RELATING SYNTAX AND SEMANTICS: THE SYNTACTICO-SEMANTIC LEXICON OF THE SYSTEM VIE-LANG

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ABSTRACT

This paper describes the structure and evaluation of the syntactico-semantic lexicon (SSL) of the German Natural Language Understanding System VIE-LANG [3]. VIE-LANG uses an SI-Net [2] as internal representation. The SSL contains the rules according to which the mapping between net-structures and surface structures of a sentence is carried out. This information is structured in a way that it can be evaluated from two sides. The parser interprets it as production-rules that control the analysis. Syntactic and semantic features of the input sentence are evaluated and individuals are created in the semantic net. The generator uses the same rules to express selected net-structures in adequate natural language expressions. It is shown how both processes can make effective use of the SSL. The different possibilities for evaluating the SSL are explained and illustrated by examples.

I OVERVIEW OF THE SYSTEM VIE-LANG

A. Representation

In the system VIE-LANG real world knowledge is represented within a semantic net (SN) which is realized in the formalism of an SI-Net [2]. The net is organized in two layers.

The generic layer contains the static knowledge of the system. At the generic level real world knowledge is represented in the form of concepts and roles. A concept is defined by its attributes which consist of two parts: role and value restriction. The value restriction is a concept which defines the range of possible fillers for the attribute, the role defines the relation of the filler to the concept being defined. Generic concepts are organized in a hierarchy of super- and subconcepts in which a subconcept inherits all attributes of its superconcepts.

The second layer of the net contains the dynamic knowledge which consists of individualized concepts. The parser creates individuals of those net structures which are addressed by the input words. As more input is analyzed more individuals and links are created. These individuals constitute the episodic layer of the net.

The conceptual content of the net is organized according to the idea of semantic primitives [8] which are characterized by typical attributes. Action primitives have attributes which correspond to cases of a case grammar (AGENT, OBJECT, RECIPIENT, LOCATION, etc.) [4], [11].

B. Parsing

Our parser belongs to the class of semantic parsers as suggested by [1], [7]. Since syntax carries a lot of information in German it has to be considered in analysis: The syntactic role of a constituent cannot be determined by word-order, instead its morphological endings which indicate the surface case of the constituent have to be evaluated.

The parser is a data-driven system, which combines syntactic and semantic processes. Syntax is used as the tool to gain information concerning the constituents of the sentence, but the syntactic processes interact with semantic ones in order to confirm their hypotheses about a constituent. To recognize NPs and PPs the parser uses an ATN, which accepts semantically valid interpretations only. The resultant structures include syntactic and semantic information about the constituent. These structures are then collected in a constituent list.

The semantic representation of a sentence is built by linking the constituents to the predicate. This process is controlled by the SSL-entry for the verb. First the dominant verb has to be disambiguated [9]. SSL entries for verbs contain the information how verb-dependent constituents are mapped onto the cases represented within the net. In a last step referents for modifying constituents are determined and attached.

A sentence is considered to have been parsed successfully after all constituents of the sentence have been incorporated. As a result the parser produces a configuration of individuals in the net - the semantic representation of the input.

C. Generation

The task of the generator is to convert a selected part of the episodic layer of the semantic net into surface sentences. This part - a root node and vertices and nodes attached to it form a coherent graph - is assumed to have been determined previously by the dialogue component. Generation is accomplished in two steps: step one performs a mapping of the SN to an intermediate structure (IMS) containing words together with syntactical and morphological data, and step two transforms the IMS to surface sentences by applying syntactical transformations, linearizations and a morphological synthesis.

To produce a single sentence, the dominating verb is selected first, as it plays a central role in a sentence. The semantic primitives of which the SN is composed imply that there is no one-to-one correspondence between concepts in the net and words of the language. Therefore the decision which verb to select depends on the pattern of individuals in the episodic layer of the net. The criteria for this selection are attached to the generic concept of the root node in form of a discrimination net (DN) [5]. Its tests evaluate the filled attributes of the root primitive. The evaluation of this DN results not only in a verb, but in a verb-sense.

