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Labeling Chinese Pivotal Sentence with Semantic Dependency Graph

Lijuan Zheng, Yanqiu Shao and Erhong Yang
School of Information Science
Beijing Language and Culture University
No.15, Xueyuan Road, Haidian District
Beijing, China
lijuanzhengzai@126.com; yqshao@blcu.edu.cn; yerhong@blcu.edu.cn

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ABSTRACT. Semantic analysis is one of the most important and challenging topics in the field of modern linguistics and computational linguistics. However, the semantic labeling of special sentence patterns in Chinese is more difficult. In this paper, we propose a semantic annotation approach based on semantic dependency graph (SDG) and construct a corpus consisting of 30,000 sentences. Take the Chinese pivotal sentence for example, we briefly introduce the labeling methods, summarize four types of pivotal sentence and compare the results of SDG with the results of traditional dependency trees. The comparing results show that the results of SDG could annotate more necessary semantic information than traditional methods. So SDG can express the information which is more close to the meaning the sentence want to express.

Keywords: Pivotal sentence; Semantic labeling; Semantic dependency graph; Dependency trees

1. **Introduction.** Semantic analysis is one of the most challenging topics in the field of modern linguistics and computational linguistics, and it is also the major bottleneck restricting the large-scale application of language information technology at present. Especially for Chinese, due to the particularities of the language: flexible word order, lots of function words and so on, the semantic analysis of Chinese is not so easy. Furthermore, for Chinese natural language processing (NLP), the semantic labeling of special sentence patterns is tougher, such as serial-verbs sentence, pivotal sentence, subject-predicate predicate sentence, nominal predicate sentence and comparative sentence. On the one hand, it is because there are a lot of controversies about these sentence patterns in the field of linguistics; on the other hand, in NLP, generalizing these controversial issues itself is also a difficulty.

In the field of linguistics, take pivotal sentence as an example, it is a special sentence pattern in Chinese sentence patterns. As a kind of commonly used special sentence patterns, pivotal sentence has been studied for a long time and the study of pivotal sentence has achieved some accomplishments, but there are still many problems: whether the pivotal sentence is an independent sentence pattern, the classification of pivotal sentences, the standards of pivotal sentence and so on.

How to find a more effective method for the semantic labeling of these special sentence patterns in Chinese is very important for linguistics and NLP. In this paper, we propose a new semantic dependency graph (SDG) theory, and annotate about 30,000 sentences. Based on the corpus, in this paper, we focus on the study of pivotal sentences for semantic parsing, and get good results.

2. **The study of pivotal sentence in linguistics and NLP.**

2.1. **The study of pivotal sentence in linguistics.**

The achievements of the study of pivotal sentence are very rich, but the opinions of every expert are not the same. Pivotal phenomenon was mentioned in *Ma's Grammar* [1], which is the first Chinese grammar book written by a native scholar. The name of pivotal construction was first proposed in *Modern Chinese grammar* written [2] by DING Shengshu .et in 1952. Before 1952, there were a lot of grammar books discussed this phenomenon, but the only difference between them is the name: 递系式(pivotal construction) by WANG Li [3]，递谓式(pivotal construction) by LV Shuxiang [4]and so on. Though the names are different, the essence is the same: there is a nominal, and it is not only the object or predicative of the verb before, but also the subject of the word behind. The generally acknowledged definition of pivotal sentence is that the pivotal sentence is a sentence in which the pivotal phrase is the predicate or an independent sentence [5]. Pivotal phrase is the phrase that is partly overlapped by verb-object phrase and subject-predicate phrase, that is to say, it is such a phrase that the object of verb-object phrase is the subject of subject-predicate phrase. For example, the phrase "请(request)他(him)来(come)", "他(he)" is the object of "请(request)", and it is also the subject of "来(come)". We call "他(he)" pivot. In the field of linguistics, pivotal sentence can be described as "$(N_1)+V_1+N_2+V_2$". In the formula, N_1 refers to the subject of the sentence. V_1 refers to the first predicate of the sentence and we also call V_1 pivotal verb. N_2 refers to pivot, and V_2 refers to the second verb of the sentence.

