Context and ontology in understanding of dialogs

Wlodek Zadrozny
IBM Research, T. J. Watson Research Center
Yorktown Heights, NY 10598
wlodz@watson.ibm.com

Abstract

We present a model of NLP in which ontology and context are directly included in a grammar. The model is based on the concept of construction, consisting of a set of features of form, a set of semantic and pragmatic conditions describing its application context, and a description of its meaning. In this model ontology is embedded into the grammar; e.g. the hierarchy of np constructions is based on the corresponding ontology. Ontology is also used in defining contextual parameters; e.g. [current question time ( )].

A parser based on this model allowed us to build a set of dialog understanding systems that include an on-line calendar, a banking machine, and an insurance quote system. The proposed approach is an alternative to the standard "pipeline" design of morphology-syntax-semantics-pragmatics; the account of meaning conforms to our intuitions about compositionality, but there is no homomorphism from syntax to semantics.

1 Introduction: arguments for linking forms, meanings and contexts

We present a new model of natural language based on the concept of construction, consisting of a set of features of form, a set of semantic and pragmatic conditions describing its application context, and a description of its meaning. The model gives us a better handle on phenomena of real language than the standard approaches, such as syntax + semantics a la Montague. It is also an alternative to the standard design based on the pipeline syntax-semantics-pragmatics; the account of meaning conforms to our intuitions about compositionality, but there is no homomorphism from syntax to semantics.

We claim that a linking of form, meaning and context is needed to accurately describe NL constructions, both "standard" and "non-standard". However, we are not arguing for the unsuitability of syntax for describing a "core" of language or a universal grammar. We believe, that such a language core is small, and that the syntactic descriptions of this core are naturally paired with their meanings, which produces a construction-based universal grammar. Furthermore, new methods are needed to handle phenomena of real languages. In this paper, our aim is not to come with linguistic generalizations about universal structural properties of sentences (although, of course, we have nothing against them), but to come with an effective method for natural language understanding, which in addition to computational effectiveness would also have some linguistic and psychological plausibility.

The first argument for the linking of forms, meanings and contexts is that it has been the experience of of many people working in the field of computational linguistics that combining syntactic and semantic information increases the efficiency and effectiveness of processing; e.g. [Lytinen, 1991] has shown that a semantically driven approach is superior to syntax-first approach in processing text in narrow domains.

The second group of arguments is strictly linguistic. Many linguistic phenomena can be naturally described by the pairing of their syntactic form with their semantic features. Such patterns of interdependence of syntax and semantics are common both for standard constructions, like NPs, VPs, or Ss, and for more exotic ones, such as sentences with "let alone". Attempts to account for those phenomena in systems without such interdependence of syntax and semantics lead to drastic overgeneralizations.

As an example involving familiar constructions, consider conjunctions. It is easily seen that particular conjunctions select clauses with a specific logical relation between their respective meanings:

* This is a regular chair, but you can sit on it.
* This is an old chair, but you can sit on it.

In this case, the two phrases conjoined by "but" agree if the second clause contradicts what is typically believed
about entities mentioned in the first clause. This kind of agreement cannot be described without access to semantic information and world knowledge.

Virtually every construction of English displays a similar interplay of form and meaning. We can refer the reader to Fillmore et al., 1988 for a discussion e.g. of the semantic significance of the order of modifiers of NPs, on the semantic conditions on the progressive, etc. Regarding more exotic constructions, Fillmore et al. observe that standard grammars do not handle open idioms such as The more you work, the easier it will get or He doesn’t eat fish, let alone shrimp. They note that each of these expressions "exhibits properties that are not fully predictable from independently known properties of its lexical make-up and its grammatical structure" Fillmore et al., 1988, p. 511.

To show that these types of constructions (and the standard ones) can be handled computationally, Jurafsky, 1992 proposed a construction formalism to build "a linguistically motivated grammar (...) compatible with psycholinguistic results on sentence processing". (His grammar, however, does not include contextual information, nor handle dialogues.)

