualization processes with the semantics of aspectual operators provides an account of the discourse use of aspect.

INTRODUCTION

In partitioned representations (Dinsmore, 1987a) the information conveyed in a natural language discourse is distributed appropriately over multiple *spaces*, which function as small, distinct, logically coherent knowledge bases within which objects and relations can be represented, and reasoning processes can be performed. Spaces represent such things as hypothetical realities, belief systems, quantified domains, thematically defined domains, fictions, and situations located in time and space. Spaces in this sense differ from the focus or thematic spaces of Grosz (1977), Reichman (1985) and others in that

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Once upon a time, there was a tailor named Siegfried.

Siegfried had once consulted a famous wizard. The wizard mistakenly thought Siegfried was an alcoholic. Still, if Siegfried would work hard, he would be very successful. The wizard assumed that anyone who was rich was happy. Well, Siegfried would be rich, and would even stop drinking.


Now the tailor Siegfried did work hard and had in fact become rich. But he was not happy, and he had actually become an alcoholic.

Fig. 1. The Siegfried story.

the former have a logical or semantic function not found in the latter, as detailed in Dinsmore (1988, 1987). During discourse understanding, knowledge is appropriately distributed over spaces, lower-level processes are delegated to spaces, and spaces are thereby allowed to accumulate knowledge. For instance, in understanding the story of Fig. 1 a set of spaces are constructed as in Fig. 2 and knowledge distributed over the spaces as indicated. A linear notation of the form $S \mid P$ will be convenient to show that a proposition P belongs to a space S . We call such an expression a *statement*. For instance, one of the statements recognizable in Fig. 2 would be,

sp_4 | Siegfried is rich

Each space has a role or function of known as its *primary context*. Fig. 3 shows how the primary contexts of the Siegfried story embed spaces. Our convenient linear notation extends to contexts: a context looks like an ordinary statement, but contains a *space term* of the form $[[S]]$. For instance, some of the contexts recognizable in Fig. 3 are the following.

sp_0 | At time time_2, [[sp_2]]
sp_2 | wizard_8 believes that [[sp_3]]
sp_3 | Siegfried works hard  [[sp_4]]

Language understanding can be considered a transductive process whereby the discourse sentence is gradually transformed into its partitioned internal representation while passing through a series of intermediate representations. The transformation process involves identifying constituent structures, distributing structures over spaces, and processing structures at a low level within spaces. For a discourse sentence P , *contextualization* determines the space, S , that P is intended to say something about. That space is known as the *focus space* for P . In the story of Fig. 1 the focus space starts at **sp_1** then moves to **sp_2** for “*Siegfried had once consulted a famous wizard,*” and for the

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sp_1	<p style="text-align: center;">there is a tailor named Siegfried Siegfried works hard Siegfried has become rich Siegfried is not happy Siegfried has become an alcoholic</p>
sp_2	<p style="text-align: center;">Siegfried consults a famous wizard</p>
sp_3	<p style="text-align: center;">Siegfried is an alcoholic anyone who is rich is happy</p>
sp_4	<p style="text-align: center;">Siegfried is very successful Siegfried is rich Siegfried stops drinking</p>

Fig. 2. Partitioned representation of the Siegfried story.

following sentence. It then moves to **sp_3** for “*But if Siegfried ...*,” then back to **sp_2**. It moves to **sp_4** for “*Well, Siegfried would be rich, ...*”, and finally returns to **sp_1** for the final two sentences.

Construction transforms the statement **S | P** through the progressive refinement of knowledge structures until a permanent internal representation is produced. During construction new spaces and their associated contexts will often be set up, and existing contexts will be used to access spaces for distributing information. At the same time various semantic processes will occur locally within spaces, such as determining referents for definite descriptions and satisfying the presuppositions of certain grammatical constructions. For instance, in the processing of the sentence “*The wizard mistakenly thought that Siegfried was an alcoholic,*” **sp_2** is used as the focus space. Within **sp_2** a referent for “*the wizard*”, call it **wizard_8**, is located. The belief space **sp_3** is then created along with the context **sp_2 | wizard_8 believes that [[sp_3]]**, and the statement **sp_3 | Siegfried is an alcoholic** is further restructured.

