Computer Interpretation of Chinese Declarative Sentences Based on Situation Semantics

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ABSTRACT

In this paper, we present a method for interpreting Chinese declarative sentences by Head-driven Phrase Structure Grammar (HPSG), which is a unification-based grammatical formalisms with situation semantics as its semantic theory. The primary reasons for using such an approach are that HPSG performs syntactic and semantic analysis in an integrated way and that situation semantics provides a realistic and sound theoretic foundation. There are two kinds of feature structures used in the semantic representations of words, phrases and sentences. The first type of feature structures is the basic type which consists of quantifier, indexed-object, circumstance, and description types. They are used to represent the meanings of lexical signs and unquantified phrasal signs. The second type of feature structure is the complex type, which is are composed of quantified-object types and quantified-circumstance types. They are applied to represent quantified phrasal signs. The process of semantic interpretation is carried out by combining the semantic representations of heads and complements/adjuncts according to their types and then generating a new semantic representation for the larger phrase. A practical system is designed with a set of examples.

1. INTRODUCTION

There are various aspects of natural language processing: syntactic processing, semantic interpretation, discourse interpretation, language generation, knowledge representation, etc.[Allen, 1987]. This paper is mainly concerned with semantic interpretation, which is used to obtain the meaning of a sentence. The primary motivations for semantic interpretation in natural language processing systems are (a). eliminating semantic anomalies, (b). resolving ambiguities, and (c). drawing inferences.

Semantic interpretation is also needed in machine translation systems which translate sentences from a source language to a target language. The more analysis is done, the less human involvement is needed. Taking advantage of the cooperation between linguistics and machine translation systems [Raskin, 1987], linguistic theories are often applied to the system to put semantic interpretation on a theoretical basis and to produce better quality of translation.

Grammar formalisms are developed by linguists to describe the string set, syntax, and semantics of a language [Shieber, 1986]. Examples include transformational grammar, definite-clause grammar, lexical-functional grammar, generalized phrase structure grammar (GPSG) [Gazdar, et al. 1985], head-driven phrase structure grammar, and so on. We consider below how semantics is dealt with by the three formalisms: modular logic grammar, generalized phrase structure grammar, and head-driven phrase structure grammar.

In Modular Logic Grammar (MLG) [McCord, 1987], Logical Form Language (LFL), some kind of second-order predicate calculus, is used as the semantic representation for natural language sentences. The process of semantic interpretation is performed by first recursively interpreting the components in the daughter list of the input syntactic item, reordering them when needed, and lastly combining them by the use of a set of modification rules to obtain the logical form for the sentence. To resolve scoping problems, reshaping operations are done to achieve the desired logical order.

The semantic theory adopted in GPSG is Montague semantics, which uses a model of the world in which linguistic elements, such as nouns and sentences, are assigned denotations (meanings), such as entities and truth-values [Sells, 1985; Hirst, 1987]. Instead of mapping linguistic expressions directly to denotations in a model, Intensional Logic (IL) is used as an intermediate representation language. A natural language sentence is translated into an expression of intensional logic that will be associated with an interpretation in the model.

Situation semantics, which is applied in HPSG, develop a theory of situations that are considered to be components of reality [Barwise and Perry, 1983]. Real situations consist of four primitives: individuals, relations, properties (relations whose arity is one), and space-time locations. Abstract situations (such as situation types, states of affairs, courses of events, and more abstract objects, event-types), which are built up by these primitives, are used to classify and represent real situations. Situation semantics adopts the relation theory of meaning, which takes linguistic meaning as a relation between the types of situations in which utterances are spoken and the types of situations that are described by those utterances. The described situation is the interpretation of an utterance on a particular In HPSG, feature structures of various types are utilized to describe the semantic contents of lexical signs, which provide the information about the primitives of the described situation. A universal principle called the Semantic Principle, accompanied with the Subcategorization Principle, is followed in combining the semantic contents of the head daughter and of the complement daughters to produce the phrasal sign's semantic content.

