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# A Theme Structure Method for the Ellipsis Resolution

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## Abstract

The purpose of this paper is to solve the contextual ellipsis problem that is popular in our Chinese spoken dialogue system named *EasyNav*. A Theme Structure is proposed to describe the attentional state. Its dynamic generation feature makes it suitable to model the topic transition in user-initiative dialogues. By studying the differences and the similarities between the ellipsis and the anaphora phenomena, we extend the resolution procedure and the theory from anaphora to ellipsis. The ellipsis resolution is now based on the semantic knowledge and the discourse factor other than the syntactic information. A Theme Structure Method proposed in this paper for the ellipsis resolution is uniform to not only all kinds of elliptical elements but also some particular ellipsis types such as the fragmental ellipsis and the default ellipsis.

## 1. Introduction

Both anaphora and ellipsis account for cohesion in text and are phenomena of active study in formal and computational linguistics. The correct interpretation of the anaphora and the ellipsis is important for the Natural Language Processing (NLP). In this paper, we focus our study on the ellipsis phenomena in Chinese spoken language dialogue systems. On one hand, the ellipsis phenomena in Chinese occur more frequently than those in English. On the other hand, the frequency of occurrence of the ellipsis phenomena in the spoken language greatly exceeds that in the formal language. These two reasons imply great significance of the ellipsis resolution method in the Chinese spoken language dialogue system.

The anaphora and ellipsis resolution belongs to the analysis of the local linguistic context, whose purpose is to provide information of previous utterances for the understanding of the current utterance. While the anaphora and ellipsis resolution is supported by the dialogue system, the conversation appears more consistent and natural, and the interface appears more intelligent and user-friendly. It may contribute much to the evaluation of subjective satisfaction on the dialogue system.

We define the **Syntactic Ellipsis** as a kind of ellipsis that can be determined by the syntactic structure incompleteness or other explicit linguistic clues. The **Contextual Ellipsis** is defined as a kind of ellipsis that should be determined by the linguistic context. While the ellipsis that the linguists typically define and investigate [1] can be classified as the syntactic ellipsis, we find most of ellipses occurring in our dialogue system should be classified as the contextual ellipsis. There are another two specific ellipsis categories occurring in our system, which are to be defined in the following section as the fragmental ellipsis and the default ellipsis.

In this paper we propose a Theme Structure Method for the ellipsis resolution. The Theme Structure models the attentional state, which underlies the method. Its dynamic generation feature makes it suitable for the topic variation modeling in the user-initiative dialogue systems. After the analysis of differences and similarities between the ellipsis and the anaphora phenomena, we extend the theory and the procedure of anaphora resolution method to the ellipsis resolution. Different from the previous ellipsis resolution methods that mostly focus on the syntactic structure and the semantic restriction, the Theme Structure Method focuses on the semantic structure and makes use of the discourse knowledge and the domain knowledge. The method provides a uniform resolution framework to all kinds of ellipsis items, and to the specific types of the fragmental ellipsis and the default ellipsis.

The rest of the paper is organized as follows. In Section 2, we describe the Theme Structure and the Theme Structure Method. In Section 3, we define some terms and give some examples to illustrate the details of ellipsis resolution. In Section 4, the resolution algorithm will be given completely. Summaries and our future work will be discussed in Section 5 finally.

## 2. Theme structure method

The Campus Navigation System *EasyNav* [2] is a spoken dialogue system providing information about buildings, routes, offices and services inside the Tsinghua University. The conversation is of a user-initiative continuous query style. Therefore more topic variations can be observed than those in the non-user-initiative systems. Thus we introduce a Theme Structure to describe the objects, properties and relations of the current theme (i.e. the query topic) and provide a basis for the study of theme variation and reference analysis. Figure 1 is an illustration of the Theme Structure. Nodes shown as blocks are the theme items. Links that connect nodes are the theme relations, while the start and end nodes are called parent items and child items, respectively.

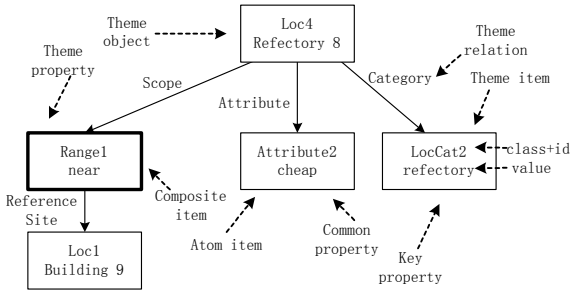


*Figure 1: Theme structure illustration.* (*The block with thick borders indicates a composite item.*)

There are 12 categories of theme items, which can be divided into two types: the atom item and the composite item. The atom item is a theme item that can represent a full meaning by itself, while the composite item is an item that needs the combination of its child items to be understood. The theme object and property correspond to the parent item and the child item of the dynamically generated theme structure respectively. The *LocCat* and the *Function* properties are key properties, while others are common ones. We assign priority level to each item category.

