Annotating Chinese Noun Phrases Based on Semantic Dependency Graph

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Abstract

Annotating complicated noun phrases is difficult in semantic analysis. In this paper we investigate the annotation schemes of noun phrases in Nombank, Chinese Nombank and Sinica Treebank and propose an annotation scheme based on semantic dependency graph for Chinese noun phrases. We labeled 1830 Chinese noun phrases trying to describe the semantic relations existing between the words and propose an annotation scheme based on the investigation of the three mentioned corpora. The labeling is based on semantic dependency graph which indicates semantic relations between every two words with few restrictions. According to whether the noun phrase contains a predicate, we divide Chinese noun phrases into two categories: the ones with predicate and the ones without predicate. We find that predicates in noun phrases are more likely to be the connection of the root and other components, while in noun phrases without predicate all the words are more likely to directly modify the root.

Keywords

noun phrase; dependency graph; semantic annotation

1   Introduction

1.1 Complex Chinese Noun Phrases

F. Xing calls the complex noun phrases containing[1] verbs "NVN structure". He believes that the function of such structures is to construct nouns, and the whole phrase represents a specific event. G. Zhang[2] uses prototype theory to study the cognitive schemata of V+N structures, and puts forward the factors that influence the understanding of such phrases. Y. Gu and Y. Shen[3] think the feature of the structures like "汽车修理工" is that the verb and the internal argument are enhanced and have become a part of the whole noun phrase through the penetration function of the head. That is to say, the verb "修理"(repair) first combines with the inner argument "汽车" (automobile), and the semantics produced by them again combine with the outside element "工"(worker). Because the head of this structure is "工"(worker), its semantics will penetrate into the N+V structure and make the whole a noun.

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D. Shi[4] believes that the length of Chinese noun compound is not restricted, and at least in theory can be infinitely extended. The "N+V" structure is dynamic and capable of producing new noun phrases as long as there is a need to create new words. The composition of this compound has strong regularity, and the formation process can be described by several limited rules. Therefore, it is possible to solve this linguistic phenomenon by the generative method of formal syntax. F. Hu[5] discusses NP(V) classification methods of internal semantic relations, using relational database to describe the internal structure of NP(V). A. Fu[6] defines the complex noun phrases that contain verbs but without the auxiliary word "de" adhesive noun phrases and list three boundary conditions of NP (V): (1) a self-sufficient noun structure; (2) without structural auxiliary word "de"; (3) the direct compositions contain event verbs". H. Liu[7] examines the inner limits of modifier-head construction in terms of speech, grammar and semantics. From the perspective of linguistic typology, D. Liu[8] sums up the main syntactic types of noun phrases in modern Chinese from three aspects: word order, marker and category, through the comparison of Chinese and other languages and the synchronic and diachronic comparison of Chinese. W. Wu [9] investigates the origin, attribute and integration effect of event appellation NV structure based on the conceptual integration theory in modern Chinese.

1.2 Semantic Dependency Parsing

At present, the main methods of sentence semantic analysis can be divided into two types: shallow semantic analysis and deep semantic analysis. Semantic role labeling (SRL) is a way of shallow semantic analysis, the main purpose of which is to annotate predicate-argument structure. Since SRL mainly focuses on the predicate-argument structure, the internal semantic relations of noun phrases such as "台北国际书展" (Taipei International Book Exhibition), "西方现代音乐潮流" (modern western music trend), "心理咨询机制" (psychological counseling mechanism),"农业技术合作协议" (agriculture technique cooperation agreement) are not labeled.

Different from SQL, Semantic Dependency Parsing is a kind of deep semantic analysis, which can integrate dependency and semantic information in order to better describe the structure and the implied meaning of a sentence. Fraser0 and Hudson[11] define dependency as non-symmetric relation between two words, one of which is called governor or head and the other is called dependant or modifier. Robinson[12] sums up four axioms of dependency syntax: single parent node, connectivity, acyclic and projection.