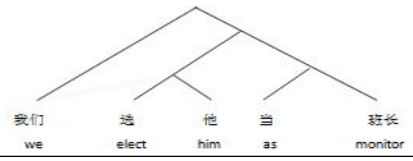
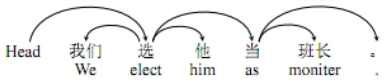
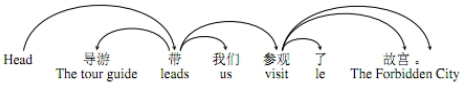
As a special sentence pattern, different expert has different opinion about the classification of pivotal sentence. According to the meanings of pivotal verbs, Lv [6] divides the pivotal construction into three types: command, approval or blame and give. Ding [2] considers that pivotal constructions can also be "有(have)" and "没有(have not)". According to the meanings of pivotal verbs, Song [7] divides them into the category of 使令(request), 帮陪(help and accompany), 有无(presence or absence), 心理活动(mental activity),推举(elect) and 称名(appellation) etc. You [8] generalizes it into 11 kinds: 使令(request),命令(order),劝令(persuasion),委托(delegation),提供(supply),推举(elect),协同(accompany), 协助(aid), 跟随(follow), 喜恶(likes and dislikes) and 有无(presence or absence)

In pivotal sentence, there are complex semantic relations between V_1,V_2 and N_2, it is difficult to determine exactly how many types. In this paper, we will not try to classify the semantic relations between V_1,V_2 and N_2 in pivotal sentence from the perspective of pure linguistics, but to study the classification of semantic relations between V_1,V_2 and N_2 in pivotal sentence for NLP.

2.2. **The study and problems of pivotal sentence in NLP.** There are a lot of studies about pivotal sentence in linguistics, but there are little studies about pivotal sentence from the perspective of NLP. Some papers have already discussed the automatic recognition of pivotal sentence in large scale of sentence annotation [9-12]. In these papers, researchers mainly put emphasis on the design of algorithm and the labeling of semantic role of V_2, and then according to the different roles, classifying the pivotal sentence. But those kinds of analysis are similar with the analysis of pivotal sentence in linguistics. They also did not break through the methods used in linguistics. In Sun's study [13] on pivotal sentence, according to the semantic roles of N_2, he generalized 35 kinds of structure patterns of pivotal sentence. Among them, there are only 7 kinds of patterns that are usually used.

For language analysis, there are two traditional methods: phrase-structure analyzing and dependency grammar analyzing. At present, the methods adopted by Chinese labeling are mainly these two methods. But it will encounter with some problems if we annotate the special sentence patterns in Chinese with these two methods, as shown in Table 1.

TABLE 1. THE SYNTACTIC PARSING OF PIVOTAL SENTENCE

Sentences	***Methods***	
	我们(we)选(elect)他(him)当(as)班长(monitor)	*导游(the tour guide)带(led)我们(us)参观(visit)了(le)故宫(the Forbidden City)*
Phrase-structure tree		
Dependency tree		

For the sentence "导游(the tour guide)带(led)我们(us)参观(visit)了(le)故宫(the Forbidden City)", when we analyze the structure by trees, some semantic relations are lost: the relations between "参观(visit)"and "我们(we)" and the relations between "参观(visit)" and "导游(the tour guide)", while these lost information are very important for understanding the whole sentence meaning. If we apply the tree analysis results into automatic question answering, when the question is "who visited the Forbidden City?", we are hard to get the answer. However, in fact, we can get the answer from the sentence information. It means that the parsing by trees is not so ideal as we expect. That is to say, there are still some flaws in analyzing the pivotal sentence with these traditional tree-structure analysis methods: 1) It is easy to describe the surface structure of a sentence,

but describing the deep semantic information of a sentence is very difficult; 2) Though they have described parts of semantic relations, the obtained semantic information is not so complete. Moreover, the lost information may be the key information, thus, it brings difficulty for language processing; 3) Due to the special of pivotal sentence, the long distance of semantic relations may occur wrong annotation.

3. **Semantic dependency graph theory.**

3.1. **Semantic dependency graph.** Semantic dependency graph is constructed based on extended dependency grammar theory [14]. Thus, SDG partially satisfies the condition of dependency grammar. The dependency structure of SDG should be: 1) Only one word in a sentence is independent, which is usually the predicate of the sentence. In most cases, the predicate is a verb or adjective; 2) Except for the predicate, each word depends directly on another word by dependency arc. There are two words connected by directed dependency arc. One is the modifier or dependent word which the arc arrow points to, and the other one is the head, father or governor word that the arc comes out from.