Finally, we note that context, especially dialog context, changes the range of applicable constructions. Everybody knows that Kissinger thinks bananas makes sense as an answer to the question What is (was) Nixon’s favorite fruit. And, in spoken discourse context, “fragments” behave like open idioms; e.g. ”afternoon” might mean ”in the afternoon”, ”two” the second of the choices (e.g. for a meeting time), and ”checking” can stand for ”from (the) checking (account)”, i.e. semantically be a ”source”.

The paper is organized as follows: In Section 2, we present our NLU system and an example that illustrates the need for contextual information in understanding dialogues. In Section 3 we describe the formalism of constructions; Section 4 presents examples of construction (from words to discourse). Section 5 is about the role of ontologies in the grammar. Section 6 contains an example of parsing with a construction grammar. In Section 7, we argue that construction-based approach captures the intuition of compositional semantics, and that it is an effective and reusable encoding of linguistic knowledge.

2 Grammar, context and ontology in a dialog system

We have built a dialog understanding system, Mincal, for a small domain and a specific task, namely, for scheduling (as well as canceling, and moving) meetings in an on-line calendar Zadrozny et al., 1994. This work has later been extended to other small discourse domains (fast food, banking, insurance premium quotes etc.).

In Mincal, the grammar consists of about a hundred constructions and a few hundred lexical entries, and includes both sentential constructions and discourse constructions. (Similar numbers for other applications). The system also contains an encoding of elementary facts about time and parameters of meetings; this background knowledge is encoded in about a hundred Prolog clauses.

The system is capable of understanding dialogues such as this:

- Schedule a meeting with Bob.
- At what time and date?
- On August 30th.
- At what time?
- 8.
- Morning or afternoon?
- In the evening.

It contains three main components with the following functions:

1. The parser takes an input utterance from the user and a context information from the discourse model. It outputs the set of messages corresponding to the possible meanings of the uttered phrase. The components of the parser are: the parser itself, a lexicon, a set of constructions and a set of filters.

2. The interpretation module (semantic engine) translates the messages it receives from the parser to a set of slots with values, corresponding to the entities recognized in the phrase, like [action_name reschedule], [new_event_place "my manager’s office"] etc.

3. The discourse module gathers the computed slots, the current state of its internal database and the current context. From this it computes the new context, changes the database if necessary, informs the user about the action taken, and carries on the dialog.

MINCAL parser recognizes Schedule a meeting with Bob as an instance of sent(imp), the imperative construction consisting of a verb and an np, in this case np(event). Then, in the context of the task and the question asked, it parses, the subsequent sentences. At each step of the dialog, the semantic engine extracts information from the results of parsing to yield (at the end of the dialog):

```plaintext
***Slots:
[ [ action_name schedule]
[ event_name meeting]
[ event_time
  [ [ minute 0] [ hour 20]
  [ day 30] [ month 8]
[ event_partner
  [ bob]
```

1We will use the convention that np, np(x), vp, vp(\_) etc. refer to elements of our construction grammar, while traditional linguistic/syntactic categories will be denoted by NP, VP, S etc.
At the end of the processing, another component of the program changes the format of this data, and schedules the meeting in an on-line calendar, xdiary.

We can make the following observations. (a) From the point of view of the operation of the system, we do not care about the structure of the sentences (provided the parser can handle them); we care only about their meanings, and these meanings depend on context. (b) The issue of ontology is not trivial. Namely, we have to distinguish not between three languages (representations) and corresponding ontologies: the language/ontology for parsing, the language/ontology for representing information about the domain, e.g. the calendar functions, and the language/ontology for representing information about the particular application, e.g. xdiary. A natural question arising is the role of all three representations in parsing.

We will talk about the interaction of form and meaning in the next section. Now we want to make a few observations about the context-dependence of interpreting dialogs. In the first sentence of the above dialog, the context is used to prevent another reading in which with Bob modifies schedule, as in Dance a tango with Bob! That is, we use a contextual rule saying that for the calendar application people do not modify actions, nor places. By setting up a set of such domain- and application-specific filters, we can remove ambiguities of PP attachment in most cases, e.g. in

Set up a lunch in the cafeteria with my boss
Postpone the interview at 10 to Monday.