The generator accesses the SSL entry for this verb-sense and continues by processing the different rules of which it is composed. The rules are evaluated from right to left. Right sides mainly deal with entities in the SN, especially individuals. If an individual is relevant to generation, it is put on a stack ("current individual"). When the left side is processed, syntactical data along with the result of a recursive call of this part of the generator is passed to the IMS. The current individual (the argument of this call) is then removed from the stack and control is returned to the calling procedure, thus allowing the next rule to be processed. The IMS which is created during this part of the process forms the input for the step two processor which will finally produce the output sentence [6].

II THE SYNTACTICO-SEMANTIC LEXICON

By means of the SSL the mapping between surface expressions in natural language and structures of the representation is achieved. For an NLU dialogue system the relation between surface and representation is of interest in the context of parsing and the context of generating. The structure of the SSL allows interpretation by both processes.

Attributes of actions realize the ideas of a case grammar. This leads to a correspondence between roles in the net and surface cases within the sentence. Cases of a case grammar at the one hand show regularities in their relation to syntactic constituents (subject -> AGENT), at the other hand the relation between a role and a surface case is verb-dependent. E.g. the verb 'bekommen' (to get) relates the subject to the role RECIPIENT, the verb 'geben' (to give) relates the subject to the role SOURCE. The verb 'geben' requires the RECIPIENT to be expressed by a dative. Such dependencies are captured in the entries of the SSL whereas the regularities are treated by defaults.

A. Structure of the SSL

The basic unit in the SSL is the entry for a word-sense. Associated to each word-sense is an optional number of pairs which we will describe by the terms 'Left Side' (LS) and 'Right Side' (RS). A pair describes how a word (phrase) of the sentence is represented within the semantic net.

LSs describe features of the surface sentence. Most features refer to syntactic properties, e.g. constituents of a given surface case, infinitive constructions, lexical categories, surface words, and some features indicate selectional restrictions. If a LS contains more than one feature they are combined with an operator. One of the most frequent patterns that is used in LSs combines a syntactic feature with a net concept which is interpreted as selectional restriction. This combination reflects our general parsing approach to combine syntax with semantics.

RSs refer mostly to structures within the semantic net. There is no one-to-one correspondence between word-senses and conceptual primitives. To represent word (or phrase) meanings primitives are linked forming more complex structures. By definition there is one distinguished concept in each RS 'the root concept' which is the central element of the representation. All other structures referenced in an RS are linked to it.

Although the number of action-primitives is relatively small (14), the net provides possibilities to express differences between related verbs. This is done by filling attributes with certain values by default. Such an attribute does not correspond to a constituent of the sentence but is 'part' of the verb-sense, e,g. 'gehen' (to go) is represented by the concept CHANGE_OF_LOCATION, 'laufen' (to run) addresses the same concept, but its attribute SPEED is filled by a different value.

Not all SSL entries are relevant to parser and generator - some entries are relevant to one process only. This should not be regarded as a disadvantage, on the contrary, such entries support efficient use of the SSL. Since each subsystem has its own typical way of interpreting entries (LS and RS), process-specific entries are simply disregarded by the other system.

B. Evaluation of the SSL

Parser and generator treat the entries in the SSL as production-rules, each interpreting LS and RS in its own way. The parser works from LSs to RSs whereas the generator works in the opposite direction.

1. Parsing

The parser needs to map surface-constituents onto elements of the semantic net. To produce the semantic representation of an input word the parser accesses the SSL entry of this word. For each word there may be several word-sense entries. The LSs of all word-sense entries for a word incorporate the information necessary to distinguish one sense from the others. The parser interprets the LSs as conditions that have to be fulfilled by the input sentence. The SSL contains at least one pair LS - RS for each word-sense. In order to choose the correct interpretation the LSs of the different word-senses are evaluated. After the parser has chosen a word-sense by matching sentence-patterns and LS-conditions the associated RSs are interpreted as actions and evaluated sequentially. For the parser the structures in the RS are interpreted as representation of the word, therefore the indicated net-structures are individualized. The complete structure that has been created after all RSs have been executed is used as the representation of the input-word.