On the other hand, SDG is different from traditional dependency grammar in allowing more than one head on certain word and crossing of arcs, which means that in SDG, except for the root word, any other word could have more than two arc arrows point to it and the existence of crossing arcs is also allowed. In fact, by statistics of our corpus, the ratio of the former situation in real corpus is about 21.96% and the ratio of latter situation is about 17.4% [15]. SDG system aims to find all the word pairs with real semantic relations and link up each word pair with a dependency arc with a semantic label on it. Fig.1 shows an example of analysis result by using SDG. As shown in the figure, the word "妹妹 (sister)" has semantic relations with both "有(has)" and "能干(competent)", which means that "妹妹(sister)" has two heads, which does not consist with traditional dependency grammar. The semantic role of the word pair (有(have),妹妹(sister)) is belongings (Belg) and the semantic role of the word pair (能干(competent), 妹妹(sister)) is experiencer (Exp). It can be seen that there are two arrows point to the word "妹妹(sister)". Fig.2 shows an example with crossing arcs. As shown in the picture, the two arcs connecting "好(good)" and "成绩(score)" as well as "他(he)" and "我(I)" cross. This phenomenon is called non-projective which is also not reasonable for traditional semantic dependency tree (SDT). We have discussed this kind of phenomenon in another paper [15].

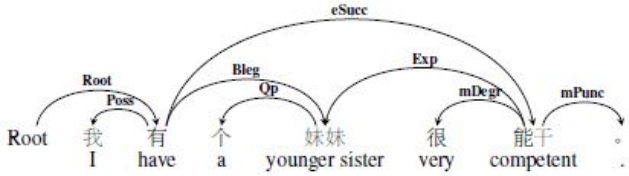


FIGURE 1. A SAMPLE SENTENCE ANNOTATED WITH MULTIPLE HEADS

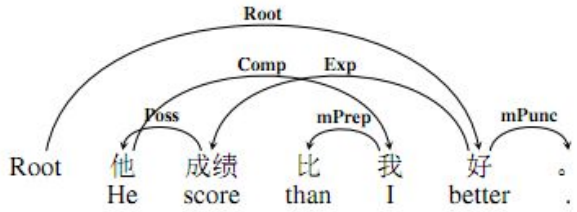


FIGURE 2. A SAMPLE SENTENCE ANNOTATED WITH CROSSING ARCS

3.2. **Comparison with other graphs.** Except for the graph described above, there are also other graphs, i.e. the syntactic dependency graph by Sun [16] and the semantic dependency graph by Ji [17]. There are some similarities between these three kinds of graphs in allowing more than one head on certain word and crossing of arcs. But they are also different from each other. Sun's [16] work is mainly related to syntactic analysis, while our work is mainly on semantics. Compared with Ji's dependency graph [17], we have different definition of semantic relations and larger number of semantic labels. Besides, JI's graph is an undirected graph while our SDG is directed graph. Furthermore, the theories based on are different, our SDG is on the basis of dependency grammar [14], parataxis net by Lu [18] and semantic relations set by HowNet [19], Lu [18] and Yuan [20]; while Ji's graph is on the basis of feature structure.

Take the sentence "他(he)性格(disposition)坚强(staunch)" as an example, by JI's theory, the analysis result is expressed by the tri-tuple: (他(he), 性格(disposition),坚强(staunch)). In the tuple, the first element refers to entity, i.e. 他(he), while the second element refers to feature, that is to say, "性格(disposition)" is one of the features of "他(he)", and the last element refers to value of feature, such as "坚强(staunch)" which is the value of feature "性格(disposition)". While by our theory, the analysis result are also tri-tuples: (坚强(staunch), 性格(disposition), Exp) and (性格(disposition), 他(he), Host). In our tri-tuple, the first element refers to the head of the two words, and the second element refers to the dependency node of the two word, in other words, "坚强(staunch)" is the head and "性格(disposition)" is the dependency node. The last element refers to the semantic relation between the head and the dependency node. Besides, in JI's theory, the second element can be Null, while this kind of phenomenon is not allowed in ours tri-tuple. To describe more vividly, we can see the analysis results in Table 2. From Table 2, we can see that as a semantic analysis theory, the presentation of semantic relations in this paper is more direct. We could use a set of semantic labels to describe different semantic relations.