In general, taking the context into account during parsing allows the parser to focus on certain constructions rather than others, as well as to compute certain meanings more accurately. Using context to restrict the constructions that are triggered during parsing greatly reduces the number of edges our parser has to consider, resulting in the increase of speed. The dependence of meaning on context is well known, e.g. deixis or decision of the reference of pronouns. But there are very natural examples not connected to deixis: in our dialog, the expression δ is interpreted only as a time expression (and not a place or something else), because of the context of the preceding question (asking about the time of the meeting). Similarly, for computing the meaning of other time expressions: 4 to 6 is more likely to mean "beginning at 4 and ending at 6" than "5:56" in the context of a question about the time of a meeting. But by using the context the application, we can completely eliminate the second reading, since all meetings are scheduled in 5 minute increments.

3 Constructions: integrating forms, meanings and contexts

3.1 Constructions: The concept

A grammar is a collection of constructions. Each construction is given by the matrix:

\[
\begin{bmatrix}
N & name_of_construction \\
C & context \\
V & structure/vehicle \\
M & message/meaning
\end{bmatrix}
\]

The \textit{structure/vehicle} \(V\) consists of formulas describing presence (or perhaps absence) of certain features of form within the construction, e.g. a list of subconstructions and the way they have been put together – in all our examples this is concatenation, but there are other possibilities, e.g. wrapping. Since in practice generative grammars use only taxemes that are "meaningful", i.e. one can associate some meanings with their presence, we can include in our description of constructions some of the features used by GB, GPSG or PEG such as agreement and lexical markings. (cf. e.g. \cite{Sells,1985} and \cite{Jensen,1986}).

The \textit{context} \(C\) consists of a set of semantic and pragmatic constraints limiting the application of the construction. It can be viewed as a set of \textit{preconditions} that must be satisfied in order for a construction to be used in parsing. The message \(M\) describes the meaning of the construction, via a set of syntactic, semantic and pragmatic constraints. \footnote{The language of meanings is to a large extent an open problem, but \cite{Talmy,1985} presents a catalogue of semantic relations which are lexically expressible (in different languages). We believe that an extension of this list can be used to classify meanings of all constructions.}

For example, we can analyze expressions No, but I’ll do it now/send it tomorrow/..., typically given as an answer to a question whether something has been done, as a discourse construction. Its description uses such relations as previous utterance/\(p_{\text{utter}}\), previous sentence/\(p_{\text{sent}}\) (i.e. the propositional content of the previous utterance), the message/meaning of \(S\), \(m(S)\).

\[
\begin{align*}
N :& \text{sent}(assrt, no\text{.}but.S) \\
C :& \left[ p_{\text{utter}}(X) & cons\_name(X, sent(ques, .)) \right] \\
V :& \left[ cons\_name(S, sent(assrt, .)) \right] \\
M :& \left[ p_{\text{sent}}(Y) & truth\_value(Y, 0) & m(S) \right]
\end{align*}
\]

As we can see, the construction applies only in the context of a previously asked question, and its message says that the answer to the question is negative, after which it elaborates the answer with a sentence \(S\).

There is no agreement on what is context, or, even more important, on what is not. But, again, from the
point of view of an abstract computing device, a context is a collection of relations that are interpreted as constraints. A partial list of such relations can be found in the books on pragmatics and it includes such relations as speaker, hearer, topic, presupposed, assertion, question, command, declaration, … To this list we can add previous utterance, current domain, current application, current question, default value, etc.

3.2 Types and properties of constructions

As we have said before, we see constructions as sets of constraints on the relation between forms, meanings and contexts. [Nerbonne, 1993] argues that this view arises naturally in computational linguistics, and discusses its implications for the syntax-semantics interface and parsing.