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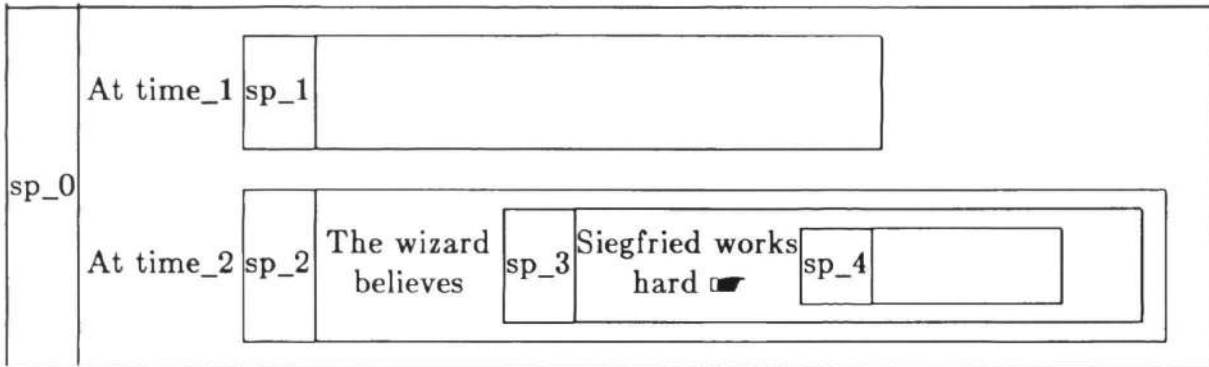


Fig. 3. The contexts used in representing the Siegfried story.

CONTEXTUALIZATION

Contextualization concerns the identification of the *focus space* in which to begin reconstructing the semantic content of the discourse sentence. It provides an associated context which is necessary for the full semantic significance of the discourse sentence to be realized. The contextualization step provides a key distinction between the current model and most other models of semantic processing.

For instance, in a fictional discourse like that excerpted below it is necessary to identify a focus space **sp_21** such that we have a primary context like **sp_2** | *In The Dog of the Burgervilles*, **[[sp_21]]**.

Sherlock turned slowly around. Suddenly a poisoned dart whizzed by. "Yikes," said he.

Since **sp_21** is in focus, the meanings of the sentences of the discourse are represented by statements specifically in **sp_21**. Accordingly, the full meaning of the discourse is represented, and questions like "*In the Dog of the Burgervilles, what made Sherlock say, 'Yikes'?*" can be answered when **sp_21** is no longer in focus. The following discourse is analogous to the last.

Arthur believes it is the duty of everyone to fight what he thinks is an invasion of space frogs. Before this situation gets out of hand, every homeowner should defrog his own yard, taking care to ...

After the first sentence of the first discourse the focus space **sp_7** has a primary context something like **sp_3** | *Arthur believes that* **[[sp_7]]**.

Tracking the Focus for Contextualization

A main contribution of this paper is to define what the contextualization process is and to provide a framework in which it can be discussed. Nevertheless, a full account of the process awaits future research; like many interpretive tasks it involves a wide range of poorly understood cognitive factors. However, our initial model of the contextualization process identifies the focus space as:

- The most *active* space,
- that is consistent with the *focus cues* of the current discourse sentence, and
- that has a content *conceptually consistent* with the intermediate representation of the current discourse sentence.

Spaces are *active* to a degree dependent on how recently or how often they have been used in recent discourse processing. The reader will notice that in the Siegfried story the focus space for every sentence but the first corresponds to a space used or created shortly before the the sentence was processed. We also observe a tendency to return to a previous focus space, or to use the same focus space in successive contextualizations. We can model this by assuming varying levels of activation, with the last focus space most active, and spaces that have not been focused or recently accessed less active. More active spaces are thereby the best candidates for focus.

Focus cues are inflectional morphemes and other syntactic structures occurring in the discourse sentence that restrict the set of focus space candidates for contextualization. Focus cues are generally verb forms, like the Past tense or the conditional mood, and certain adverbials. We will return to this kind of grammatical conditioning of the contextualization process momentarily.

Ultimately, the current intermediate representation should be conceptually consistent with the contents of the focus space. This generally means that its presuppositions should be satisfied there, the objects it mentions should reside there, and it should not contradict knowledge that is already stored there. For instance, before we contextualize the sentence “*The wizard mistakenly thought Siegfried was an alcoholic,*” in Fig. 1 we have **sp_0**, **sp_1** and **sp_2** as active spaces. Among the focus cues is **Past**, which is compatible with any of these spaces. Because a referent for “*the wizard*” can be found there, **sp_2** is strongly recommended as the focus space. Likewise, the focus space in the Sherlock Holmes discourse is readily identified as fictional since Sherlock Holmes is generally known not to exist in reality.