There are various problems in semantic interpretation, including lexical ambiguities, scoping ambiguities, referential ambiguities, noun-noun modifications, etc. Many issues are appealing to natural language processing researches. The former two problems can be partially solved by our system. Words that have multiple senses, i.e., lexical ambiguities, are the usual source of sentences' semantic ambiguity [Raskin, 1987]. Some of them may be disambiguated by using syntactic analysis. Some of them may be disambiguated by using case structures and selectional restrictions. Some of them may be disambiguated by lexical association, i.e., word-word interaction. Scoping problems are often introduced into sentences by quantifiers, negations, adverbs, coordinators, etc.

Semantic interpretation is the process of mapping a natural language sentence (or its well-formed part) to its meaning representation or intermediate representation. A sentence's complete meaning representation contains features about lexical meanings, the entities that are referred to, the relations that are explicitly or implicitly specified in the sentence and their arguments, speaker's intention, etc. Knowledge about the context and the world as well as syntactic and semantic knowledge is needed to determine these features [Grosz et al., 1986]. What we are concerned with in this paper is the intermediate representations of the sentences without considering the context.

Since the primary goal of semantic interpretation is to obtain the intermediate meaning representations of natural language sentences, a variety of meaning representation formalisms were proposed in natural language processing systems in the literature. These formalisms represent the meaning of a sentence, which can be used to generate a corresponding sentence in another language in machine translation systems.

In Wilks' Preference Semantics (PS) system [Wilks, 1986], which translates English texts into French, some semantic items are used to represent text items. Word senses are associated with semantic formulas, which are composed of primitive semantic elements. Templates are constructed from formulas for word senses of a sentence as its meaning representation. Paraplates and case-extraction/common-sense inferences are used to bind templates together in the semantic block that represents a fragmented text.

ABSITY (A Better Semantic Interpreter Than Yours) [Hirst, 1987] takes input from PARAGRAM parser and generates output in a frame representation language, FRAIL, which is used to retrieve and infer knowledge in a knowledgfe base. In ABSITY, each syntactic category has a type of FRAIL element, making use of the strong typing feature of Montague semantics. LUNAR [Woods, 1986] uses a meaning representation language MRL, a variant of the first-order predicate calculus, as the semantic representation for the meanings of sentences.

In the traditional approach to natural language processing, semantic interpretation is performed after syntactic analysis and before pragmatic processing. The separation of syntactic analysis and semantic interpretation makes the natural language processing system more modular. But such an approach may produce a lot of syntactic analysis structures that will be judged to be semantically anomalous, resulting in the inefficiency of the system.

The recent approaches to semantic interpretation [Allen, 1987] tend to integrate syntactic and semantic processing. The semantic grammars approach, as in the SOPHIE system [Tennant, 1981], parses sentences according to the semantic categories rather than the syntactic categories of words and phrases. It is easy and efficient in limited domains, but problems occur in making it more general or transportable. In the interleaved approach, as in the SHRDLU system [Tennant, 1981], the semantic interpreter is called immediately when each major syntactic constituent such as a noun phrase is proposed by the syntactic parser. Many syntactically possible constituents that are semantically anomalous can be eliminated by the semantic interpreter as soon as they are proposed by the syntactic parser.

The rule-by-rule approach, as in the ABSITY system [Hirst, 1987], has a set of semantic rules paired with a set of syntactic rules. Each time some syntactic rule is applied to construct a syntactic structure, the semantic interpretation is performed by using the semantic rule to build a semantic representation. The semantic rule is usually specified as part of the annotation on the syntactic grammar rule. Another approach called the semantically driven approach, as in the PS system [Wilks, 1986], carries out semantic interpretation directly on the input using only minimal local syntactic information. More syntactic information will be needed to help the semantic interpretation of complex sentences.

We intend to design a semantic interpretation system that is a part of the Chinese-to-English machine translation system, CEMAT. We wish to interpret the meanings of Chinese sentences, by using one of the current grammar formalisms based on some semantic theory, eliminate semantically anomalous sentences, provide semantic information for other stages (such as word selection and generation) in the machine translation system to improve the quality of translation, and hopefully deal with part of the semantic issues.