1.3 Semantic Dependency Graph

Previous semantic dependency studies are mostly based on dependency tree analysis. However, Chinese is a kind of parataxis language with flexible word order and diversified functions of word class. In real language phenomenon there are many words depending on more than one words and that is to say there are many words having direct semantic relation with many words. The non-projective problem can not be solved with traditional dependency tree. In order to solve such problem, we use semantic dependency graph which allows multiple father nodes to describe the semantic relations that hold between two words. The result of semantic dependency graph analysis is shown in figure 1.
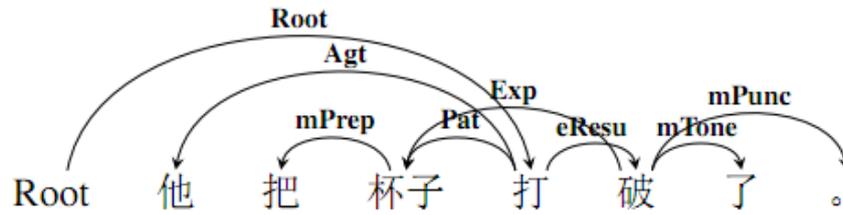
Fig. 1. Example of semantic dependency graph analysis.

From the example we can see that "杯子"(cup) has direct semantic relation with "打"(break) and "破"(broken), which means that the word "杯子"(cup) has two father nodes: "打"(break) and "破"(broken). From the point of view of semantic understanding, such phenomenon of multi father nodes is pretty important in expressing semantics. Considering the semantics of the sentence can not be described completely by dependency tree, we have partially revised the axioms in the traditional Robinson dependency theory, breaking through the limitations of the original dependency tree, and constructing dependency graphs to enhance the vitality of dependency expression through the analysis and research of a large number of linguistic facts. The dependency graph follows the following axioms:

- There is only one root of each sentence;
- Other components directly depend on a certain word;
- A component can depend on more than one words;
- If the component A directly depends on B, and C is located between A and B, then C can depend on the left components of A or the right components of the B, which means that crossing dependency arcs are allowed.

2   Distinction between Complex Noun Phrases and Verb Phrases

The research object of this paper is Chinese complex noun phrases containing predicates, and this kind of phrases are easily confused with verb phrases due to the fact that Chinese lacks inflection. The "verb" in complex noun phrases is a gerund in general sense, and this may lead to the recognition errors of "Root" of the phrase in the automatic semantic analysis. So it is of great importance to distinguish between complex noun phrases and verb phrases. The complex noun phrases in this paper meet the following four conditions:

- phrases that are composed of at least three components;
- the nominal structure is self-sufficient;
- does not contain structural auxiliary word "de";
- phrases contain event verbs;

Examples are "基础/n 设施/n 建设/v" (basic facilities construction), "农业/n技术/n合作/v协定/n"(agricultural cooperation agreement), "重大/a海洋/n污染/v事件/n处理/v专案/n小组/n" (the team of major marine pollution events). These phrases contain verbs, but the grammatical functions of the whole and the meaning of the expressions are nominal. In contrast, the grammatical function and meaning of the verb phrases such as "落实/v节能/v目标/n责任制/n" (implement energy-saving target responsibility system), "改善/v消费/v环境/n" (improve the consumption environment), "加快/v展览/v更换/v速度/n"(accelerate the speed of the

replacement of exhibition) are verbal, so they are not within the scope of our investigation. The meaning to distinguish these two structures is to determine the root node (Root) of the phrase. The root node is the central component of the whole phrase and can determine the grammatical function and semantics of the phrase. Therefore, the determination of the root node is the key step of semantic analysis of the phrase or sentence.

Y. Yuan[13] studies the structure N_1+N_2 from the perspective of grammar, finding that words like "人海"(sea of boks), "书林"(forest of books) are in accordance with the modern Chinese word order that the latter word is the head of the phrase. N_2 is the central morpheme and has the same function with the whole composition while N_1 is the restriction to N_2. For example, "cross the sea" and "walk through the forest" are permitted and the component that has the same function with the entire structure is the central component (head) in structuralism. C. T. Huang [14] also thinks that the head of Chinese compound words "N+N" is on the right. The noun on the left modifies the noun on the right, and the noun on the right determines the semantics of the whole word. For example "bed leg" is a "leg", rather than a "bed". According to the "centering theory" the head is the second noun when we use classifiers to test. The grammatical function of N+N compound is similar to that of complex noun phrases because they generally serve as subject and object, so the complex noun phrase is to follow the Chinese dominant word order. W. Zhan[15] studies the structure "NP 的 VP", and thinks that the whole function of this structure is to express referential meaning. General nouns refer to "things", but this structure refers to "events", which means that the semantic center is the last "verb", which proves the Chinese semantic center is on the right.