TABLE 2. COMPARISON OF SDG BY JI AND SDG IN THIS PAPER

Sentences	***Methods***	
	SDG by Ji	***SDG in this paper***
他(he)性格(disposition)坚强(staunch)	*[他(he), 性格(disposition),坚强(staunch)]*	*[坚强(staunch), 性格(disposition), Exp] [性格(disposition), 他(he), Host]*
他(he)坚强(is staunch)	*[他(he), ,坚强(staunch)]*	*[坚强(staunch), 他(he), Exp]*

4. Semantic Dependency Graph Corpus.

4.1. **Corpus.** Our corpus contains more than 30,000 sentences. The sentences are from newspapers, the textbooks of primary and junior school, Sina microblog and sentences for machine translation. We have already finished the annotation of newspapers (10,068), textbooks (10,038), Sina microblog(5,000) and sentences for machine translation (4900). All of the sentences are annotated by 4 master students who all major in linguistics. To evaluate the agreement of their annotation, we employed three of them to annotate the same small corpus blindly. The small corpus includes 422 randomly selected sentences from 30,000 sentences. We evaluate agreements on the level of dependency arcs and both arcs and relations respectively. The average agreements among three pairs of annotators are 88.78% (arcs only) and 72.15% (arcs and relations). The semantic labeling is more difficult than many other corpus annotations. The agreement ratio could be accepted.

4.2. **Annotation scheme.** Our annotation unit is sentence, other than paragraph and text. From high to low, our semantic units can be divided into event chain, event, argument, concept and mark [21]. With referring to the system of parataxis network [18] and some concept of HowNet [19], by revising the set of semantic labels constantly based on the practice of annotation, finally, we have defined a set consisting of 127 semantic labels. The set can be divided into 5 parts. They are semantic roles (32), reverse relations (29), nested relations (30), event relations (19) and syntactic marks (17). Event relations refer to the syntactic relations between multiple events in compound and contracted sentences, such as supposition (eSupp), progression (eProg), adversative (eAdvt), while syntactic marks refer to the words with grammatical meaning and non-lexical meaning, such as conjunction (mConj), modal (mMod), preposition (mPrep), etc.

A reverse relation is marked when the modifier in a noun phrase is a verb. For example, for the two noun phrases “出现(appear)的(de)彗星(comet)”and “彗星(comet)的(de)出现(appear)”, apart from the opposite direction of arcs, the semantic relation between“出现(appear)”and “彗星(comet) is the same. Both refer to an experience relation. To avoid the influences of syntactic structure on semantic analysis, the semantic relation between the head word“彗星(comet)”and modifer “出现(appear)” in Fig.3(a) is reverse experiencer (r-Exp).

(a) Sample of reverse relation (b) Sample of common relation

FIGURE 3. COMPARISON OF REVERSE RELATION AND COMMON RELATION

When one event is degraded as a constituent of another event, a nested relation is marked on the dependency arc. For example, in the sentence “爷爷(grandfather)看见(see)小(little)

孙女(granddaughter)在(is)玩(play)计算机(computer) .” The underlined part is degraded as the object of “看见(see)”. A tag “d-Cont” which means degraded content role is labeled between the predicate “看见(see)” and another verb “玩(play)”. “玩(play)” is the predicate of the degraded event. Fig.4 is the annotation results.

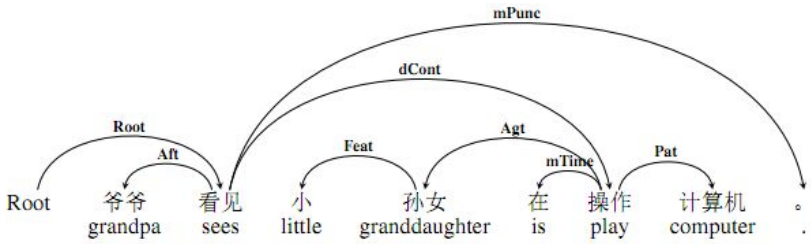


FIGURE 4. A SAMPLE SENTENCE WITH NESTED RELATIONS

5. **The semantic labeling of Chinese pivotal sentence based on SDG.**

5.1. **The labeling of pivotal sentence based on SDG.** Take the sentences in Table 1 for example, the sentence “我们(we)选(elect)他(him)当(as)班长(monitor)”, the analysis result by SDG is shown in Fig.5.

