A compositional view of questions

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Abstract

We present a research on compositional treatment of questions in neo-Davidsonian event semantics style. (Champollion, 2011) presented a dynamic neo-Davidsonian compositional treatment of declarative sentences. Starting from complex formal examples we enrich Champollion's framework with ways of handling phenomena specific to questions-answers pair representation. This research can be applied in multiple fields ranging from questions answering tasks in information retrieval and chatbot programming to human interaction studies.

1 Introduction

Semantic representation of questions is a sophisticated research issue. In the modern NLP landscape, formal semantics offer ways to produce fine-grained descriptions of precise linguistic phenomena, without needing enormous amounts of data. There is a huge lack of transcriptions of questions and answers in real-life settings. Using formal semantics formalisms that are built on hand-crafted examples then tested on real-life data is a way to overcome this shortage. Formal semantics studies of declarative sentences traditionally aim on producing representations whose truth-value can be assessed. Yet, assigning a truth value to a question is a tricky if not impossible task, so one needs to think in a slightly different direction.

Semantic representation of declarative sentences has been thoroughly studied over the years through several formalisms, each crafted with a focus on a different discourse phenomenon. Montague semantics allow one to represent isolated declarative sentences in a simple and robust way. The elementary constituents of those sentences are typed, which gives a compositional way of computing their semantics. However, this approach is not wide enough when one wants to handle dynamic phenomena such as anaphora resolution. Discourse Representation Theory (Kamp, 1981; Heim, 1982) is designed in order to model dynamic phenomena and represent them in a computational-friendly way. Attempts have been made to reconcile both approaches by combining Montague semantics with DRT – (Muskens, 1996) and more recently, (de Groote, 2006). The latest formalisms produce compositional and dynamic representations of declarative sentences with a continuation style process.

Another classical way of representing declarative sentences is through event semantics, among which are neo-Davidsonian approaches (Parsons, 1995; Bayer, 2013). Recent updates such as (Champollion, 2015) have transformed neo-Davidsonian event semantics into a compositional and somehow dynamic framework. Representations of declarative sentences can then be built in a way that flattens down the sentences syntactic structure and makes thematic roles accessible for further work (Amblard, 2007). Representations of elementary constituents of the sentences are typed and several closure operators allow us to handle dynamicity issues when left-hand context appears.

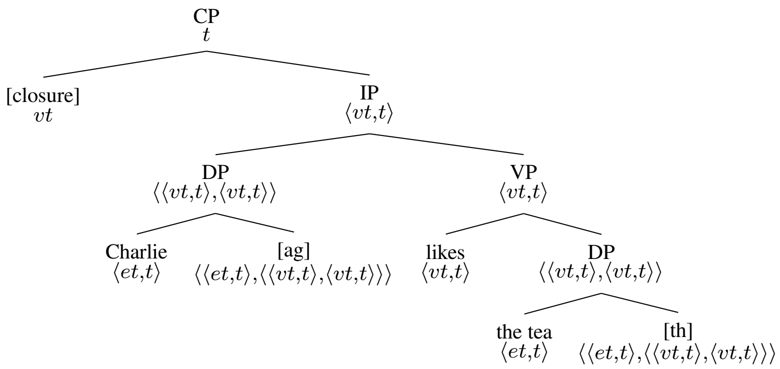
There have been several attempts to produce semantic representations of questions over the years, see in particular (Ginzburg and Sag, 2000) for an overview. We are especially interested in the Minimal Recursion Semantics (MRS) approach (Copestake et al., 2005) that presents a compositional formalism and in particular a way of treating specific types of questions (Egg, 1998). MRS introduces syntactically flat representations with feature structures. As a consequence, one needs to use unification algorithms to compose these representations, and those raise issues of computational concern (see (Huet, 2002)). Furthermore, feature structures are also used in MRS to model quantification, therefore quantifiers can not be accessed in a direct way. Also, quantification management is strongly linked to negation management (see (Champollion, 2011)) and negation is very important for us to be able to deal with negative answers (see section 2.2). We would like to use the ideas developed by Markus Egg while shifting to a quantifier-friendly framework. Therefore, we chose to create a way of representing questions that is based on declarative sentences representation in neo-Davidsonian dynamic event semantics.

2 Questions

One can distinguish two types of questions in English: *wh*-ones and polar ones. *Wh*-questions are questions that give rise to answers whose semantics matches the semantics of the *wh*-phrase contained in the interrogative (Ginzburg and Sag, 2000). A *wh*-phrase is introduced by a *wh*-word; *what, when, where, who, whom, which, whose, why, how* (Aarts et al., 2014). A polar question is used to ask a question that awaits for yes or no as an answer (Aarts et al., 2014). The following gives a very short demonstration of the results of our question representation computations.

