A Layered Approach to Semantic Representation

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RÉSUMÉ
Une approche stratifiée pour la représentation sémantique

Nous présentons une première version de notre approche de la représentation sémantique. Bien qu'il existe de nombreux formalismes pour la sémantique, parvenir à rassembler plusieurs informations sémantiques tout en restant lisible reste une tâche difficile. Nous proposons de nous appuyer sur la structure prédicat-argument (PA) utilisée dans les AMR et d'étendre la représentation avec de nouveaux type de sommets et d'arêtes. Nous introduisons la notion de "caractéristiques" qui représente des phénomènes sémantiques nouvellement encodés sous forme de couches. Des arêtes font le lien avec les caractéristiques sémantiques et la structure PA, ou dans le cas de phénomènes sémantiques en interaction avec d'autres caractéristiques. Notre approche permet de conserver la traditionnelle structure PA et de se focaliser sur des phénomènes particuliers et leurs interactions. Un avantage explicite est aussi de permettre de rendre compte de phénomènes complexes qui utilise la portée (négation, quantification, etc.).

ABSTRACT
In this article, we present a first version of a layered approach we take to semantic representation. Our approach is motivated by the need for a semantic representation formalism which can encode a rich variety of semantic phenomena, while remaining simple to annotate and easy to read. Our representation derives its core predicate-argument structure from Abstract Meaning Representation (AMR), but is then extended with a number of types of nodes and edges. We introduce "features" - nodes for each semantic phenomenon we wish to encode. Features represent various layers of our representation. Edges are then attached to each feature node, that can link to nodes from the predicate-argument structure of the representation or, in the case of interacting semantic phenomena, to edges from other layers. An advantage of our approach is the possibility to exclude layers from the representation easily, while still being able to represent phenomena such as scope that are difficult for most graph-oriented formalisms.

MOTS-CLÉS : formalismes de représentation sémantique.

KEYWORDS: semantic representation formalisms, layered semantic representation.

1 Introduction

Current semantic representation formalisms can be compared across multiple aspects, as shown in the literature (Abend & Rappoport, 2017; Žabokrtský *et al.*, 2020; Pavlova *et al.*, 2023b). In this work, we want to focus on the distinction in their ability to encode various semantic phenomena, and their readability. Thus, we split formalisms into two broad categories - logic-based (Kamp & Reyle, 1993; Montague, 1970), and graph-based (Banarescu *et al.*, 2013; Abend & Rappoport, 2013; White *et al.*, 2016). Logic-based formalisms tend to be powerful in terms of encoding, being able to express phenomena such as quantifier scope, but are not easy to read and interpret without prior training in Logic. Graph-based ones, on the other hand, are easier to read and annotate, but often lack when it comes to expressing scope or being compositional. Admittedly, some graph-based formalisms, such Minimal Recursion Semantics (MRS) (Copestake *et al.*, 2005) are able to encode a large set of phenomena. However, the way this is realised still makes the formalism difficult to read. Similarly, logic formulas can be represented as graphs. However, interpreting those still requires an understanding of Logic.

Many of the more recent graph-based formalisms have been proposed with large-scale annotation in mind, Abstract Meaning Representation (AMR) (Banarescu *et al.*, 2013) being the most popular one. However, to achieve this, they do not annotate various phenomena, such as temporal information, definiteness, plurality, etc. Uniform Meaning Representation (Van Gysel *et al.*, 2021), which can be seen as a standalone formalism, puts together a number of AMR extensions, achieving a rather more powerful representation than AMR alone. However, as can be seen in Figure 1 of (Zhao *et al.*, 2021), since all semantic phenomena are added as nodes and edges of the same status as those in the original AMR structure, the representation becomes rather messy for longer texts.

Our goal with this work is to create a formalism which is a common ground between logic-based and graph-based ones - easy to read and annotate, but also able to encode multiple semantic phenomena. Furthermore, we want to keep each phenomenon separate from the central predicate-argument structure in order to keep the overall structure more organised, and to allow for the independent exploration of different phenomena. Thus, we propose a way to modify and extend an AMR-inspired graph representation by adding explicit layers to the structure. Each layer is designed to encode a different semantic phenomenon, allowing a straightforward way to "switch off" the layer. This avoids cluttering of the representation when certain phenomena are not the focus of a given task.