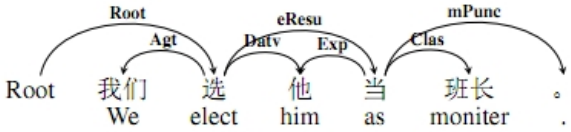


FIGURE 5. A SEMANTIC LABELING SAMPLE OF PIVOTAL SENTENCE WITH SDG

“我们(we)选(elect)他(him)” and “他(he)当(is)班长(monitor)” both are independent events that can express integrated meaning. In this sentence, two independent events make up a pivotal sentence, thus, the information expressed by the pivotal sentence is richer. “他(he)” is the object of “选(elect)” on syntactic level, and Comitative on semantic level. At the same time, “他(he)” is the subject of “当(is)”, expressing the meaning of experiencer. The labeling results of the pivotal phrase is: (选(elect), 他(him), Comt), (选(elect), 当(is),eSucc), (当(is), 他(he) Exp). The semantic dependency graph of the sentence “导游(the tour guide)带(led)我们(us)参观(visit)了(le)故宫(the Forbidden City)” is shown in Fig.6.

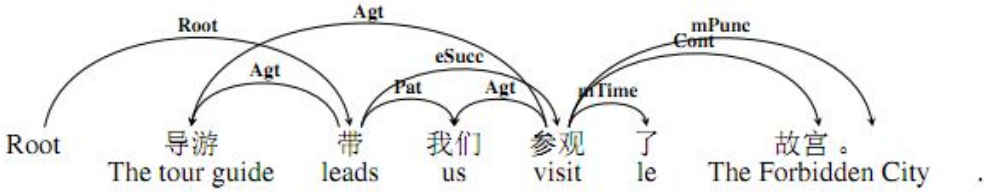


FIGURE 6. A SDG LABELING SAMPLE COMBINED PIVOTAL CONSTRUCTION WITH SERIAL-VERBS CONSTRUCTION

It is also a pivotal sentence, but this pivotal sentence is more complex than the sentence in Fig.5. We usually call this kind of pivotal sentence the sentence combined pivotal construction with serial-verbs construction. In the whole sentence, the words have semantic relations with "参观(visit)", besides the pivot "我们(us)", the subject of the whole sentence "导游(the tour guide)" also has semantic relationship with "参观(visit)", referring to agent(Agt). Thus, the subject of "参观(visit)" is made up of two parts: "我们(us)" and "导游(the tour guide)". (参观(visit),我们(we),Agt) and (参观(visit),导游(the tour guide),Agt). While SDT is applied, the analysis results are shown in Table 1. The comparison of SDT and SDG is shown in Table 3.

TABLE 3. COMPARISON OF TWO ANALYSIS RESULTS

Words pairs with semantic relations	***The analysis results of dependency trees***	***The analysis results of dependency graph***
带(led)，导游(the tour guide)	+	+
带(led)，我们(us)	+	+
带(led)，参观(visit)	+	+
参观(visit)，我们(us)	-	+
参观(visit)，导游(the tour guide)	-	+
参观(visit)，了(le)	+	+
参观(visit)，故宫(the Forbidden City)	+	+

As shown in Table.3, the effect of semantic analysis on pivotal sentences by SDT and SDG is obvious. In SDT, the semantic relations between "参观(visit)" and "导游(the tour guide)", "参观(visit) and 我们(us)"cannot be expressed, while the 2 semantic relations are very important for "参观(visit)", but the semantic relations can be exactly expressed if SDG is applied. Thus, SDG can describe more words pairs than traditional dependency trees, that is to say, it can express the information which is more close to the meaning the sentence want to express. According to the actual situation of language, SDG reflects the semantic relation between pivot and V_2.

5.2. **The pivotal sentence types based on SDG.** Though there are a lot of classifications of pivotal verbs in Linguistics, there are little classifications of pivotal verbs from the perspective of NLP, while the analysis of special sentence patterns is so important for the performance of automatic semantic labeling parsing. Referring to the pivotal verbs in all kinds of books and papers, we label the pivotal sentences in the corpus based on SDG theory, and according to the visual graphics, divide them into 4 types. The types are shown in Table 4.

From Table 4, we can see that the four types are easy to distinguish, especially the first and the second type. The pivotal words are totally different. In a sentence with the pivotal words from the first type, V_2 only has semantic relation with N_2, while in the second type, V_2 has semantic relation not only with N_2, but also N_1, the visual graphics are shown in Table 5. The pivotal words in the third and forth types may be the same, but due to the

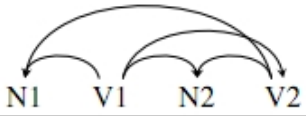
appearance of "ba" construction, the visual graphics are totally different. On the other hand, in a pivotal sentence with the form of the forth type, if we delete V_2 in the pivotal sentence, it is still an independent sentence, but it is a sentence with two objects. If we delete V_2 in the third type, it cannot be an independent sentence.

