

Object Oriented Concept Representation

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Abstract

Concept representation is a key to natural language understanding. Several strategies have previously been proposed. But many of them have been confined to illustrations in text books rather than been actually implemented in large scale natural language systems. We propose a concept representation strategy that treats each "concept" as an object. Manipulating the relationships among the concepts are considered as operating on the corresponding objects. We find that this representation not only is convenient in consolidating our view on "concepts", but can be readily implemented using an object oriented language such as C++.

1. Introduction

Several representations (cf. [1-8]) have been proposed for syntactic and semantic analysis in natural language processing. But few of them have actually been implemented in real world NL systems. We propose a concept representation scheme that treats each "concept" as an "object". Manipulating the relationships among the concepts are considered as operating on the corresponding objects. The idea of such representation schemes can be used in all NL related systems. Throughout this paper we shall illustrate the basic idea by

way of an English-to-Chinese machine translation (MT) system.

Representing concepts as objects not only is convenient in consolidating our view on "concepts", such a representation can be readily implemented using an object oriented language such as C++. However, our approach as described in this paper should be viewed only as "object oriented analysis". Our usage of the words "objects" and "inheritance" is more on a conceptual level and does not necessarily correspond exactly to the same terms in the C++ language. The reader should decide for themselves the best strategies for actual implementation. We believe that the idea of this representation scheme is quite natural and useful for machine translation system (which is currently implemented in our own lab). Nevertheless, its full potential is yet to be discovered through more real world experiments.

In our approach, every word in either English or Chinese can be considered as a concept. Such a concept will be modeled by an object. We intentionally set aside the question on what a "primitive" concept is, though certain concepts are indeed composed from other concepts (many of which can be "inherited from" or "reduced to" others). The reason is three folds. First, many complicated concepts have already established their own identities in our common sense and should be treated as a single object. Any further reduction into more primitive concepts would only create additional burden in our

inferencing process. Examples of these words are "sightseeing", "space project". Basically, these words serve as indices linking us to the complicated descriptions behind them. These descriptions and any other related indices will be contained within their objects. Secondly, the input-output relationships we shall use to describe a concept have absolutely no bearing on whether a concept is primitive or composite. Thirdly, we believe that the reason for creating the so-called primitive concepts is mainly for efficient memory (space) utilization such as to reduce the amount of descriptions for each concept. Such a concern is not imperative in modern computing and can always be handled through inheritance in later stages of our system development.

2. Concept Objects

A concept object contains the descriptions of the concept itself as well as the descriptions about the relationships of events related to the concept. We shall first illustrate this using a simple example from an English-to-Chinese MT system.

Consider the indefinite article "a" for example. The translation of the phrase "a + noun" into Chinese normally requires additional quantifiers inserted between "a" and the "noun". There are several hundred quantifiers in Chinese and each is associated with a particular type of noun. Such a quantifier-noun association can best be described in a table. Thus, we can imagine that there is an object representing the article "a" and inside the object, there is a "quantifier-noun" association table. The translation of "a + noun" can then be accomplished by passing message about the type of the noun following "a" to the object representing "a".

In the above example one only has to classify the types of nouns and associate different quantifiers with them. In general, the description in the table might

contain more abstract items such as "current event" and "expected event"; or, the information could be too complex to be stored in a simple table and we need to "compose" the required information through additional inferencing and calculation. To implement this we need to first symbolize our description about events. Such a description will be discussed more in detail in Section 4. For simplicity of discussion we shall concentrate on those descriptions based on association tables in this paper.

Now, assume we have symbolic descriptions about various events and such descriptions have been stored in the computer's memory. We now illustrate our descriptions about a more complex word object, "honest".

As far as the computer is concerned, without additional information, this word is just a sequence of alphabets. Our approach to enrich the computer's knowledge is first to provide some definitions of the word "honest" by synonymous words or phrases such as those used in a dictionary and then to specify certain input-output relationships related to "honest". We believe that this latter approach is crucial in that it creates the infrastructure necessary for us to represent and to understand the meaning of the word. Furthermore, it is in this approach where a lot of common sense can be naturally applied in the description.

For example, one can ask many questions (as inputs) about what an honest person would react under different situations. Theoretically speaking, a computer that "understands" the word "honest" should be able to output a common sense answer. For example, an answer to the question:

"What if he finds a parcel on the street?"

could be:

"He would pick up the parcel and hand it over to the police";

an answer to another question:

"Would he cheat in an exam?"

could be simply: "No!"

We believe what we need to store in the computer is a description of the effects of being honest. Hence, we can store a table listing (abstractly) all relevant situations on one side and their corresponding common sense reactions on the other side. Our ability to represent the concept "honest" satisfactory has to do with the following three factors:

- (1) our ability to symbolize the relevant situations.
- (2) the number of relevant situations (through common sense).
- (3) the amount of effort we spent on describing the situations in (2) about the concept "honest".

In our next example we study the translation of the phrase "to make room for" into Chinese. Consider the following three sentences:

- (1) He moves the motor cycle away to make room for his car.
- (2) Big trucks are forbidden on this road to make room for small cars.
- (3) They tear down the old building to make room for a new road.