2 Proposal

We present here our proposal to extend graph structures in order to encode various semantic phenomena in specifically dedicated layers. For this purpose, we add a number of node types

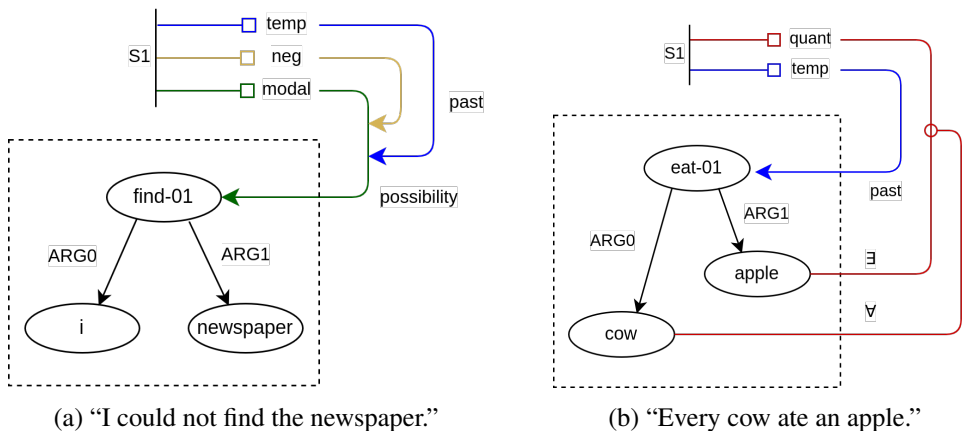(a) "I could not find the newspaper." (b) "Every cow ate an apple."

Figure 1: Our representation for two sentences

and relation types. We will explore these with the help of the two examples in English shown in Figure 1: for the sentence "*I could not find the newspaper*" (Figure 1a) with negation and modality, and "*Every cow ate an apple*" (Figure 1b), with the usual scope ambiguity.

The predicate-argument structure of each sentence is represented as a standard graph (the part inside the dashed rectangle), with nodes (from a set of nodes V) and edges (from a set of edges E). The nodes are predicates and concepts. The edges are argument roles, and are labeled. The predicates and the argument roles have been taken from PropBank (Palmer *et al.*, 2005). This is the standard structure we see in AMR and AMR-derived formalisms.

However, we restrict the usual AMR notation to the predicate-argument structure of the main predicate of a phrase. By doing this we assume to follow a neo-davidsonian representation of semantics (Davidson, 1967; Parsons, 1990). In this line, we extend this by first adding a node S to represent the event itself (S1 in the two figures). For multiple events in the same sentence, we introduce a node of the same type for each event, as we will see in section 3.

Then, a set of features F is added, each representing a semantic phenomenon that we wish to encode in the structure. Each feature is linked to an event node. In Figure 1a, we represent temporality, modality and negation. In Figure 1b, in addition to temporality, we also encode quantification.

Next, we introduce a set of edges, E', which link a feature to a node from V, as we see with modal and find-01 in Figure 1a, or with temp and eat-01 in Figure 1b.

Figure 1a demonstrates that there are cases where it is not enough to link features only to nodes from V. In that sentence, it is not the *finding* event that is expressed in the past, but the speaker's *ability* to do so. Thus, we introduce another set of edges, which link a feature to an edge from E'. This is also useful for negation as we can see in the same sentence.

Finally, as demonstrated in Figure 1b, when more than one quantifier is present in a sentence,
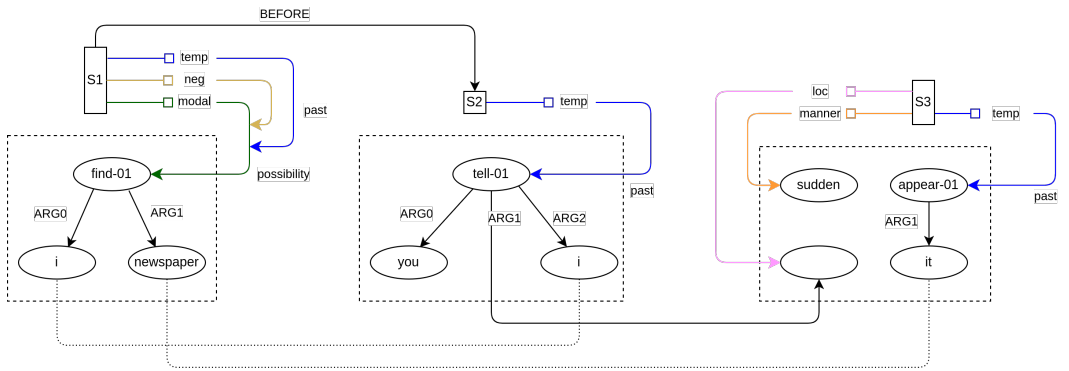
Figure 2: "I could not find the newspaper until you told me where it would suddenly appear."

we might need to specify which one takes scope over which other ones. To be able to do this, in the quantification layer we introduce another type of edges, which can link an edge from E' to a node from V. Edges linking to and from features are labeled or unlabeled, depending on the feature they are linked to.