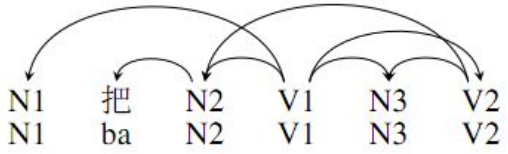
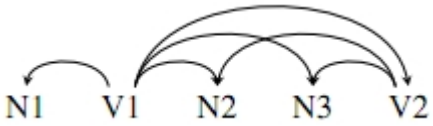
In a word, there are four types of annotation scheme of pivotal sentence with SDG, but the frequency of usage of every type is different. From 10,038 sentences, we extract 310 pivotal sentences. We make statistical analyses of those sentences, and the result of distribution of every type is shown in Table 5. The first type of sentence is most commonly used.

TABLE 4. THE SDG TYPES OF PIVOTAL SENTENCE

Types	***Representative examples***	***Representative pivotal verbs examples***
Representative pivotal sentences : $N_1+V_1+N_2+V_2$, and V2 has semantic relations only with N_2	*我们(we) 请求(ask) 您(you) 留下来(to stay)。*	*使令(request)、命令(order)、赞许(approval)、责怪(blame)、有无(presence or absence)、推举(elect)、提供(supply)、派遣(send)、请求(ask)、催逼(force)、嘱托(entrust)、培养(train) and 称呼(call) 等(etc)*
the sentence combined pivotal construction with serial-verbs construction: $N_1+V_1+N_2+V_2$, and V_2 has semantic relations both with N_2 and N_1	*妈妈(mom) 帮(help) 我(me) 打包(to pack) 行李(luggage)。*	*帮助(help)、带领(led)、陪伴(accompany)、跟随(follow)、协助(aid)、协同(accompany) 等(etc)*
N_1+把(ba) +N2+V_1+N_3+V_2; put a "ba" construction into the location between N_1 and V_1, "ba" construction put the direct object in front of V_1	*老板(boss) 把(ba) 工作(work) 扔给(throw) 他(him) 做(do)。*	*给予(give)、租借(rent or lend)、递给(pass)、讲给(speak to) 等(etc)*
$N_1+V_1+N_2+N_3+V_2$; V_1 and V_2 both have relations with N2 and N_3; if delete V_2, this is a sentence with two objects.	*我(I) 给(give) 它(it) 两(two) 片(pieces of) 面包(bread) 吃(to eat)。*	*给予(give)、租借(rent or lend)、递给(pass)、讲给(speak to) 等(etc)*

TABLE 5. THE VISUAL GRAPHICS OF THE FOUR TYPES ABOVE

Types	***Visual graphics***	***Percentage (%)***
The first type		*95.16*
The second type		*3.87*

The third type		*0.65*
The forth type		*0.32*

This kind of classification is totally different from the classifications before. The foundation is semantic relationship, other than semantic roles of N_2 and lexical meaning of V_1.

6. **Conclusions.** Pivotal sentence is a kind of commonly used special sentence patterns in Chinese, and it has been studied for a long time. Even though it has been studied for a long time in the field of linguistics, there are still some controversial questions, let alone the studies of pivotal sentence in NLP. Except the controversial questions, they will encounter more difficult questions, the definition of a widely accepted theory, an automatic system and so on. In this paper, we try to divide the pivotal sentence into several classes with clear boundaries on the basis of SDG, and finally, according to the visual graphics, we divide them into four types. This kind of generalization is similar to making rules for computer. For the building of an automatic semantic annotation system, this kind of work is very significant.

SDG is a new attempt of semantic analysis. From the analysis above, we can see that if the SDG theory is applied to the sentence semantic labeling, it can reflect whether there is a semantic relation between the two words and what the semantic relation is clearly and completely. Later, the resources labeled by SDG can be used to train to construct an automatic semantic parsing system, which could automatically label more hidden semantic relations in sentences. All of the semantic relations can be applied to the fields of question answering and information extraction etc.

Because Chinese is a language with flexible words order and it changes now and then, we cannot list all the phenomena, such as a lot of special sentence patterns and those temporary usages in real condition. So in the process of labeling, there are still some difficulties that we cannot avoid. But all of these problems will become our future study objects.

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