In [3] the discourse is modeled with three components: the linguistic structure, the intentional structure and the attentional state, while the focused spaces are proposed to describe the attentional state. In [4] the centering theory is presented and centers are used to describe the attentional state. The Theme structure has many similarities to the center and it also describes the attentional state. The Theme structure is both a discourse structure and a semantic object, but not a syntactic concept. It has the locality feature since the referent matching is only performed on the theme structure of the last utterance. It contains no intentional and task information.

Although both the theme structure and the topic forest [5] describe topics, there are great differences because the theme structure is generated dynamically during the semantic parsing period while the topic forest is pre-defined. In *EasyNav*, user naturally provides all necessary information for the query. The combinations of the information are too many to be enumerated beforehand. It is even harder to predefine which information needs to be retained when topic varies.

The anaphora resolution usually takes a *Collect-Filter-Preference* procedure [6]. The *Collecting* Step records the semantic objects occurring during the conversation into the history list. The *Filtering* Step matches the anaphora or ellipsis item with the semantic objects in the history list, which is also called the referent matching. The *Preference* Step selects one from the multiple candidates that remain after the *Filtering* Step

The ellipsis resolution in *EasyNav* applies a procedure similar to the anaphora resolution except two differences. While anaphora can be easily indicated by pronouns and noun phrases, the ellipsis is hard to be determined by linguistic clues. Thus the first difference is that the ellipsis resolution needs an **Ellipsis Detection** Step. We mark the tokens of semantic rules that can be elliptical. If there is one or some marked tokens leaving unmatched while others are all matched, a possible ellipsis is detected and an ellipsis item is to be reconstructed by the theme items in the linguistic context.

The second difference is that the *Preference* Step may have a choice of no ellipsis, which is called an **Ellipsis Preference**. Even when there is only one plausible candidate found in the context, it might not be preferred according to the discourse coherence. The *Ellipsis Detection* Step detects possible ellipses according to the semantic knowledge and the Ellipsis Preference Step further restrains the ellipses according to the discourse knowledge. These two additional steps, together with three normal steps of the anaphora resolution, constitute the ellipsis resolution procedure in *EasyNav*.

Our ellipsis resolution method is called a Theme Structure Method because it is performed on the theme structure. The feature of the method is that it makes use of the semantic knowledge, the discourse knowledge and the domain knowledge altogether to solve the contextual ellipsis problem. The domain knowledge is a kind of knowledge about the property priority level, the omissible or optional item, the value or function ellipsis, and the default value. The discourse knowledge is a kind of knowledge used to determine the continuation of the query so as to judge whether it should be referred in the Ellipsis Preference Step.

## 3. Study of ellipsis phenomena

In this section, we will study the ellipsis phenomena. On one hand, some terms are defined after the examples are studied. On the other hand, each factor that influences the ellipsis resolution is investigated so that the full resolution algorithm can be given in the next section. Because it is hard to keep both the meaning and the ellipsis phenomena when translating Chinese examples to English, we only give the translation of the phrases into English.

### 3.1. Examples and terms

Example 1: the continuous conversation.
1-a) User: 请问　计算机系学生　住在　哪里？
　　(*please, students of Dept. CST, live, where*)
1-b) Agent: 九号楼
　　(*Building 9*)
2-a) User: 附近　都有　哪些　食堂？
　　(*nearby, exist, which, refectory*)
　omitted: 九号楼 (*Building 9*)
2-b) Agent: 七、八、九食堂
　　(*Refectories 7, 8 and 9.*)
3-a) User: 哪个　食堂　的东西　比较好吃？
　　(*which, refectory, food, taste better*)
　omitted: 九号楼附近 (*near Building 9*)
3-b) Agent: 九食堂
　　(*Refectory 9.*)
4-a) User: 那　比较便宜　的呢？
　　(*well, cheaper, <particle word>*)
　omitted: 九号楼附近 (*near Building 9*); 食堂 (*refectory*)
4-b) Agent: 八食堂
　　(*Refectory 8*)

The ellipsis items indicated by the marked tokens in the semantic rules can be divided into two types, the omissible item and the optional item. The omissible item cannot be ignored while nothing is matched, but the optional item can be ignored. If the token is matched with the concept in the current utterance or in the history list, the processing of both types makes no difference. If nothing can be matched, the omissible item either will be assigned a default value to match the rule or will cause the rule fail to match, while the optional item will just be dropped and the rule can still be matched. As shown in example 1, 2-a) detects an omissible ellipsis item of *Loc*, and 3-a) detects an optional item of *Range*.