Verb-entries for example specify the relation between surface constituents and the cases which are attributes of the action concept. Each verb-sense calls for a typical sentential pattern in which each constituent has to fulfil certain semantic restrictions. The parser selects a verb-sense if the features of constituents in the constituent list satisfy the conditions of the LSs. After having selected one word-sense its RSs are evaluated and the constituents are linked to the action as case-fillers.

The parser uses the SSL entries to disambiguate verbs. The LSs incorporate the factors by which word-senses can be discriminated from each other. For many verbs the selectional restriction of the direct object is a decisive factor. E.g. the verb 'bekommen' (to get) is interpreted as OBJTRANS iff the semantic restriction of the direct object belongs to the class OWNABLE-OBJECT (see Fig. 1). The mechanisms by which disambiguation is carried out if the LS is not met is explained elsewhere [10].

```
(BEKOMMEN
 (1
   [(AND (CASE ACC)
         (RESTR OWNABLE-OBJECT))
    -->
    ((IND OBJTRANS)
     (VAL + OBJECT *))]

   [(T (CASE NOM))
    -->
    ((VAL + RECIPIENT *))]

   [(AND (PP VON)
         (RESTR PERSON INSTITUTION))
    -->
    ((VAL + SOURCE *))]))
```

Fig. 1
SSL entry for 'bekommen', word-sense-1
('to get an object')

When the parser analyses the sentence 'Hans bekommt von dieser Frau ein Buch.' (John gets a book from this woman.) there are three constituents on the constituent list.

Interpretation of the first pair of the entry for bekommen-1 leads to the instantiation of the root concept OBJTRANS (RS: (IND OBJTRANS)) and the creation of the value OBJECT filled by the representation of book.

The parameter '+' refers to the root individual for all pairs of the word-sense entry. For the parser the parameter '*' in the SSL refers to the representation of the constituent selected by the LS which is local to one pair.

The second pair leads to the instantiation of the value RECIPIENT filled by the representation for 'Hans' and the third one finally instantiates SOURCE filled by the representation of 'Frau'. The resulting representation of the sentence is shown in Fig. 2.

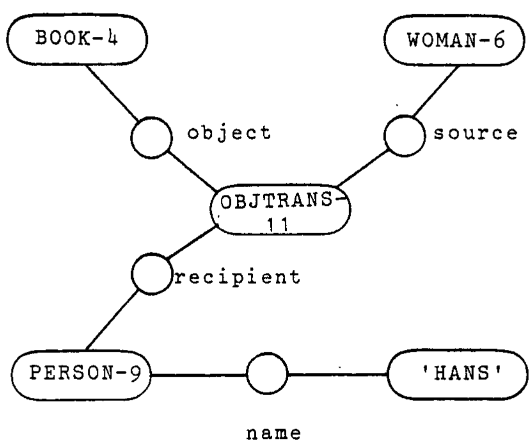

Fig. 2
Net structure for
'Hans bekommt von dieser Frau ein Buch.'

Action primitives typically have an AGENT and an OBJECT attribute. In most cases their surface equivalents are subject and direct object respectively. Therefore it would be redundant to include these relations for every verb. In these cases only the root concept is given in the RS (see Fig. 3). The mapping is carried out by default mechanisms which are applied whenever the LSs do not refer to subject or direct object.

```
(ESSEN
  (1
    [(T) -->((IND INGEST))]))
```

Fig. 3
SSL entry for 'essen' , word-sense-1
('to eat')

In the default cases the selectional restrictions are checked implicitly. The net does not allow instantiation of structures that do not correspond to the patterns given in the generic concepts. If this occurs e.g. in the sentence 'He will eat his hat.' an error-message is generated because the semantic concept for 'hat', GARMENT, is not compatible with the restriction SUBSTANCE for the OBJECT of the concept INGEST. At this stage of development we do not loosen selectional restrictions as suggested by Wilk's preference semantics [12].