Focus Cues

A number of adverbials of little apparent semantic content seem to play a role in tracking the focus space. In the Siegfried story, “*Once upon a time, ...*” would seem actually to trigger the initialization of a *new* temporal/situational space embedded within a story

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space. “*Well*” seems to indicate that the focus space is different than that for the previous sentence. “*Now*” seems to indicate a return from a temporally prior focus space. However, the most consistently present type of cue seems to be associated with the form of the main verb of the discourse sentence: **Past**, **Present**, or **conditional**.

English requires the conditional (usually indicated by “*would*”) for any sentence or embedded clause assimilated into a counterfactual space **S1**, one whose primary context is of the form **S0 | P** ▮ **[[S1]]** and prohibits its use in any other sentence or embedded clause. For instance, in the following discourse,

If cars had never been invented, people would still ride horses. Furthermore, shopping malls would not exist. At least there would be less smog.

processing the first sentence will set up a space, call it **sp_12**, with a context something like **sp_10 | Cars have never been invented** ▮ **[[sp_12]]**. The clause “*people would still ride horses*” uses the conditional, since **sp_12 | people ride horses** is constructed, where **sp_12** is a counterfactual space. This space then becomes the focus space for the next two conditional sentences. It is instructive to contrast the use of the conditional with the use of a non-conditional form in sentences that are otherwise identical. If the discourse were to continue,

We would have a lot to blame Henry Ford for.

sp_12 would likely remain in focus, since it is a counterfactual space as required. On the other hand, if the discourse were to continue,

We have a lot to blame Henry Ford for.

then a shift to some other space, probably back to the previous focus space **sp_10**, would be forced, giving the sentence almost the opposite semantic interpretation.

TENSE AND ASPECT

Researchers in the semantics of tense and aspect have looked at sets of sentences like the following,

Fred won \$1,000,000 in the lottery.

Fred has won \$1,000,000 in the lottery.

Fred had won \$1,000,000 in the lottery.

and in view of their apparent truth-conditional identity have proposed semantic analyses which attribute the same explicit semantic content to them (cf., Taylor, 1977).

Reichenbach (1947) uses the term *reference time* to characterize such differences. If the event time is **E** (in this case, the time at which Fred wins the lottery), the time of speech **S**, and the reference time is **R**, then **R = E < S** for the first of these sentences, **E < R = S** for the second, and **E < R < S** for the third.

It turns out that we can show how Reichenbach’s concept of *reference time* can be defined as an artifact of the more general discourse process of *contextualization*. This

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account additionally shows how the relationships of **R**, **E** and **S** (*reference time*, *event time*, and the *time of speech*) follow from the actual semantics of the aspects in a compositional way. Space limitations prohibit developing this account fully, but I can at least suggest what is involved here, and refer the reader to another paper for details.

A temporal space has the same role as any other space in the contextualization process, with tenses acting as focus cues. For instance, the following discourse exhibits the usual pattern of using the same focus space for consecutive sentence until a focus cue indicates a shift as well as the tendency to return to a previous focus space.

Fred's car was parked at the corner. Fred himself was looking under the hood. Fred has only recently learned anything about auto mechanics. It was already dark.

Let us define a *temporal space* as any space **S** with a primary context of the form **S0** | **At time T**, **[[S]]**. We define the's concept of *reference time* simply as the time mentioned in the context of a temporal focus space, i.e.:

- If there is a context of the form **S0** | **At time R**, **[[S1]]** then **R** is the *reference time* of **S1**.

We also speak of the *reference time of a sentence* as shorthand for the reference time of the focus space into which the sentence is contextualized. In any case, English permits the Past tense only in a sentence or embedded clause that is assimilated into a temporal space with a reference time **R** before the time of speech **S**, i.e., **R** < **S**. English requires the Present tense in any sentence or embedded clause that is assimilated into a temporal space with a reference time **R** at the time of speech **S**, i.e., **R** = **S**.

In the current model, the sentences above do differ in the kinds of internal representations they give rise to, but their truth conditions collapse together because of the different focus spaces they are forced to contextualize to along with the differing semantic interpretations of Past and Perfect.

Dinsmore (1982, in press) presents and motivates the precise semantics. Dinsmore (in press) shows how these semantic rules interact with contextualization to account for the use and understanding of these sentences. This account generalizes to the *Prospective* and *Future* sentences that Reichenbach also describes, and to the other aspects *Inceptive*, *Terminative* and *Progressive* (Dinsmore, in press, 1987b). Both Dinsmore (1982) and Johnson (1981) have foreseen that Reichenbach's system might generalize in this way.

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