Semantic Hierarchies in Dialogue Systems

ROMAN MOUČEK
Department of Computer Science and Engineering
University of West Bohemia
Univerzitní 8, 306 14 Plzeň
CZECH REPUBLIC

Abstract: - This paper deals with the semantic representation of user utterances within development of computerized dialogue system intended for city information center. The formalisms for description of natural language are mentioned and verified on user utterances and first dialogue turns within selected domain areas. A parser analyzing the utterance segments according to given rules is presented. Then the problem of building semantic hierarchies and obtaining an appropriate abstract level of semantic representation is discussed.

Key-Words: - computerized dialogue system, semantic representation, semantic hierarchy, syntactic-semantic patterns, semantic roles, utterance segments, domain concept, task concept

1 Introduction

This paper deals with computerized dialogue system LINGVO/LASER developed at the University of West Bohemia, Czech Republic, in co-operation with Technical University in Dresden, Germany, which is intended for city information center. The aim of this dialogue system is to introduce a more natural dialogue between a user and computer. A module of linguistic analysis interprets the input word sequence and produces a semantic representation of this sequence. A parser analyzes the utterance according to given rules and generates a corresponding structured representation.

- A dialogue manager compares the semantic representation of the user utterance with former utterances of this user and performs the interpretation within the dialogue context. Then the next system utterance is generated. Also the strategies for communication problems are also included.

- A speech synthesizer transforms the textual representation of the system utterance into a sound signal. This sound is presented to the user.

2 Architecture of Dialogue Systems

Building architecture of the dialogue system needs a special knowledge from many research areas. We have also to choose between several design decisions. The modular architecture of LINGVO/LASER dialogue system is presented in Figure 1.

- A word recognizer takes the speech signal and converts it to a sequence of recognized words. Ideally the recognized words are the same as the word sequence spoken by the user.

- A module of linguistic analysis interprets the input word sequence and produces a semantic representation of this sequence. A parser analyzes the utterance according to given rules and generates a corresponding structured representation.
3 Syntactic-Semantic Patterns

The basic idea of description of user spoken utterances comes out from theories of syntactic-semantic patterns [3], extra-language microsituations [3], utterance dynamics [4] and hierarchy of conceptual structures [2]. The theory of syntactic-semantic patterns is based on predominant position of predicators on the semantic and formally syntactic level. The corresponding extra-language microsituations are elaborated by so called language models from different points of view. The language models are additionally generalized to be applied on any participant of the elaborated microsituation [3].

This theory operates on the whole natural language and tries to build structures, which are independent on the given situation. However, taking into account the insufficient results of classification of microsituations and predications in two elaborated domains, domain of city public transport and domain of accommodation, we have had to give up describing spoken utterances within specific domain by set of extra-language microsituations.

On the other side, we can use up the whole situation. Then the domain is described with a specific elementary situation, which is finally represented by task concept (corresponds to the frame structure), which is relevant to the final database structure. This elementary situation also corresponds to the set of synonymous domain relevant predications. This set is represented by domain concept. Then the predications are not more elaborated. The values of components (actants) of elementary situation are changing according to information obtained from user, from application database or according to situation filled by semantic and knowledge interpretation on both, local and global level.

The focus of the user (leading to the change in component values of an elementary situation) can be uncontrolled by dialogue manager or by contrast several dialogue strategies are used. From the psychological point of view a user does not want to be restricted by a non-human device. On the other side only restricted dialogue strategies forcing a user to answer question of dialogue manager are more successful. In this case a semantic prediction of dialogue manager can be used and limitation of user association network is pursued.

4 Classes of Semantic Roles

As the last components of semantic-syntactic pattern we focus on the semantic roles of actants. Because of no relevant importance of predicat in processing of spoken language in specific domain there is no need to consider their valence and position in the sentence. That is why we also give up the notion actant and introduce a notion utterance segment.

Thus, we focus on the semantic roles of utterance segments and possibility to build a semantic hierarchy of these semantic roles. Then a potential domain independency of this hierarchy can be discussed. The general set of semantic roles of actants mentioned in [3] was completely reworked. Some of the semantic roles of utterance segments covering the semantic-syntactic parts of user utterances in domain of city public transport are presented in Section 5.

The semantic roles cover usually utterance segments consisting of one word or word collocations with respect to the selected abstract level of description. There were built two abstract levels of semantic roles for the city transport domain and one abstract level for domain of accommodation. The abstract level A (both city transport domain and domain of accommodation share some of the semantic roles) is more domain specific. The abstract level B (only for domain of city transport) introduces more general semantic roles.

4 Parsing

The syntactic-semantic parsing is based on retrieval of utterance segments in the user utterance. The meaning range of semantic roles is dependent on the selected abstract level. In general, it is supposed a usability of compositional theory on conceptual meaning of utterance. Moreover, in the case of invalidity of compositional theory in a high abstract level, the interpretation process is able to modify the composition of conceptual meanings. The parsing of user utterance is proceeded in the following steps:

- retrieval of utterance segments in the user utterance, these are assigned by semantic roles according to selected abstract level; several sets of semantic roles are possible,
- selection of the best hypothesis from the sets of semantic roles,
- transformation of semantic roles into linguistic concepts by common transformational mechanism,
- covering of linguistic concepts by domain concept corresponding to the situation,
- local and global semantic interpretation; local hierarchies of concepts are created (hardly depends on selected abstract level) and the set of world indices is built (global semantic interpretation).
The correct selection of semantic roles (number of words they consist of) is a very difficult one. Then the highly abstract level (level B) respects the utterance segments, which are closer to syntax; an effect of domain-independency is produced. The more domain oriented abstract level (level A) permits utterance segments semantically typical for elaborated domain. Then the syntactically correct parts of user utterance are mostly represented.