In each sentence "to make room for" has an implied (common sense) connotation. In the first sentence, the person wants to park his car. In the second sentence, the road would only allow small cars to pass. In the third sentence, they want to build a new road. Although it is a common practice in English in these cases not to mention the "implied" meaning (since it is already well understood by everyone), a proper Chinese translation in those cases would normally require that such implications be spelled out. Thus, the translation of "to make room for" into Chinese relies heavily on the background information. Therefore, the ability to represent the background events and to make out (or compute) the expected events is crucial for appropriate machine translation.

In the next section we concentrate on the concept objects useful for machine translation. Our classification of objects is mainly based on syntactic analysis. The semantic analysis is largely carried out through message passing among the objects.

3. Grammatical Classification of Objects

We shall use machine translation as an example to illustrate a possible implementation of concept objects. Based on structural analysis, we divide the basic objects into the following groups: (1) determiner objects; (2) noun objects; (3) verb objects; (4) modifier objects; and (5) idiomatic phrase objects. Besides these "static objects" we also have "dynamic objects" that are created during the process of sentence analysis such as noun phrase objects, verb phrase objects and sentence objects.

In the last section we have already seen how to describe the determiner object "a". In most cases, a simple association table storing the relationships between the determiner and the following noun would be sufficient for the determiner object as illustrated before. We should note that determiner objects are important for translation into Chinese.

A modifier could be either an adverb or an adjective such as the word "honest" described in the last section. Basically, we need to describe the types of nouns or verbs it can modify, the possible effects of this modifier such as how it would affect the noun object or the verb object it modifies, or what reaction would be produced after the noun with this attribute has been acted on.

The description about a verb usually involves its agents and thematic objects (in its literal sense). One needs to list what types of agents and thematic objects this verb can have, the various cause-effect events related to this verb. Take sentence (1) in the last section for

example. In the verb object "move" we need to state the expected events after something has been "moved". After the motorcycle has been moved away the person could do the following:

- (1) use (drive) the motorcycle.
- (2) use the space originally occupied by the motorcycle for something else.
- (3) do something to the motorcycle (such as fixing it).

These expected events should be obtained through common sense reasoning and its description should be as abstract as possible. For example, one could describe the event as:

(person, move, vehicle)

and its expected events as:

- (1) (person, use, vehicle)
- (2) (person, use, space occupied by the vehicle)
- (3) (person, do, vehicle)

The description about a noun can be broken down into two parts: (1) the first part deals with the attributes of the noun itself; (2) the second part is centered around the most common actions that the noun can exert or those that are taken against this noun (namely, what we can do to this noun). We shall focus our description on the second part.

In the case of a car, the possible actions taken on the car are: drive, wash, fix, move, park, trade and etc. In the last section the phrase "to make room for" tries to connect the above three possible events with possible actions that can take on the object "car". An event pattern matching would eliminate events (1) and (3); since they are related to the motorcycle and thus, cannot match with any action related to the car. Now, event (2) would possibly match with the actions: wash, fix and park. Suppose, in addition, the action "wash" requires the background information that the car is dirty and the action "fix" requires the information that something is wrong

with the car. When the background provides no such information, then the action "park" would be most probable and thus, be chosen eventually. If instead, we are translating the sentence: "They move the car from the car wash to make room for another car", then the expected event would become

(2') (person, wash, another car)

and the possible action matched with the second car would be "wash".

An idiomatic phrase very often can be regarded as a verb, a noun or a modifier. In translation, an idiomatic phrase in one language could correspond to a verb, a noun, a modifier or a phrase in the other language or vice versa. For example, "make room for" or "be reduced to" could be regarded as a transitive verb; "sort of" could be regarded as an adverb. Thus, it can be reduced to one of the above objects.

A sentence object normally contains the thematic roles in a sentence. Each such description can be regarded as an event. It usually takes the following form:

(agent, verb, thematic object, instrument, time, place)

where irrelevant component can be eliminated or ignored.

The interactions among different grammatical objects will be discussed at the end of Section 6.

4. Object Organization

As much as there is freedom in defining concept objects, one needs to create and arrange them carefully in order to take full advantage of this conceptual structure. As an illustration, we shall discuss the organization of various concept objects in the MT system.

In C++, similar objects are placed inside one module and inheritance relationships are created among them. Our word concepts can also be grouped according to synonyms. One can pick a popular word from each synonymous word group as its representative. A detailed description for this word can then be inherited by others in the same group. Furthermore, one can classify words according to the synonymous relation and label each word in the same synonymous group by its "representative word" as its "word sense". These word labels serve the same role as regular semantic labels. Such a strategy is particularly convenient in machine translation.