We do not assume any specific constraint formalism; however we do assume that the constraints can be inherited, and they can be nonmonotonic, that is, more specific constraints might invalidate the inherited ones. Also, in the process of writing a grammar we do not have to specify all constraints at once, e.g. for no. but S construction there should be a relationship, like shared topic, between the sentence S and the preceding question, however this constraint should can be added at any time, and the lack of it should have no impact on the rest of the grammar. We assume that the difference of form implies the difference of meanings of two constructions (cf. Gold, 1994 p.3), but the opposite does not hold (ambiguity and multiple word senses).

Also we should note that apart from the inheritance hierarchy grammars of constructions can be also partitioned "horizontally", each class with its own subtheory. For example, [Zwicky, 1994] divides constructions into four types:

1. sentence-type constructions;
2. constituency constructions, e.g. clauses, phrases, words;
3. valency constructions (head+dependents); and
4. substitution constructions (e.g. pro-forms and zeros).

We can hypothesize the existence of a universal grammar of constructions; e.g. [Goldberg, 1994] p.5, says that "simple clause constructions are associated directly with structures which reflect scenes basic to human experience". She then presents arguments supporting this thesis. Similar arguments can be made for other types of constructions, e.g. basic discourse constructions (cf. e.g. Langacker, 1991) and anaphoric reference [Kay, 1994].

To end this general exposition, we list four basic differences between construction grammars and other grammars. (1) Construction grammars are not lexicalized; (2) They are not head driven (since in real dialogs and texts it is often impossible to find the head of a clause); (3) Parsing produces only flat, two level, "semantic" structures – which is important from the point of view of efficiency; (4) Ontology plays an important role in organizing the grammar and in guiding the parsing.

4 Examples of constructions

4.1 Sentences and phrases

The set of core constructions describes an agent performing an action; the NP is as an agent and a verb as an action. The English constructions SV, SVO, SVOC, SVOC (subject-verb-object-complement), ... could all be described in a similar fashion. But we show only the SVO construction.

\[
\begin{align*}
N & : \text{sent} (\text{assert}, \text{svo}(\_)) \\
C & : [g2p, \text{english}] \\
F & : [\text{struct}(N1, V P, N P1) & \text{con}_{\text{name}}(N1, np(\_)) & \text{con}_{\text{name}}(N2, np(\_)) & \text{con}_{\text{name}}(V P, vp(\_)) & [\text{agent}, m(V P)] , [\text{object}, m(N P2)] ] \end{align*}
\]

The construction specifies that the action is given by the meaning of the VP (which we assume would consist of a V and adverbials); the agent and object are given by the meanings of the two NPs.

For computational reasons it is often convenient to assume that meanings are expressed as lists of [attribute, value] pairs together with formulas constraining those values. We put no restrictions on either the form or the semantics of those formulas; in particular they can refer to extralinguistic properties. In the "atomic" case meanings consist simply of "denotations". For example, for "dog" and "walk" we could have (respectively) [den, dog] and [den, walk]. The SV construction would then specify the meaning of the verb is combined with the meaning of the subject (noun) to produce

\[[\text{agent, dog}], [\text{action, walk}]\]

Notice that at this point the exact choice of notation is immaterial, e.g. we could have written den(dog) for [den, dog]. The point is that constructions explicitly specify how the meanings of subconstructions contribute to the meaning of a whole, and this can be done in a number of ways: by logical formulas, by combining features, functionally, etc. We will use notation which seems the most easy to read.

Construction grammars make use of defaults (that can be overridden). Hence action verbs do not have to be specified as such, but stative verbs must be specified as stative. ACTIONS and verbs can be further subdivided, e.g. along the lines proposed by Dixon, 1992.
into motion-type, affect-type, attention-type, etc. Correspondingly, the defaults would be elaborated into AGENT is MOVABLE for motion-type actions (walk, run, etc.); OBJECT is TARGET and complement is MANIP for affect-type actions (e.g. kick); AGENT is PERCEIVER for attention-type verbs; and so on.