Example 2: the separate queries.
1) 计算机系　在　哪里？
　(*Dept. of CST, is at, where*)
　omitted: 系馆 (*office building*)
2) 计算机系　学生　在　哪里？
　(*Dept. of CST, students, are at, where*)
　omitted: 住 (*live*)

3) 附近　有没有　食堂？
　(*nearby, exist or not, refectory*)
　omitted: 这里 (*here*)

The **Default Ellipsis** is a kind of ellipsis that is reconstructed according to the domain knowledge instead of the context information, as shown in example 2. However if there is any relevant context information, the referent value from the context is preferred to the default value from the domain knowledge. So we do not regard the default ellipsis as a new kind of ellipsis. When an omissible item fails to match a referent in the context, it is a possible solution to assign the item a default value. Usually, a value-type item (i.e. corresponding to a value-type slot in the query frame) can be assigned a default value, while a function-type item (i.e. corresponding to a function-type slot in the query frame) cannot.

The **Fragmental Ellipsis** is a syntactically incomplete structure such as a single query word, a single noun phrase (NP) or a single adjective phrase (AP), like 4-a) in example 1. One solution to the fragmental ellipsis is to reconstruct the whole structure as a parallel structure of the last utterance and make a substitution. However there are many complex situations. The fragment may contain several words and need semantic analysis first. The fragment may be a concept newly introduced and thus need an insertion instead of a substitution. The fragment may cause a cancellation of some retained constraints. If the fragmental ellipsis is regarded as a new kind of ellipsis, it should deal with most problems of the non-fragmental ellipsis. Therefore, we extend the semantic rules to support the ellipsis of the query word so that any meaningful fragment could finally reconstruct a complete sentence.

Example 3: the continuous queries.
1) 九号楼 在 哪儿?
(*Building 9, is at, where*)
2) 到主楼 怎么走?
(*to the Main Building, how to go*)
omitted: 九号楼 (*from Building 9*)

Example 4: the continuous queries.
1) 从九号楼 到图书馆 怎么走?
(*from Building 9, to the library, how to go*)
2) 到主楼 怎么走?
(*to the Main Building, how to go*)
omitted: 九号楼 (*from Building 9*)

In the *Filtering* Step, the semantic matching condition is required to guide the comparison between the ellipsis item and the referent items. If the referent item is an object, the matching condition is the theme class consistent. If the referent item is a property, the matching condition is the theme relation consistent. As shown in examples 3 and 4, 2) detects an ellipsis of *Loc* with the relation *Source-Location* to its parent item. In example 3, 九号楼(Building 9) is matched because its class is *Loc*. In example 4, although the classes of 九号楼(Building 9) and 图书馆(the library) are both *Loc*, only 九号楼(Building 9) can be matched with the relation *Source-Location*, while 图书馆(the Library) is dropped because its relation to parent is *Dest-Location*.

### 3.2. Query with multiple constraints

Example 5: the continuous queries.
1) 三十号楼附近 有 哪些 食堂 比较好?
(*near Building 30, exist, which, refectory, better*)
2) 一号楼附近 有 哪些 食堂?
(*near Building 1, exist, which, refectory*)
omitted: none

Example 6: the continuous queries.
1) 三十号楼附近 有 哪些 食堂 比较好?
(*near Building 30, exist, which, refectory, better*)
2) 一号楼附近 有 哪些 呢?
(*near Building 1, exist, which*, *<particle word>*)
omitted: 食堂(*refectory*); 比较好(*better*)

Example 7: the continuous queries.
1) 三十号楼附近 有 哪些 食堂 比较好?
(*near Building 30, exist, which, refectory, better*)
2) 哪些 食堂 比较便宜?
(*which, refectory, cheaper*)
omitted: 三十号楼附近(*near Building 30*)

As shown in examples 5, 6 and 7, for the query with multiple constraints it needs to judge which constraint is retained. The judging needs the knowledge of the discourse coherence. Therefore, we define the query theme continuation, the retaining and the shifting according to the similar ideas in the Centering Theory [4]. The constraint corresponds to the theme property in the theme structure and thus has a priority level. We define the Retaining Priority Level as the highest priority level of the newly occurring constraints. The judging rules of the theme variation are listed below:

1. If the theme class of the parent item, or the theme relation to the parent item, is changed, the query theme shifts;
2. If there is an ellipsis of a query word or a key property, the query theme continues;
3. If the constraint set is a subset of the constraint set of the last query or it is null, the query theme shifts;
4. If all the above rules fail, the query theme retains.