2. Generator

When generating a sentence, the generator starts by regarding the root node which has been passed to it by the dialogue component. Normally, this root node will, together with the attributes attached to it, correspond to a verb, so this verb is selected first. As mentioned above, a discrimination net is used to accomplish this task. The DN selects a verb-sense according to the attributes of the root node.

We will show the further processing by means of the example shown in Fig. 2. Let us assume the verb-sense 1 of the verb 'bekommen' (Fig. 1) has already been selected. The entries of the SSL are treated from right to left by the generator, so we start with (IND OBJTRANS). This will result in a null action for the generator, as an instance of OBJTRANS (OBJTRANS-11) is already known as current root node and it has been put as first element onto the stack for the current individual. (VAL + OBJECT *) is considered next. + denotes the root node, * the individual attached to that role of it which is specified by the second parameter, i.e. OBJECT. This element, namely BOOK-4, is put on the stack.

Now the generator proceeds with the LS: (CASE ACC) is a recursive call to the generator with the current individual, BOOK-4, as new root node together with the information that the result shall bear accusative case endings. The generator processes the DN for the concept 'BOOK' and returns 'Buch'. This lexeme together with the case information now forms part of the IMS. After having processed the current individual BOOK-4, it is removed from the stack. The action (RESTR OWNABLE_OBJECT) results in a no-op for the generator, as this information has already been processed in the DN when deciding to use the verb-sense 'bekommen-1' (see below).

The second RS-LS-pair is treated in a similar way: The individual attached to RECIPIENT is put on the stack, (CASE NOM) calls the generator with PERSON-9 as new root node and says that the resultant structure shall be rendered as a nominative. The DN of PERSON supplies the information that persons are best specified by their names (if present in the net - if not, other criteria are considered), and so the word 'Hans' completes the structure being passed to the IMS.

As for the last test-action-pair, PP causes a prepositional phrase, 'von der Frau', to be created. In German, the preposition 'von' implies dative case, so no additional entry (CASE DAT) is required in the SSL. (Note that this omission enables the parser to ignore case errors in the input sentence that do not influence the semantics.)

3. Creating Discrimination Nets

So far, the use of the SSL has been demonstrated only partially: in the example above some of the elements in RSs and LSs have been treated as no-ops, especially INDIV and RESTR. These elements, instead of being used in the process of generation, provide information for building data structures for the generator, namely the above mentioned DNs.

As an example, consider the entry for 'bekommen' (Fig. 1), (INDIV OBJTRANS) informs us about a correspondence between the concept OBJTRANS and the verb-sense 'bekommen-1'. This correspondence leads to the incorporation of 'bekommen-1' as a leaf node in the DN for the concept OBJTRANS. Other clues for constructing the DNs are provided by the VALs, thus giving them a double usage: (VAL + RECIPIENT *) in the SSL entry for 'bekommen-1' (Fig. 1) implies that an individual attached to the RECIPIENT role of an OBJTRANS individual is a prerequisite for selecting this verb-sense. (The absence of a recipient in the net would lead to the selection of 'weggeben' (to give away).)

III SUMMARY

We have shown how a lexicon that includes syntactic and semantic information has to be structured to allow efficient use by two processes, parser and generator. Whereas both must have access to knowledge about syntax as well as representation, their starting position differs: The parser is confronted with surface expressions, therefore LSs are evaluated first. The generator has to process net structures, so it begins by evaluating RSs. The reciprocal relation between analysis and synthesis is realized in the SSL by pairing off LSs and RSs. Flexibility is insured by the fact that parser as well as generator treat LS and RS each in an idiosyncratic way.

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