Since the usage of synonymous words depends heavily on the context, we could use representative words in an intermediate stage in translation. This will make it easier to test the MT system whether it has chosen the "correct" word sense without worrying about exactly which word it has chosen. More appropriate words for the current context can be replaced through operations on the representative word objects described below. For example, there are many words which are synonymous to "reduce" such as: deduct, lessen, abate, cut, lower, though the use of each of them is restricted to its own special context. We can label all of them by "reduce" as the basic word sense. On the other hand, there are also quite a number of synonymous words in Chinese with the meaning "reduce". We could put these Chinese synonymous words into the same group of English words synonymous to "reduce". All of these word concepts will inherit the object "reduce". Thus, by matching with the current context, we can choose the appropriate Chinese translation for any English word in the group for "reduce".

Another advantage of having both English and Chinese synonymous words in the same group is that the above process of translating English to Chinese can be easily reversed so that, analogously, one can choose the appropriate English translation for any Chinese word in the synonymous group of "reduce". Thus, the

representative word "reduce" serves only as a concept "label", which is language independent.

5. Event Objects and Query Processing

An event object contains the description about one or a collection of events. A sentence object contains the events related to one sentence and a paragraph object contains the events related to one paragraph and so forth. An event object should also contain the cause-effect associated events. An example was illustrated in the event "He moves the motorcycle away" in Section 3. This is where common sense can direct us to concentrate on only a few possibilities. It greatly reduces the search effort and enhances the efficiency. Event association is a powerful function of the event object as mentioned in examples of Section 3.

For events happened up to the current sentence, we can store them (or their related indices) in the "background object". To make common sense reasoning we shall construct event matching template and consider the proximity between two events.

The process of making inferences can be considered as message passing among various objects. Each object can send out queries or answers (information). These processes are often asynchronous. In general we need to consider the following items:

- (1) query formalization: a free form query would be most desirable, but we envision that in the initial stage, restricted queries would be more effective.
- (2) the ability of an object to answer queries: this is the same as to recognize which piece of information is missing.
- (3) the ability of an object to form queries

We now discuss the above in detail. The interaction among the different grammatical objects in a sentence can be set as follows: first of all, the sentence object is created dynamically as a central message clearing house. Each word object in a sentence can pass message to other objects as required by its internal description. Such a message could be either a query or an answer. For example, an adjective object would ask the sentence object which noun object it modifies. A verb object would ask the sentence object what its agent and thematic object are. If certain background information is required in such a translation a query would also be formed and passed to the background object.

In order to accomplish this one need to define the structure of a query as well as what constitutes an answer. Since a complete answer often is not readily available by asking just one object, subsequent queries will be formed to obtain additional information from other objects. To avoid gratuitous effort, one has to set a limit on the number of subsequent queries that can be formed following an initial query since the knowledge-base as a whole might not contain enough information to answer the initial query. To equip the computer with the ability to recognize that current information is not sufficient is essential for building a learning system in automatic knowledge acquisition.

The amount of information contained in the background object varies a lot from system to system. In general, adding information to the background object is like painting in a big picture. One has to decide what items to be included that are useful for future reference. The "order" among various items could be arbitrary or some relations could form a sort of directed graph. Whenever such an ordering is important proper scheduling is required to produce a logical event sequence. One thing that could always be included is the sentence objects for the last, say ten, sentences, or even paragraph objects.

6. Conclusion

As illustrated by the synonymous group of "reduce" for both English and Chinese, there seems to be a way to represent concept objects that are language independent. A native Chinese speaker may want to symbolize the concept objects based on Chinese words or phrases and supplement these with cultural dependent expressions (those that are hard to be translated) in other languages like English, French or Japanese. A native English speaker might start with English based concept objects. A general guideline is that the meaning of each concept constituting an object should be relatively unique. If a word has several different meanings then each such usage should form an object by itself. In this way, the "symbol" (or the language) used to represent a concept is not important at all. Two concepts symbolized in different languages are equivalent if their internal descriptions are more or less the same. Hence, they might as well be combined to share the same symbol, be it Chinese or English.

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References

- [1] R. J. Brachman and H. J. Levesque (ed.), *Readings in Knowledge Representation*, Morgan-Kaufman Publisher, Los Altos, CA, 1985.

- [2] N. Chomsky, *Syntactic Structures*, Mouton, The Hague, 1957.
- [3] N. Chomsky, *Lectures on Government and Binding*, Foris, Dordrecht, Holland, 1981.
- [4] C. J. Fillmore, "The Case for Case," in *Universals in Linguistic Theory*, edited by E. Bach and R. Harms, Holt, Rinehart, and Winston, New York, 1968.
- [5] G. G. Hendrix, E. D. Sacerdoti, D. Sagalowicz, and J. Slocum, "Developing a Natural Language Interface to Complex Data," *ACM Transactions on Database Systems*, Vol. 8, no. 3, 1978.
- [6] M. P. Marcus, *A Theory of Syntactic Recognition of Natural Language*, MIT Press, Cambridge, MA, 1980.
- [7] R. C. Schank, "Conceptual Dependency: A Theory of Natural Language Understanding," *Cognitive Psychology*, Vol. 3, no. 4, 1972.
- [8] T. Winograd, *Language as a Cognitive Process*, Volume 1: Syntax, Addison-Wesley, Reading, MA, 1983.