This paper consists of four additional sections. Section 2 describes the semantic representations that we take to express the meanings of sentences (and their constituents). The process of semantic interpretation and the combination operations are discussed in Section 3. Section 4 illustrates the implemented system and some examples of interpretation. Conclusions are drawn in the last section.

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2. SEMANTIC REPRESENTATION

The grammar formalism we adopt is HPSG, whose semantics is based on situation semantics. The primary reason for using HPSG is that the theory performs syntactic and semantic analysis in an integrated way. HPSG can be regarded as a theory of signs; it directly explains the connection between syntactic and semantic phenomena, e.g., subcategorization and semantic roles in the described relation [Pollard and Sag, 1987]. The adopted semantic theory seems to provide a more realistic and reasonable theoretic foundation than other theories that use formal mathematical models of the world, such as Montague semantics. From the viewpoint of design, HPSG makes use of unification so that it can be efficiently implemented by logic programs such as Prolog programs in computers, and the semantic information such as case relation and selectional restrictions can be utilized to describe relations and their roles in situation semantics.

The semantic interpretation system is supposed to take an input sign from the syntactic chart parser, in which the information from the lexicon (including the semantic information of constituents) and the syntactic information proposed by the parser (such as complements and/or adjuncts of the lexical head in a phrase) is specified. It generates the sign with its semantic information as output, when it is semantically valid. The system now can deal with declarative sentences in Chinese

2.1 Semantic Information about Signs

Signs are (partially) described by feature structures which provide phonological, syntactic, and semantic information. Semantic information specified as values for the *sem* attribute will sketch the described situation by the use of individuals and relations in it. The *sem* values consist of two attributes: the *cont* attribute which specifies the contribution of a sign to the described situation, and the *inds* attribute which specifies those restricted variables met so far. The outline of a sign's structure looks like:

```
[phon  ...,
 syn   ...,
 sem   [cont  ...,
        inds  ...].
```

The semantic content of a sign can be described by a feature structure of basic types or complex types. The former includes quantifier, indexed-object, circumstance, or description type. The latter consists of quantified-object or quantified-circumstance type. For the roles in the relations, i.e., the ways that things participate in relations (events), which are specified in the content of lexical signs, we adopt the general semantic roles in relations instead of specific roles for each relation in HPSG. This makes the case relation information to be accessed more easily by other modules of the machine translation system. The number of semantic roles ranges from the order of ten (e.g., thirteen in [Winston, 1984]) to the order of thirty (e.g., thirty-four in [Nagao et al., 1986]). Too few roles can not provide enough information to identify an event uniquely, e.g., the inability to distinguish between the instrument case of the word "以" in the sentence "他以書當枕" and the cause case of "以" in "桂林以山水聞名" [Winston, 1984]. Too many roles may result in the similarities of some cases, e.g., the case "*space-from*" and the case "*time-from*" [Nagao et al., 1986]. Based on such consideration, the following semantic roles are proposed: agent, patient, recipient, benefactive, experiencer, company, comparison, instrument, cause, purpose, result, theme, accordance, trajectory, point, source, goal, duration, advantage, inclusion, exclusion, identity, and proposition.

2.2 Basic Types of Feature Structures

The semantic contents of lexical signs and phrasal signs that are not quantified are represented by feature structures of basic types: *quantifier, indexed-object, circumstance,* and *description.*

2.2.1 Quantifier Type

The semantic content of numbers such as "一" and "十", demonstratives such as "這" and "那", and classifiers such as "個" and "塊" [Li and Thompson, 1981] is a feature structure of type *quantifier*. It is of the form:

sem [cont [qua [ATTRIBUTE VALUE]]]

where ATTRIBUTE can be one of {num, det, unit}. For example, the lexical sign for the determiner "這些" is:

```
[phon  zhei4_xie1,
 syn   [loc   [head  [maj   det,
                      type  demonstrative],
               lex   +]],
 sem   [cont  [qua   [det   zhei4_xie1]]],
 trans [these]] .
```