Similarly, nouns would form a hierarchy in which there is a general category \( n(\cdot) \), with a default meaning ”entity”, and many subcategories \( n(thing(\cdot)), n(person(\cdot)), n(idea(\cdot)), n(time(\cdot)), n(time(relative(\cdot))) \) (e.g. afternoon), etc. (see Section 5 below). The noun phrase can then be defined, as usual, as a noun with modifiers (MODS), with the order to be specified for each language separately. And the default meaning of the NP is a conjunction of the meaning of the noun with the relation defined by the modifiers. Notice that the type of a noun phrase \((X)\) is the type of its head (as usual).

\[
\begin{bmatrix}
N : np(X) \\
C : [\text{nil}] \\
F : \begin{bmatrix}
\text{struc}((N, MODS)) \\
\text{cons}\_\text{name}(N, n(X)) \\
\text{cons}\_\text{name}(MODS, T) \\
\text{noun}\_\text{modifier}(T) \\
\text{m}(N) & \text{m}(MODS)(m(N))
\end{bmatrix}
\end{bmatrix}
\]

### 4.2 Words as constructions

We view languages as collections of constructions which range from words to discourse. We have seen how the same representation scheme can be used for different constructions. In this subsection we apply it to lexical items. For instance, the verbs ”see” and ”hit” can be represented as follows:

\[
\begin{bmatrix}
N : \text{verb}(\text{perception}(\text{see})) \\
C : [\text{english}] \\
V : [\text{struc}(\text{see})] \\
M : [\text{perceiver}, X, [\text{impression}, Y]]
\end{bmatrix}
\]

\[
\begin{bmatrix}
N : \text{verb}(\text{affect}(\text{hit})) \\
C : [\text{english}] \\
V : [\text{struc}(\text{hit})] \\
M : [\text{target}, Y, [\text{manip}, Z]]
\end{bmatrix}
\]

The lexical entry specifies the semantic type of the verbs (after [Dixon, 1991]), and the subcategorization information. This information determines the default semantics of the clause in which the verb appears. Notice that (a) even simple words require context to get an interpretation; we say in C that the language code is english (but in other cases it could also be spoken French, etc.); (b) some pieces of information do not have to be explicitly specified and can be replaced by defaults. E.g. for ”hit” we do not have to say that the subject is an agent; it is enough to specify the semantic roles of the object and the complement.

The simplicity of the meanings is a result of a deliberate simplification. In reality, the lexical meaning of any word is a much more complicated matter. Any review of issues of of computational lexicography contains a list of the types of features of lexical entries and inference methods for natural language understanding. For instance, in our lexicon the messages of words may contain many of the attributes that appear in the explanatory combinatorial dictionary of Melcuk (cf. e.g. [Melcuk and Polguere, 1987] and [Melcuk, 1988], pp.92-101) and the functions used there.

We end showing how one can write the matrices of the constructions \( \text{pronoun}(\text{him}) \) and \( \text{determiner}(\text{the}) \).

\[
\begin{bmatrix}
N : \text{pronoun}(\text{him}) \\
C : \text{english} \\
V : [\text{struc}(\text{him})] \\
M : [\text{case}, \text{acc}] & \text{[person, third]}
\end{bmatrix}
\]

\[
\begin{bmatrix}
N : \text{determiner}(\text{the}) \\
C : \text{english} & \text{current}, \text{discourse}(DS) \land DS \neq [\text{nil}] \\
V : [\text{subcat}, \text{bare}\_\text{np}(X)] \\
M : [\text{definite}, m(X)]
\end{bmatrix}
\]

Clearly, this is a very sketchy characterization of the definite article. It says that there is a non-empty discourse context, that it subcategorizes for a bare NP, and meaning is given by the attribute definite. Although it captures the main properties of ”the”, we refer the reader to [Langacker, 1991] p.96-103 and [Fauconnier, 1985] for a discussion of definite descriptions and determiners, and for a characterization of the attribute definite in terms of ”mental spaces”.

### 5 Embedding ontology into grammar

In our construction grammar the representation of constructions is closely coupled with a semantic taxonomy. Thus, for instance, not only do we have an np construction, but also such constructions as np(place), np(duration), np(time), np(time(hour)) etc. In other words, the semantic hierarchy is reflected in the set of linguistic categories. (Notice that categories are not the same as features). Hence we do not have a list, but a tree of grammatical categories.