4.1 Retrieval of Utterance Segments

All the utterance segments with corresponding semantic roles are stored in a dictionary. The semantic roles only serve as the denotations for linguistic concepts built consecutively. The robustness of the parser is increased by the possibility to retrieve utterance segments regardless of immediate succession of the segment components.

Example: jak se tam dostanu (how can I get there)

The utterance segment se dostanu is found.

Retrieval of utterance segments is realized by a special kind of finite automaton [1]. This automaton has several extensions to make the linguistic analysis more robust (to process word phrases). The first extension permits to continue from the semifinal state of automaton (a word is accepted by automaton, but other component of utterance segment can be accepted by automaton continuing from this state) during processing of next component of utterance segment. The second extension provides a possibility that the parsing process runs independently in several states of automaton at a time. Information about states, which are initial ones for the next step, is maintained in a special list. The states are maintained in the list for all the time a user utterance is elaborated. This is a requirement to the successful retrieval of utterance segments, which components are interleaved by other words or word phrases. Because of high memory complexity of the parser this is used in the modified form with packed states. More information about parser and parsing process is available in [1].

4.2 Best Hypothesis

Because of possible overlapping of semantic roles representing utterance segments, it is necessary to find such set of semantic roles, which enables and simplifies the next step of semantic analysis. Nowadays, the criterion of maximal number of words within utterance segment is used. Then this approach looks for maximal utterance segments, which do not overlap. The best hypothesis serves as a base for building the chain of linguistic concepts.

4.3 Local Linguistic Concepts

Taking into account the description of SIL concept [2] and principles of object oriented programming, each linguistic concept has the following features:

- it is typed,
- it includes a list of roles, which specify the features of the concept,
- concepts are organized in a tree-structure – each concept includes the names of concepts it consists of,
- it has a parent.

According to the position of concept within a semantic hierarchy there are distinguished the following types of concepts:

- atomic concepts - contain only data,
- compositional concepts - consist of other concepts.

Each semantic role is replaced by a linguistic concept at the next step of semantic analysis. This kind of concept includes the name of corresponding semantic role as an attribute and a method building the concept. Moreover, all the linguistic concepts (atomic and compositional) inherit other attributes and methods important for semantic interpretation. The chain of linguistic concepts is covered by domain concept and passed by for the next elaboration. There is important an order of the linguistic concepts in the chain of concepts especially in the case of modified information given by user.

4.4 Domain Concept

The semantics of predicador is represented by domain concept, which is highly domain dependent. It corresponds to the situation and to the set of relevant predicadors. Thus, there is possible to compare the domain concept to the conceptual meaning of set of predicadors typical for utterances in given domain (e.g. the set of synonymous predicadors get, go, arrive, depart, etc. are elaborated in the city transport domain). Domain concept can be also described as a concept covering the chain of competing linguistic concepts including the type of question and cover structure for the next step of linguistic analysis – semantic interpretation (it includes the methods for knowledge anchoring).
4.5 Task Concept

Task concept is a fully application dependent concept corresponding to the application database. It is build as a frame structure for storing results of semantic interpretation. The interpretation process also supplies an extraction of information from linguistic concepts to the final task concept. Then the task concept consists of slots containing information obtained by interpretation of user utterances including the question type. Modified task concept includes also type of knowledge (new, modified and contradicted).

5 Semantic Hierarchies

A language expression of our thoughts can be considered as an abstract level describing our inner brain processes and world perception. This language expression is on one hand redundant and on the other hand it suffers from incompleteness and limited means to transfer all the possible information. Moreover, if we transcribe the utterance to the written form we lose further information. There is a question if the building of higher abstract level of semantic representation disables the utterance comprehension. On the other hand, we need a higher abstract level to make machine comprehension possible.

The abstract levels of semantic roles and consequently built linguistic concepts were analyzed to find their position in the semantic hierarchies. The organization of these hierarchies is determined by the selected abstract level, domain width, perception of the situation and also by needs of semantic interpretation process. Inspecting the possibility to build general hierarchies only the set of the time concepts can be considered as reusable in various kinds of domains.

There are even the same words in domain of transport and domain of accommodation with the different meaning and with different requirements for interpretation.

Example: The word *autobus* (bus) has the semantic role *Cvehicle* in the city transport domain, but *Cnumber* in the domain of accommodation (number of people to be accommodated).

The semantic hierarchy of linguistic concepts, which is built for the domain of city transport, is presented as a component structure. The domain concept is a composition of linguistic concepts, which can create strictly local hierarchies. Finally, within domain of city transport e.g. the following linguistic concepts at level A enter the process of semantic interpretation:

- Cgo - concept denoting occurrence of predicator or another word from defined set - domain concept is confirmed,
- Cloc - denotes location (city suburb or stop),
- Cdestloc - denotes destination location (city suburb or stop),
- Csourcecloc - denotes source location (city suburb or stop),
- Cvehicle - denotes means of transport,
- Ctime, Ctimerelative, Ctimeperiod, Ctimepoint, Ctimeprep - denote time interval,
- Csourcetime - denotes source time,
- Cgoalttime - denotes goal time,
- Ccontradiction - denotes modification,
- Qall, Qtime, Qsourcecloc, Qvehicle, Qloc, Qconfirm, Qdestloc - denote type of question.

6 Conclusion

The experiments performed on the corpus of spoken utterances have confirmed the presuppositions that building a domain independent semantic hierarchy would be a critical problem during construction of computerized dialogue system. A problematic selection of abstract level of semantic representation, overlapping of semantic categories and occurrence of incoherent rules for consequent semantic interpretation enabled to build a real application, which is strictly domain dependent and uses up a small number of linguistic concepts and interpretation rules. Dialogue strategy with a strong semantic prediction is proposed.

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