2.2.2 Indexed-Object Type

The use of noun phrases in natural languages depends on the context of utterances in general. They usually contribute restricted variables to the semantic content of sentences containing the phrases. The index attribute, *inds*, has as its value (Y) a feature structure of type *index* containing a variable (X) and the restrictions, *rest*, upon the variable. The agreement information includes person and domain hierarchy, *d_hier* ; see Section 4. Each indexed-object is assigned an implicit relation name according to the syntactic type of the sign. For example, the common noun involved in sortal properties with the instance role, as in "花" is represented as:

```
[phon  hua1,
 syn   [loc   [head  [maj         n,
                      type        individual,
```

```
                    adjuncts      [Poss; Det; Classifier]],
               subcat [],
               lex     +]],
sem     [cont  [ind    Y],
        inds   Y:[var X:[per      3rd,
                         d_hier   plant],
                 rest [reln   hua1,
                       inst   X]]].
```

2.2.3 Circumstance Type

Circumstances are used by HPSG to describe partially possible ways the world might be. They correspond to states of affairs in situation semantics. For verbs and adjectives, feature structures of type *circumstance* are taken as their semantic contents to describe circumstances:

```
sem    [cont   [reln          [E:RELNAME],
                ROLE          V(AGR),
                ...           ...,
                location      L],
        inds   [var   E:[PRO],
                rest  []],
               [var   L,
                rest  []]] .
```

where AGR specifies the agreement that must be satisfied by the filler of the role in the relation, and PRO indicates the property associated with the sign in the property hierarchy (see Section 4). The variable E, similar to the event variable [McCord, 1987], is used to represent the event (or state) denoted by the relation. The variable L, functioning like the indexed variable used in LFL [McCord, 1987], is utilized to express space-time locations in situation semantics. The following lexical signs illustrate the verb "打" :

```
[phon  da3,
```

```
syn   [loc   [head  [maj          v,
                     asp          dur; per; exp,
                     type         vtc,
                     crs          +,
                     adjuncts     [adv(manner; y-n; frequency)]],
             subcat [X2:NP2(acc), X1:NP1(nom)],
             lex    +]],
sem   [cont  [reln          [E:da3],
              agent         X1(d_hier     human),
              patient       X2(d_hier     human),
              location      L],
       inds  [var   E:[prop        action],
              rest  []],
             [var   L,
              rest  []]].
```

2.3.4 Description Type

Another type of feature structures, which is usually associated with adverbs and prepositions, is introduced to describe the event (state) or space-time location that is associated with a certain circumstance. Feature structures of this type, i.e., of *description* type, have the form:

```
sem   [cont  [reln   RELNAME,
              ROLE V(AGR),
              ...    ...,
              DESC X(PRO)],
       inds  [] .
```

where DESC can be the *event* attribute if it describes some event (state), or the *located* attribute if it describes some space-time location; and PRO will be the agreement requirement of the property of the described event (state) when DESC is *event* . The following examples show the lexical sign for "很":

```
[phon  hen3,
 syn   [loc   [head  [maj        adv,
                      adjuncts   []],
               subcat [],
               lex    +]],
 sem   [cont  [reln  hen3,
               event X(prop      stative)],
        inds  []].
```

2.3. Complex Types of Feature Structures

Quantified noun phrases such as "三朵花" and the larger phrase containing them such as "買三朵花" introduce the problems of quantification and scoping. To take them into consideration, feature structures of complex types are used to represent the semantic contents of quantified phrasal signs. They are constructed from the feature structures of basic types and divided into *quantified-object* type and *quantified-circumstance* type.