The property-retaining means that the ellipsis item can be referred to as a matched referent property item in the context. We define the property-retaining rule according to the theme variation as follows, which is used at the *Ellipsis Preference* Step:

1. If the theme continues, all the properties retains;
2. If the theme retains, the property with the priority level higher than the Retaining Priority Level retains;
3. If the theme shifts, no property retains. However its being referred to as an object is still allowed.

Let's come back to the examples. The priority levels of the properties are given here: Pri(*Range*)=5, Pri(*LocCat*)=3, and Pri(*Property*)=2.

In 2) of example 5, the theme retains and the retaining priority level is 5 because the *Range* item (*near Building 1*) has the highest level. So the constraint of the *Property* item (*better*) cannot be retained. In 2) of example 5, the theme continues because of the ellipsis of the key property and all properties could be retained. In 2) of example 7, the theme retains and the retaining priority level is 2 for the *Property* item (*cheaper*) so that the constraint of the *Range* item (*near Building 30*) can be retained.

## 4. Algorithm

In Figure 2 illustrated is the full resolution algorithm of the Theme Structure Method.

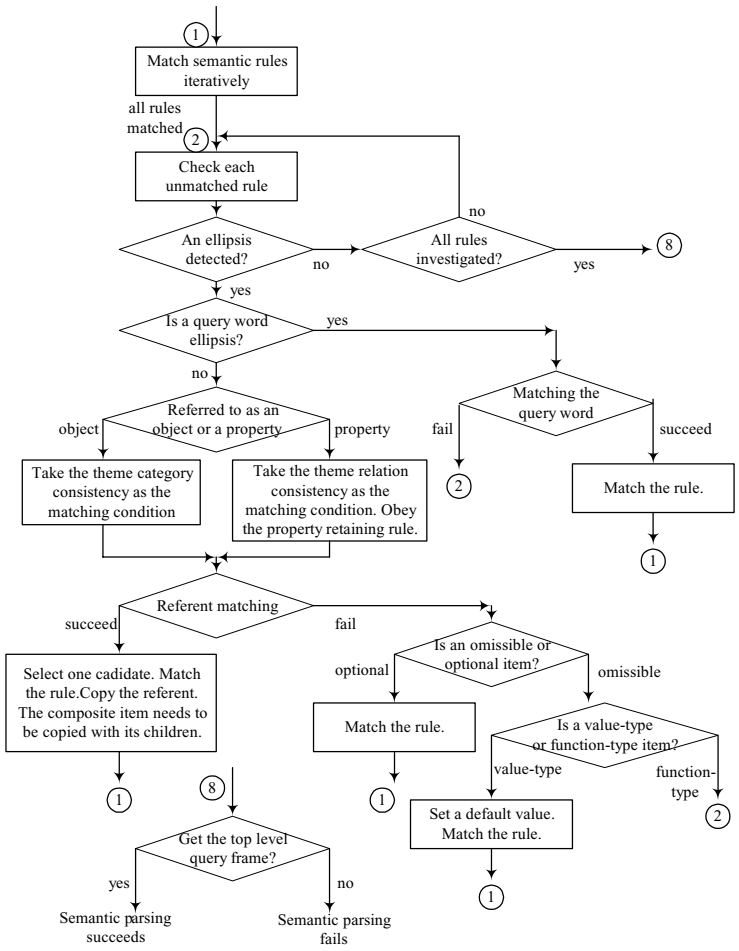


*Figure 2: The algorithm of the Theme Structure Method.*

## 5. Summary and future work

As one part of research on the Chinese spoken language dialogue system, the Theme Structure Method is presented to solve the ellipsis problem, which makes use of the semantic, discourse and task knowledge altogether. In the domain of *EasyNav*, the method provides a uniform resolution framework for all kinds of ellipsis items, and for the specific types of the fragmental ellipsis and the default ellipsis. In the preliminary tests, it is proved to be efficient and easy to be extended.

The Theme Structure Method is oriented to the theme item, which makes it more flexible than the method that is oriented to the full task tree. We will study more domains to extend the method. We will deal with the anaphora resolution and the clarification strategy in the near future.

## 6. References


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