The semantic dependency analysis demands that each sentence or phrase can only have a "root node" (Root), and the main verb tend to be the root of the sentence, because sentences and phrases are generally built around the transitive verb and verb argument structure can reflect the syntactic and semantic characteristics of sentences and phrases as is shown in Fig. 2. But the root node of noun phrase is often the last word of the phrase, because this kind of structure is characterized by the feature that the semantic center of Chinese is on the right, so the last word in the phrase determines the semantics of the whole phrase. No matter how many components and lexical categories a complex noun phrase contains, its semantics is determined by the last word in nature. So we decided to set the last word of the phrase "root node" (Root), as shown in figure 3.
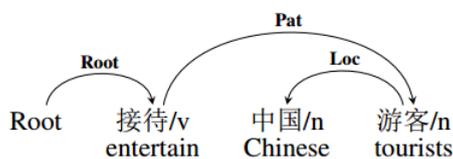

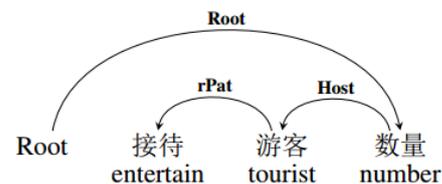**Fig.2.** Verb Phrase   **Fig.3.** Complex noun phrase

3   Semantic Relation of Chinese Noun Phrases

Semantic role refers to the function that linguistic elements perform in an event expressed by a sentence. In a sense, semantic role is a classification of semantic relations[16]. The classification of semantic roles are various in terms of standard and quantity. We investigate 2355 Chinese noun phrases based on the Beijing Language and Culture University semantic role

classification[17] and find 19 kinds of semantic relations as is shown in Table 1. The semantic relationship between these semantic roles can basically cover the complex noun phrases in real text.

Table 1. Semantic relations of complex noun phrases

	Labels	**Examples**	**Quantity**
1 Subject	1 Agent	The subject of controllable action；（总统就职）	182
	2 Experiencer	The subject of uncontrollable action；（经济发展）	136
	3 Possession	The subject of the possessive relations；（教师工资）	102
	4 Affection	The subject of uncontrollable psychological activity；（他们听到）	0
2 Object	1 Patient	The object of the subject's action；（油污清除）	731
	2 Content	The object that is involved but not changed by the action ；（资产投资）	186
	3 Product	The new object created by the subject；（汽车生产）	122
	4Datvive	Non active participants in behavior；（专家咨询）	10
	5 Link	Object of state relation；（富有弹性）	0
3Circumstance	1 Description	The description of the nature and state of the subject；（慢性疾病）	1566
	2 Location	The space of events；（边境开放）	266
	3 Manner	Attitudes and methods of subjects in events；（匿名恐吓）	182
	4 Coordinate	component having same grammatical functions；（食品生产经营）	159
	5 Scope	The scope of events；（农业适用）	109
	6 Host	Subject of attribute；（人口数量）	89

	7Reason	The cause of the events；（<u>补课</u>收费）	34
	8Tool	Tool used in events；（<u>卫星</u>传送）	33
	9Intention	The purpose of the event；（出国<u>留学</u>）	26
	10Time	Timing of events；（<u>未来</u>发展）	21
4 Reverse	Scatter in all categories	Dealing with inverse relations；（退伍<u>军</u><u>人</u>）	257

It includes the traditional subject, object and circumstance roles, and also a kind of "Reverse Relation", which can be used to mark relations between words in unusual order. For example, "彗星出现了" (the comet appears) the "彗星"(comet) is the subject of the verb "出现"(appear) which is the root of the phrase; however "出现的彗星" the verb "出现" (appear) is the modifier of the root "彗星". Although the word order is different, the semantic relation between the words does not change, so we use "r" to indicate the difference in word order. The addition of "Reverse Relation" can break through the restriction of word order, and analyze the semantic relation of noun phrase more comprehensively.

4 Annotation of Noun Phrases In Nombank , Chinese Nombank and Sinica Treebank
4.1 Annotation of Noun Phrases in Nombank

NomBank is designed to provide annotation for noun arguments in Penn Treebank II (PTB), including arguments of both nominalizations and other nouns [18].

Though the annotation system of Nombank is pretty fine, it fails to meet certain goals. Firstly, it is not easy to achieve large-scale corpus with high accuracy and consistency due to the complexity of the annotation system. Nouns in Nombank are divided into sixteen types according to their argument structures: Relational Nouns, Job Nouns, Hall Nouns, etc. The same word can have different argument structures in contexts. For example, in "Mary's leadership of the monsters", "leadership" is defined as a Job Noun, because "leadership" is represented by "Mary's. However in "the monster leadership made a decision", "leadership" is defined as a Relational Noun, because "leadership" refers to the leader himself [19].