To be more specific, let us consider temporal categories. Time is divided into the following categories minute, hour, weekday, month, relative, day_part, week_part, phase, and more categories could be added.
if needed, e.g. *century*. Some of these categories are further subdivided: *day* part into *afternoon*, *morning*, ..., or *relative_(_)* (e.g. *in two hours*) into *hour*, *minute*, *day* part, *week* part, *weekday*.

Note that (a) different constructions can describe the same object of a given category, for example *hour* can be given by a numeral or a numeral followed by the word "am" or "pm"; (b) there is a continuum of both categories and constructions describing objects of a given category, for instance, we have the following sequence of types of constructions

\[
np > np(time) > np(time(month)) >
> np(time(month(january))) = january
\]

corresponding to the sequence of categories

\[
\text{entity} > \text{time} > \text{month} = \text{time(month)} >
> \text{january} = \text{time(month(january))}
\]

In the first case *january* is a word (words are constructions), too, in the second case it is a concept.

We end this sections with two notes. First, we can ask: what about verbs and their hierarchies? — At present we have no hierarchy of actions, and no hierarchy of verbs; perhaps when related actions can appear as parameters of a plan such a need would arise. However *np* hierarchies help describe arguments of verbs.

Second, we would like to point to another, indirect, argument in favor of the coupling of grammar and ontology. Namely, the relationship between ontologies and hierarchies is needed to produce the following interpretation of a complete sentence. That is, the interpretation cannot be produced solely from the edges of the chart produced by the parser; it must e.g. be known that "set up" is means "schedule".

Let us now consider the processing of fragments, which will also explain how the interpretation above can be computed, and how ontology is used in constructions. As noted before, getting the slots from a fragment is possible only by using context (such parameters as *current_(_)* *question* or *topic*), so that its meaning can be unambiguously computed. Let us assume that the system has asked for the time and date of an appointment. The user however does not answer exactly to the point:

\[
\text{on} \text{November} 11\text{th} \text{with} \text{Martin}.
\]

**Slots:**

\[
\text{event\_time} \quad [ \text{month} 11]
\]

**event\_partner** [ martin]

1. ?- sem.

```
| i, want, to, set, up, an, appointment, on, november, 11 |
```

**slots:**

\[
\text{event\_name} \text{ schedule}
\]

```
| [ event\_name meeting ] |
```

```
| event\_time [ [ month 11 ] [
```

```
| day 11 ] |
```

```
| event\_partner [ martin ] |
```

```
| ?- lis. |
```

**Chart results:** INACTIVE EDGES

\*

0, 1, [on] : prep(on) -> [on]

\*

1, 2, [november] : n(time(month)) -> [november]

```
[ [ \text{type}, \text{time(month)} ], [\text{den}, 11] ]
```

\*

1, 2, [november] :

```
np(time(month)) -> [n(time(month))]
```

\*

2, 4, [11, th] :

```
\text{ordinal} -> [\text{numeral}, st, nd, rd, th]
```

```
[ [\text{den}, 11] ]
```

The preposition *on* by itself does not carry any meaning, we treat it as a lexicalized feature. In (2, 4), to prevent overgeneralizations such as *3 th*, the vehicle of the construction must contain the list of cases if 1 then st, if 2 then nd, ....

\*

1, 4, [november, 11, th] :

```
np(time(day)) -> [np(time(month)), ordinal]
```

```
[ [ \text{type}, \text{time} ], [\text{den}, [\text{month}, 11], [\text{day}, 11]] ]
```

\*

0, 4, [on, november, 11, th] :

```
pp(on, time) -> [prep(on), np(time(day))]
```

```
[ [ \text{type}, \text{event\_time} ], [\text{den}, [\text{month}, 11], [\text{day}, 11]] ]
```

\*

0, 4, [on, november, 11, th] :

```
pp\_list(on, time) -> [pp(on, time)]
```

\*

0, 6, [on, november, 11, th, with, martin] :

```
pp\_list(with, person) ->
```

```
[pp(on, time), pp\_list(with, person)]
```

\*

\* In the following, we do not show syntactic information, because syntactic features are standard (e.g. plural, 3rd, accusative, ...)
The innovations we have proposed — the close coupling of semantic hierarchies with linguistic categories, the use of context in representing linguistic knowledge, and the representation of the grammar as a dictionary of constructions — not only facilitate the development of the grammar, but also its interaction with the inference engine and the application.