2.3.1 Quantified-Object Type

Feature structures of type *quantified-object* are formed by combining feature structures of type *quantifier*, corresponding to classifier/measure phrases [Li and Thompson, 1981], and the ones of type *indexed-object*, corresponding to nouns. For example, the semantic content of noun phrase "兩個人" will be:

```
sem   [cont  [qua   [num   liang2,
                     unit  ge5]],
             [ind   Y],
       inds  Y:[var X:[per      3rd,
                       d_hier   human],
                rest [reln  ren2,
```

```
                        inst    X]]] .
```

2.3.2 Quantified-Circumstance Type

A feature structure of the *quantified-circumstance* type consists of two attributes: the *quant* attribute, whose value is a feature structure of type *quantified-object*, and the *scope* attribute, whose value is a feature structure of type *circumstance* or *quantified-circumstance*. The verb phrase "兩個人逃走", for instance, has the following semantic content:

```
sem   [cont  [quant [qua   [num   liang2,
                            unit  ge5]],
                    [ind   Y]],
             [scope [reln         [E:tao2_zou3],
                     agent        X:[per       3rd,
                                     d_hier    human],
                     location     L]],
       inds  [var   E:[prop       moving],
              rest  []],
             [var   L,
              rest  []],
             Y:[var X:[per        3rd,
                       d_hier     human],
                rest [reln  ren2,
                      inst  X]]] .
```

3. INTERPRETATION SCHEME

Our system will construct the semantic representation of a sign according to its syntactic information such as its complements and/or adjuncts and its semantic information such as the types of semantic representations of its constituents. Additional relevant information such as agreement features will be unified.

Combination operations combine the semantic representations of the constituents (such as the head, complements, and adjuncts) in some systematic ways to produce the semantic representation of the whole sign. The result of combination is reflected by the values in the *cont* attribute and the *inds* attribute.

3.1 Combining Heads with Complements

In general, the lexical heads except nouns of phrases, such as verbs, adjectives, and prepositions, characterize the described situation with relations that take place in it. The complements of these heads, such as noun phrases, verb phrases, and prepositional phrases, will provide information about the fillers of the roles in the relations described by lexical heads. According to the types of feature structures in the semantic contents of the head and its complement, the following steps of interpretation are taken:

- *Combining the circumstance or description type with the indexed-object type:*

When the semantic content of the head is a feature structure of type *circumstance* (e.g., for verbs) or *description* (e.g., for prepositions) and that of the head's complement is of type *indexed-object* (e.g., for noun phrases), the restricted variable in the complement's content is unified (including agreement information) with the corresponding role in the relation specified by the head. The *inds* values of the head and the complement are collected together. For example, the verb phrase "買花" has the following semantic content:

```
sem     [cont   [reln           [E:mai3],
                 agent          X1(d_hier     human),
                 patient        X:[per        3rd,
                                   d_hier     plant],
                 location       L],
         inds   [var    E:[prop        dative],  rest   []],
                [var    L,  rest       []],
                Y:[var  X:[per         3rd,
                           d_hier      plant],
```

```
            rest [reln   hua1,
                  inst   X]]] .
```

- *Combining the circumstance type with the description type:*

In this case, the head with the content of type *circumstance*, e.g., a verb, subcategorizes for a complement whose content is of type *description* (e.g., a prepositional phrase), and whose content has combined with its constituent's content (e.g., the noun phrase in the prepositional phrase). The operation described in the above paragraph is also applicable to deal with this case. The following examples show the semantic content of the verb phrase "把 花 給":

```
sem    [cont   [reln         [E:gei3],
                agent        X1(d_hier    human),
                recipient    X2(d_hier    animate),
                patient      X:[per       3rd,
                                 d_hier   plant],
                location     L],
        inds   [var    E:[prop        dative],
                rest   []],
               [var    L, rest []],
               Y:[var  X:[per         3rd,
                          d_hier      plant],
                  rest [reln   hua1,
                        inst   X]]] .
```

- *Combining the circumstance type with the quantified-object type:*

When the head's content is of type *circumstance* (or *quantified-circumstance*) and the associated complement's content is of type *quantified-object*, e.g., a quantified noun phrase, a feature structure of type *quantified-circumstance* is built from them as the semantic representation of the whole phrase. The corresponding variables are unified. The *inds* values are also collected. For instance, from the verb "喜歡" and the noun phrase "一個人", the semantic content of the verb phrase "喜歡一個人" can be constructed as:

```
sem    [cont   [quant [qua    [num   yi1,
                                unit   ge5]],
                       [ind     Y]],
               [scope [reln            [E:xi3_huan1],
                       experiencer     X1(d_hier       human),
                       patient         X:[per          3rd,

                                          d_hier       human],
                       location        L],
        inds   [var    E:[prop         mood],
                rest   []],
               [var    L,  rest[]],
               Y:[var  X:[per          3rd,
                          d_hier       human],
                  rest [reln    ren2,
                        inst    X]]] .
```