Secondly, only focusing on predicate-argument structure will result in the loss of some semantic relations. For example, "math" is annotated when occurring with "teacher" while "tall" is not, because "one can teach math", and thus "math" is related to the argument-taking property of "teacher". Besides, Nombank only annotates nouns' modifiers that can co-occur with their verbal forms. For example, in "his bad behavior", "bad" is labeled as ARGM-MNR (Manner) because one can "behave badly" while in "a significant behavior", "significant" is not annotated.

4.2 Annotation of Noun Phrases in Chinese Nombank

Chinese Nombank annotates the predicate-argument structure of nominalized verbs in Chinese. Unlike Nombank annotating argument-taking nouns, it is only interested in the nominalizations and adjuncts that can co-occur with their verbal forms [20].

Chinese Nombank has some disadvantages when annotating noun phrases. Firstly, it can not

reveal the semantic relations inside an argument. For example,"近年来 (in recent years), [ARG1 中韩两国之间 (China and South Korea) 的 (de) 经贸 (economic and trade) 往来 (exchanges)] [REL发展(developed)] 迅速 (rapidly)" (In recent years, the economic and trade exchanges between China and South Korea developed rapidly) [20]. The ARG1 is a complex phrase which also contains a nominalized verb "往来"(exchange), however, SRL does not annotate the argument structure of a nominalization inside an argument. Thus, the semantic information inside an argument has been ignored though it has great significance to the understanding of the sentence. Besides, SRL focuses on the predicate-argument structure and sometimes it fails to take the overall syntax structure of a sentence into full account. For example, "这一地区 (this region) 成为 (became) [ARG0 海峡两岸 (straits two sides)] [ARG1科技 (scientific and technological)、经贸(economic and trade)] [REL合作 (cooperation)] 的 (de) 最佳 (best) 地带 (place)"(This region became the best place for scientific and technological, economic and trade cooperation to the both sides of Taiwan Straits). Actually, the argument structure of "cooperation" is just a modifier of the object "最佳地带 (best place)"which is more important to the understanding of the whole sentence. So without knowing the overall syntax structure of a sentence, annotating predicate-argument structure has limited effect.

4.3 Annotation of Noun Phrases in Sinica Treebank

Sinica Treebank is based on Information-based Case Grammar and Head-Driven Principle. It provides five kinds of semantic roles to specifically label noun phrases: apposition, possessor, predication, property, and quantifier. When annotating the first thing is to determine the head of the noun phrase and then annotate its subordinates according to their semantic relations [22].

For example: NP (quantifier: DM: 这座| property: NP (property: Nca: 罗亚尔河| Head: Ncda:畔)| predication: VP· 的 (head: VP (time: Nddc: 最后|Head: VA12: 诞生）|Head: DE: 的)| property: Nad: 文艺复兴 |Head: Nab: 城堡). (The Renaissance castle that was born latest on the Royall River). Sinica Treebank uses dependency tree to describe the structure, and we transform it into dependency graph as shown in Fig. 1. 城堡"(castle) is the head of the entire phrase and an argument of "诞生"(be born), so we label the arc between them "predication". Definite article "这座"(the) is labeled "Quantifier"; modifiers such as "罗亚尔河畔"(on the Royall River) and "文艺复兴"(Renaissance) are labeled "property"; "head" implies that the content before "的"(de) is the semantic head, while "的"(de) is the syntactic head.
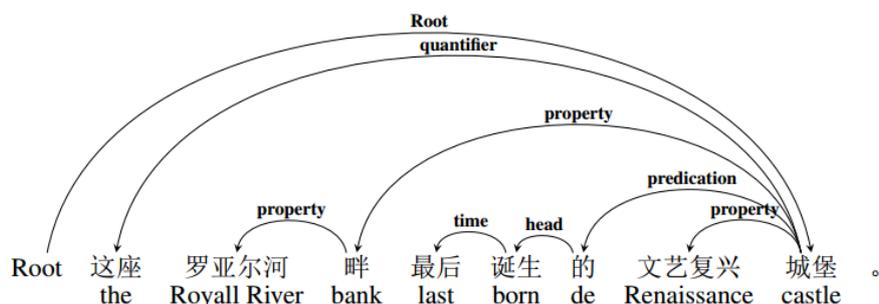

Fig. 4. The semantic graph of Sinica-style parse tree.

Sinica Treebank can label quantity and adjective phrases. However, when it comes to the situation where predicates are not the head of noun phrases, the relations between predicates and arguments are all labeled "predication", which leads to the loss of semantic relations as illustrated in Fig 4.