2.1 *Wh*-questions

A *wh*-question corresponds to a request about a missing piece of information. In other words, a request to fill an empty thematic role field. We chose to explore this through a neo-Davidsonian approach presented by Lucas Champollion (2011; 2015). Following this proposal, the representation of a declarative sentence such as *Charlie likes the tea* is computed compositionally in the following way:



$$\begin{aligned}[\![Charlie\ likes\ the\ tea]\!] &= \Big(\big([\![[agent]]\!][\![Charlie]\!]\big)\big(([\![[theme]]\!]([\![the]\!][\![tea]\!]))[\![likes]\!]\big)\Big)[\![[closure]]\!] \\ &= \exists x\ \big[\mathbf{tea}(x) \wedge \exists e\ [\mathbf{like}(e) \wedge agent(e) = \mathbf{charlie} \wedge theme(e) = x]\big]\end{aligned}$$

These nested λ-applications correspond to a tree structure that is isomorphic to a syntactic tree. Unraveling the applications along this tree allows us to define a syntax-semantics interface. Our proposal is then to represent *Who likes the tea?* by abstracting on the content of the thematic role `agent` of the previous representation.

$$[\![Who\ likes\ the\ tea?]\!] = \boldsymbol{\lambda w}.\ \exists x\ \big[\mathbf{tea}(x) \wedge \exists e\ [\mathbf{like}(e) \wedge agent(e) = \mathbf{w} \wedge theme(e) = x]\big]$$

When considering a question containing a *wh*-world that does not refer to `agent` or `theme`, the idea stays the same:

$$[\![Where\ does\ Charlie\ live?]\!] = \boldsymbol{\lambda w}.\ \exists e\ [\mathbf{like}(e) \wedge agent(e) = \mathbf{Charlie} \wedge location(e) = \mathbf{w}]$$

A correspondence between *wh*-words and thematic roles can be found in (Boritchev, 2018). However, another idea has to be used to handle polar questions.

2.2 Polar questions

A polar question requests a confirmation or a denial of its content. Therefore, one can see it as a positive declarative sentence (with the same content) that will be either directly accepted (as true) or negated and then accepted, depending of whether the answer is *Yes* or *No*. Our proposal is to represent them as already paired with their answer. As we work from a dynamic perspective, we draw a distinction between representing the meaning of an utterance (by composing the representations of its parts) and representing this utterance at the level of the question-answer relationship. Intuitively, positive/negative answers should be seen as file change potentials (Heim, 1982) of the polar questions. We introduce operators to represent *Yes* and *No*: respectively, $(\boldsymbol{\lambda P.P})$ and $(\boldsymbol{\lambda P.\ not\ P})$ [1]. Now, computing the representation of a polar question followed by its answer boils down to the following: first, we compute the representation of the declarative sentence corresponding to the declarative content of the polar question. Then, we apply the operator corresponding to the answer. For example, if $\mathbf{A}$ asks $\mathbf{A_1}$: *Does Charlie like the tea?*, depending on whether $\mathbf{B}$'s answer is $\mathbf{B_2}$: *Yes* or $\mathbf{B_2'}$: *No*, the representation of the combination will be:

$$\begin{aligned}
[\![\mathbf{B_2}]\!][\![\mathbf{decl}(\mathbf{A_1})]\!] &= [\![\mathbf{B_2}]\!][\![Charlie\ likes\ the\ tea]\!] \\
&= (\boldsymbol{\lambda P.P})\left(\exists x\left[\mathbf{tea}(x) \wedge \exists e\left[\mathbf{like}(e) \wedge agent(e) = \mathbf{charlie} \wedge theme(e) = x\right]\right]\right) \\
&= [\![\mathbf{decl}(\mathbf{A_1})]\!] = [\![Charlie\ likes\ the\ tea]\!] \\
[\![\mathbf{B_2'}]\!][\![\mathbf{decl}(\mathbf{A_1})]\!] &= (\boldsymbol{\lambda P.\ not\ P})\left(\exists x\left[\mathbf{tea}(x) \wedge \exists e\left[\mathbf{like}(e) \wedge agent(e) = \mathbf{charlie} \wedge theme(e) = x\right]\right]\right) \\
&= \left(\forall x\left[\mathbf{tea}(x) \wedge \forall e\left[\neg\mathbf{like}(e) \wedge agent(e) = \mathbf{charlie} \wedge theme(e) = x\right]\right]\right) \\
&= [\![Charlie\ doesn't\ like\ tea]\!]
\end{aligned}$$

3 Conclusion

The apparent simplicity of the representations that we present comes from the expressive power of Champollion's framework. During the computation process, terms tend to be complex because of syntactic issues, but end up by boiling to simple expressions (and we are working towards the automation of the computation process). For now, our proposal is a proof of concept. It works well on isolated questions of minimal form. We did not yet consider more complex questions such as ones introduced by prepositional phrases containing the wh-word ("*For whom is this gift?*" versus "*From whom is this gift?*"), or ones that present mixed characteristics and are neither yes/no nor wh-questions (see for example disjunctive questions: "*Is this tea for Charlie or for Sasha?*"). Context-related issues also need to be adressed: Champollion's approach gives a way of dealing with previous context by using different types of closure operators, and there are approaches that integrate both previous and upcoming context (de Groote, 2006). We are also working our way around language-related issues, extending our experiments to French, Italian, Spanish, Dutch and Chinese (Carletti et al., 2019; Cruz Blandon et al., 2019).

[1] $\boldsymbol{not}$ being a specific type of negation which raises major issues. We do not have enough space to present it here.

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