• *Combining the circumstance or description type with the circumstance type:*

When we want to combine a head having a content of type *circumstance* or *description* with a complement having a content of type *circumstance*, we fill the role in the relation described by the head with the semantic content of the complement and collect indices. For example, the verb "打 算" is combined with the complement "逃走" resulting in the semantic content of "打算逃走":

```
sem    [cont   [reln          [E1:da3_suan4],
                agent         X1 (d_hier      human),
```

```
            proposition   [reln       [E2:tao2_zou3],
                           agent      V1(d_hier     animal),
                           location   L2:[prop      moving],
            location      L1],
      inds   [var  E1:[prop      feeling], rest  []],
             [var  L1,     rest   []],
             [var  E2:[prop      moving],      rest    []],
             [var  L2,     rest   []]] .
```

3.2 Combining Heads with Adjuncts

Different actions of interpretation are taken to deal with the heads and their adjuncts in Chinese in which the adjuncts of nouns may be adjectives, classifier/measure phrases, associative phrases, and relative clauses [Li and Thompson, 1981]; and verbs' adjuncts can be prepositional phrases, adverb phrases or verb phrases.

- *Combining the quantifier type with the quantifier type:*

When the semantic contents of the head and its adjunct are both feature structures of type *quantifier* (e.g., in a classifier/measure phrase), we just take the set union of the *qua* values as the new semantic content. For example,the content of "三塊" is produced as:

```
      sem    [cont   [qua    [num   san1,
                              unit   kuai4]]] .
```

- *Combining the indexed-object type with the quantifier type:*

In this case, we form a feature structure of type *quantified-object* by joining the head's content which is of type *index-object* with the adjunct's content which is of type *quantifier*. The content of "三塊蛋糕" is represented as follows:

```
      sem    [cont   [qua    [num   san1,
```

```
                unit     kuai4]],
            [ind     Y],
      inds  Y:[var  X:[per          3rd,
                       d_hier       food],
              rest [reln   dan4_gao1,
                   inst    X]]] .
```

- *Combining the indexed-object type with the indexed-object type:*

The associative phrase introduces an adjunct having the content of type *indexed-object* to a head with the content of the same type. A relation with the name *associate* is created to relate the two restricted variables which appear in the contents. This relation will be added to the restrictions upon the variable specified in the head's content. At last indices-collecting is performed. For instance, from the contents of "我" and "蛋糕", we have the content of "我的蛋糕":

```
sem   [cont  [ind    Y1],
       inds  Y1:[var     X1:[per      3rd,
                             d_hier   food],
               rest      [reln   dan4_gao1,
                          inst   X1],
                         [reln   associate,
                          associated    X1:[per      3rd,
                                            d_hier   food],
                          associative   X2:[per      1st,

                                            d_hier   human]]],
             Y2:[var     X2:[per      1st,
                             d_hier   human],
               rest      [reln        referring,
```

```
                    referred      X2,
                    referent      speaker]]] .
```

- *Combining the indexed-object type with the circumstance type or combining the circumstance type with the description type:*

This is the case where the head such as a noun is to be combined with an adjunct such as an adjective or a relative clause; or the case where the head like a verb is to be combined with an adjunct like an adverb or a prepositional phrase. During the process of interpretation, the restricted variable specified in the head's content or the previous restriction upon the variable in the content of type *circumstance* is unified with the corresponding role in the relation specified in the adjunct's content, as well as agreement information. Then the relation is asserted as a new restriction upon the variable. The *inds* values are collected. For example, when the predicative adjective "漂亮" is combined with the adjunct "很", the predicative adjective phrase "很漂亮" has the content:

```
sem   [cont  [reln        [E:piao4_liang4],
              patient     X1(d_hier    concrete),
              location    L],
       inds  [var   E:[prop        stative],
              rest  [reln   hen3,
                     event  E:[prop       stative]]],
             [var    L,
              rest  []]] .
```