Obviously, the usefulness of this approach is not limited to natural language interfaces. We have used parts of the grammar of constructions for some information retrieval tasks; and we can easily imagine it being applied to text skimming and to machine translation in limited domains.

The approach to language understanding we are advocating has several advantages: it agrees with the facts of language; it is not restricted to a "core" of language, but applies to standard and more exotic constructions, including language fragments; and it is computationally feasible, as it has been implemented in a complete working system.

Summarizing, the most important innovations implemented in the system are the close coupling of semantic hierarchies with the set of linguistic categories; the use of context in representing linguistic knowledge, esp. for discourse constructions; and a non-lexicalist encoding of the grammar in a dictionary of constructions. We have obtained a new language model in which forms cannot be separated from meanings. We can talk about meaning in a systematic way, but we do not have compositionality described as a homomorphism from syntax to semantics. (This is theoretically interesting, also because it is closer to intuitions than current models of semantics). We have validated this model by building prototypes of natural language interfaces.

8 Conclusions

The innovations we have proposed — the close coupling of semantic hierarchies with linguistic categories, the use of context in representing linguistic knowledge, and the representation of the grammar as a dictionary of constructions — not only facilitate the development of the grammar, but also its interaction with the inference engine and the application.

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References

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[[pp_msg, [[type, partner], [den, martin]]],
 [pp_msg, [[type, event_time],
  [den, [[month, 11], [day, 11]]]]
 * 0,6, [on, november, 11, th, with, martin] :
  pp_list(on, time) ->
   [pp_list(on, time), pp(with, person)]

The meaning of the pp (0, 4) is a simple transformation of the meaning of the np in (1, 4). But notice that this happens because we have a specific construction which says that a combination of on with an np(time(_)) produces event_time. Altogether, we have encoded a few dozens various pp constructions, but in a given application only a fraction of them are used.

In the same context, please note that, because of the close relationship between the domain ontology and the hierarchy of constructions, we can also postulate a close relationship between the type of meaning a construction expresses and its category (i.e. name), for example, the type of meaning of np(time(hour)) is [type event_time].

At the end, we obtain two parses of (0, 6), but they have the same messages. The difference lies in the category assigned to pp_list; and in this particular case the choice of that category is not important.

7 Knowledge and meaning

7.1 Compositionality

The idea of compositionality is used to account for the ability of the language user to understand the meaning of sentences not encountered before. The new sentence can be understood, because it is composed of parts (words) that the user knows, and the meaning of the new sentence is computable from the meanings of the words that compose it. But the standard definition of compositionality is formally vacuous [Zadrozny, 1994] (i.e. any semantics can be compositional), so the concept of compositionality has to be reexamined.

Given that, note that a grammar of constructions can account for the ability of the language user to understand the meaning of novel sentences without separating the language into syntax, semantics and pragmatics. Namely, the meaning of a larger construction is a combination of the meanings of its parts (and the way they are put together). The message of the larger construction specifies how its meaning depends on the meanings of the parts.

7.2 Ontology and knowledge bases

We view construction grammars as representations of domain-independent linguistic knowledge. That is why we need a domain-dependent semantic module to map linguistic representations into concepts of the domain. The fact that we have been able to use the same sets of constructions for various domains is an argument for feasibility of this approach.

Obviously NLU is impossible without access to vast bodies of background knowledge. The fact that meanings of NL utterances are classified and described with the help of general ontologies suggests that linking linguistic and non-linguistic knowledge for the purpose of reasoning about dialogs and texts might be possible without the help of a translator program. Furthermore, it might be possible to modularize those sources of knowledge.