One of the advantages of the thus described structure is that while various phenomena can be encoded, it is easy to choose to not represent a layer if the phenomenon it represents is not relevant for a given task. In Figure 1a, even though it is possible, we have chosen to not represent quantification.

3 Towards more complex examples

Let us now imagine a more complex example with multiple events. In Figure 2, we have our representation for the sentence "*I could not find the newspaper until you told me where it would suddenly appear*", where we have three events: *finding*, *telling*, and *appearing*.

As pointed out earlier, when dealing with multiple events, we choose to follow a neo-davidsonian approach, treating each event separately. Thus, we introduce three event nodes, S1 for "*find*", S2 for "*told*" and S3 for "*appear*". The word "*until*" expresses the fact that "*could not find*" was happening before "*told*". Thus, we employ the use of another set of edges, E_S, which links event nodes. We add one such edge between S1 and S2 with the label BEFORE. Edges in E_S are labeled. They can be thought of as discourse relations, demonstrating our proposal's ability to go beyond semantics.

Using edges from E_S is one of the ways we propose for handling subordinate clauses, specifically those introduced by subordinating conjunctions such as "because", "although", "until". However, some subordinating conjunctions can be directly linked as arguments of the predicate in the main clause, as we see with the example of "*where it would suddenly appear*". Here, the location represented by "*where*" is the ARG1 of the predicate tell-01

as per PropBank. Thus, while the *appearing* event is represented in its own box, one of its arguments, namely, the location, is linked to `tell-01` by an edge from **E**.

As we see in `S3`'s box, we also treat AMR's non-core arguments differently. These are optional modifiers that are not predicate-dependent. As such, we link them to the event node via a new feature, rather than to the main predicate of that event. We can see that with `sudden` being linked to `S3` via the `manner` feature in Figure 2. This helps us to keep the core predicate-argument structure separate.

Finally, we have two instances of co-reference in this example, between "*I*" and "*me*" and between "*newspaper*" and "*it*". Our current approach is to link these with a pair of dashed edges, different in type from the edges in **E**, running between each instance of the co-referent. These edges are unlabeled.

With the example in this section, we demonstrate our proposal's versatility in encoding various phenomena even for longer texts. The use of layers allows us to represent a wide range of semantic phenomena while keeping it easy to identify each of them in the overall structure. Representing each event separately allows us to maintain this aspect of the representation even for longer texts.

4 Discussion and Future Work

In this work, we do not provide all the definitions of the framework, but as part of ongoing work we have explored its ability to encode a lot of different phenomena and how they could interact in the representation, namely: temporality, aspect, modality, negation, quantifier scope, definiteness, plurality and generics. Thus, we believe our representation has the potential to encode the phenomena represented by logic-based formalisms. However, with our proposal on how to visualise it, it is also more easy to read and annotate. Finally, the clear separation between phenomena allows for a more organised view and the possibility to "switch off" certain layers when irrelevant for a specific task.

As we have seen, edges linking to and from features can be labeled or unlabeled, depending on the feature they are connected to. The focus of this work so far has been the general structure of our proposal. As such, we have used only a simple set of classes for each feature: *possibility* and *necessity* for `modal`, *past*, *present* and *future* for `temp`. In the future, we intend to explore the lattice approach proposed in (Van Gysel *et al.*, 2019) and utilised in UMR. Furthermore, as we can see with the example in Figure 2, while the three events are all in the past, it is clear to a speaker that there is an order in which they occur - the *inability to find the newspaper* happens before the *telling*, while *the appearance of the newspaper* happens after it. This information is not captured by the current version of our proposal but will be the subject of future work, where we could utilise Reichenbach's notions of *speech time*, *event time* and *reference time* (Reichenbach, 1947).

Further next steps for this project will be to give the formal definition of our proposal, expand the list of phenomena we encode, annotate a first exploration corpus, and provide annotation guidelines. This work will be followed by transformation experiments between the thus proposed formalism and other semantic representation formalisms in the line of our previous work (Pavlova *et al.*, 2023a). Furthermore, to allow for this representation to be used for semantic parsing and tasks further up the NLP pipeline, we want to develop an equivalent textual representation in the spirit of PENMAN notation (Matthiessen & Bateman, 1991). Finally, our work so far has been guided and informed by examples in English. For future versions, we plan to take languages other than English into account in order to make sure we are designing a universal framework.

Acknowledgements

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