- *Combining the circumstance type with the circumstance type:*

When the semantic contents of the head and the adjunct are both of type *circumstance*, we just add the relation specified in the adjunt's content to the restrictions upon the variable specified in the head's content, and collect indices together. This kind of combination is used to handle serial verb constructions in Chinese [Li and Thompson, 1981]. For instance, the content of "買票進去" (taking "進去" as the head) is:

```
sem   [cont  [reln          [E2:jin4_qu4],
              agent          V1(d_hier     animal),
              location       L2],
       inds  [var   E2:[prop      moving],
              rest  [reln         [E1:mai3],
                     agent        X1(d_hier     human),
                     patient      X:[per        3rd,
                                     d_hier     amusement],
                     location     L1]],
             [var   L2,    rest   []],
             [var   E1:[prop      dative],      rest    []],
             [var   L1,    rest   []],
             Y:[var X:[per        3rd,
                     d_hier amusement],
               rest [reln  piao4,  inst    X]]] .
```

3.3 Interpretation Process

The whole process of semantic interpretation is that given a syntactically analyzed sign in which the head and its associated complements and adjuncts have been specified, the head's content is first successively combined with each complement from the more oblique complement to the less oblique one, and then successively combined with every adjunct. In each time the combination operations are taken according to the principles given in the previous section, and the results of interpretation are passed to the next combination stage.

For example, the interpretation process of the sentence "李四常上台北" will begin with the main verb "上" and takes nouns "台北" and "李四" as complements, the adverb "常" as an adjunct. After combining "上" with "台北", "李四" and "常", the sentence "李四常上台北" has the following forms:

```
sem    [cont   [reln          [E:shang4],
                agent         X1:[per       3rd,
                                  d_hier    human],
                goal          X2:[per       3rd,
                                  d_hier    space],
                location      L],
        inds   [var    E:[prop        active],
                rest   [reln   chang2,
                        event  E:[prop      active]]],
               [var    L,
                rest   []],
               Y2:[var        X2:[per       3rd,
                                  d_hier    space],
                   rest       [reln         naming,
                               named        X2,
                               name         tai2_bei3]],
               Y1:[var        X1:[per       3rd,
                                  d_hier    human],
                   rest       [reln         naming,
                               named        X1,
                               name         li3_si4]]] .
```

4. IMPLEMENTATION AND DISCUSSION

The semantic interpretation system is implemented on the Quintus Prolog system under VMS that is installed on a VAX 780 computer. Some data structures are defined for representations, and interpretation rules are written as Prolog programs. Examples will be given to show the results of semantic interpretation.

The type hierarchy expresses knowledge about the structure of the things that it describes. Knowledge of this kind is useful for describing the relationships between different things, e.g., what kind of objects that can play a certain role in some relation, or what kind of relations that a particular relation can describe (modify) it.

Two type hierarchies are utilized by the semantic interpretation system. The domain hierarchy is used to classify the objects, to which nouns correspond. Nouns may represent objects that are of type CONCRETE, including subtypes HUMAN, PLANT, NATURE, etc., or of type ABSTRACT, which are divided into TIME, SPACE, and CONCEPT types. Verbs are classified by another type hierarchy, the property hierarchy, according to the relations are described by them. They may describe states (i.e., of type STATIVE) or describe events (i.e., of type ACTIVE).

The information about type hierarchies is included in the agreement information of restricted variables which are associated with nouns and verbs in their semantic contents. Vaiables are unified with other restricted variables or feature structures only when their corresponding agreement information can be unified together. After successful unification, they all have the same values (variables or feature structures) with the same agreement information; otherwise, the unification fails on uncompatible values for some features.

For simplification and succinctness, only those parts that are related with semantic interpretation are specified in a sign during implementation. A feature structure is represented by a list with the feature name as the first element and the feature value as the second one. The variable and its agreement information are also put in a list. For example, the sign for "李四" is represented by the following list:

```
[li3_si4,
  [sem, [[cont, [ind,  Y]],
         [inds, [Y,   [var,  [X,    [[per, 3],    [d_hier,   human]]]],
                      [rest, [[reln, naming],
                              [named,     X],
                              [name,      li3_si4]]]]]]]] .
```

The semantic interpretation system inputs a list representing the sign that is supposed to be provided by the parser, and outputs a list that represents the input sign including its semantic representation. If the sign is semantically ill-formed, the system rejects it and informs the parser.

According to the types of feature structures appearing in semantic contents, various interpretation procedures are fired to combine the semantic information about the heads with that about the complements/adjuncts so as to build new semantic representations. The sentences listed below can be interpreted by our system currently.

1.李四常上台北。
2.李四把筆給我。
3.李四給我一支筆。
4.他去理髮。
5.學校來了兩個人。
6.他很漂亮。
7.李四替媽媽買紅花。
8.他一定不來。
9.他不一定來。
10.他是個有錢人。
11.喜歡你的是我。
12.門打開了。
13.門外有一座高山°
14.開發中國家的人民的生活水準普遍不高。
15.我昨天買票進去看電影。
16.他來的時候,我已經做完功課了。

As for the scoping problem, the portion of a sentence that follows some element such as an adverb is in the scope of that element [Li and Thompson, 1981]. Thus the sentence " 他一定不來" is interpreted as:

sem [cont [reln [E:lai2],

agent X:[per 3rd,

d_hier human],

locaiton L],

inds [var E:[prop active],

rest [reln yi2_ding4,

event [reln bu4,

event E:[prop active]]:[prop active]]],

[var L,

rest []],

Y:[var X:[per 3rd,

d_hier human],

rest [reln referring,

referred X,

referent spoken]]] ,

where the adverb "一定" has "不" in its scope, while the sentence "他不一定來" has the semantic representation:

sem [cont [reln [E:lai2],

agent X:[per 3rd,

d_hier human],

locaiton L],

inds [var E:[prop active],

rest [reln bu4,

event [reln yi2_ding4,

event E:[prop active]]:[prop active]]],

[var L, rest []],

Y:[var X:[per 3rd,

d_hier human],

rest [reln referring,

referred X,

referent spoken]]] ,

where the adverb "不" includes "一定" in its scope.

5. CONCLUSIONS

In the work that we developed, Chinese sentences are interpreted as feature structures by the use of various interpretation rules. These feature structures sketch the situations, which are described by the sentences, in terms of relations, space-time locations, and individuals that appear in the described situations. The interpretation rules, following HPSG, are devoted to combining the semantic information about heads with the one about complements/adjuncts. The implemented system can eliminate semantically anomalous sentences by means of unification on agreement information, partially interpret the sentences and handle some semantic issues.

Our semantic interpretation system allows partial semantic analysis of sentences. Since the system is compositional, the meaning of the whole is systematically and incrementally constructed from the meanings of the parts. When a partial syntactic analysis of a sentence (e.g., a verb phrase) is obtained, we can form the semantic representation of that part if such a representation is semantically valid. For example, from the verb phrase "買花" in the sentence "李四買花", we know the information about the filler (i.e., "花") of the patient role in the relation "買". The determination of such partial semantic analysis does not have to be postponed until the whole syntactic analysis of the sentence is completed.

Some lexical ambiguities are resolved by having a distinct sign for each word sense of the ambiguous word. For example, the "call" sense of the word "叫", as in the sentence "我叫他", is assigned to the lexical sign that subcategorizes for a noun phrase filling the patient role in the relation "*call_jiao4*". And the "cause" sense of "叫", as in the sentence "這件事情叫我很難過", appears in the sign which needs a clause as the complement to fill the proposition role in the relation "*cause_jiao4*". According to the complements to be combined, the correct word sense is selected.

This paper has only proposed a preliminary application of HPSG, which is based on situation semantics, to the semantic interpretation of Chinese declarative sentences. Further researches would be concerned with anaphoric reference involving the discourse context, with other syntactic constructions involving other parts of speech, with inference involving world knowledge, and so on.

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