5 Annotation of Noun Phrases With Predicate

In order to study the internal semantic relations of noun phrases, we build a semantic dependency corpus with 30, 000 sentences nearly 75, 000 words. The data are drawn from news, Chinese textbooks of primary and middle school, machine translation. We extract 1830 noun phrases without "de" (的) from the corpus and divide them into two types. One of them is the noun phrases with predicate which accounts for 718, and the other is the noun phrases without predicate which accounts for 1112 (including proper nouns). Next I will explain the annotation method of these two kinds of noun phrases.

The noun phrase with predicate is a very special structure in Chinese because though there is predicate in the structure the overall function is nominal such as "产业结构调整" (adjustment of industrial structure), "经济发展速度" (speed of economic development), "国有企业改革试点" (reforming pilot of state-owned enterprise). The annotation procedure is (1) Determine the root of the phrase; (2) Determine the predicate and find out its arguments such as agent (Agt), patient (Pat), experiencer (Exp), etc. The direction of arcs is from governor to dependent; (3) Annotate the modifiers of predicate such as place (Loc), time (Time) and manner (Mann); (4) Annotate the modifiers of nouns such as adjectives (Desc), possession (Poss) and quantity phrases (Quan). According to the position of the predicate we divide the phrases into three categories.

5.1 Predicate Is in the Middle of the Phrase

This category has two types: the first one is that the words on both sides of the predicate have direct semantic relations with the predicate. As is illustrated in Fig. 5, in "社会讨论焦点" (the focus of social discussion), since the head of Chinese is usually to the right of its modifiers, "焦点" (focus) is the root of the whole phrase. Under this situation, the predicate directly modify the root and the word before the predicate can be an argument of the predicate such as "企业经营机制" (managerial mechanism of enterprise), and "金属切削机床" (metal cutting machine), or a modifier in terms of location, time, manner, such as "田野调查资料" (field survey data), and "工业销售产值" (industrial sales output value).
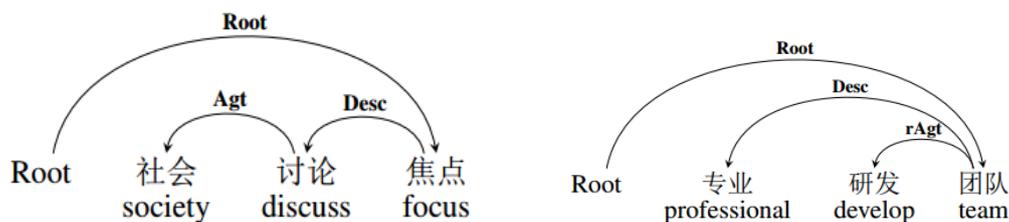
Fig. 5. Type 1.   Fig. 6. Type 2.

The other type is that all the words before the root directly modify the root. The root can be an argument or a component modified by the predicate such as "现代监管制度" (modern regulatory system), and "海外投资企业" (foreign investment enterprises). As is illustrated in Fig. 6 "团队" (professional R&D team). "专业" and "研发" have direct relations with the root "团队". Generally, predicate is the root so the direction of dependency arcs is from the predicate to the noun. However, under this situation, noun is the root of the structure so the direction of dependency arcs is from the noun to the predicate. We add "r" before the semantic role to describe the inverse relation.

5.2 Predicate Is at the End of the Phrase

Like the type we have discussed above, this category has two situations. The first type is that the component1 is usually a modifier of the component2, which tends to be an argument of the predicate, i.e., the root. This is illustrated in Fig. 7: "工业" (industrial) modifies "结构" (structure), which is a patient of the predicate "调整"(adjustment). Such examples are "国内产业升级" (domestic industrial upgrading), and "机电产品出口"(export of mechanical and electrical products).
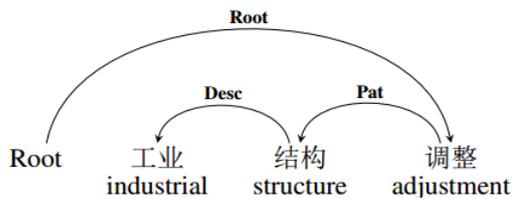

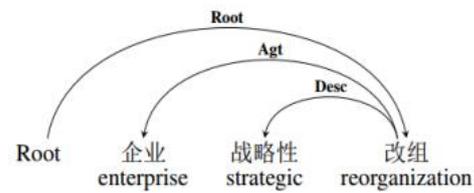Fig.7. Type 3.   Fig. 8. Type 4.

The other type is that all the words before the predicate directly modify the root. They can be arguments or modifiers of the predicate as in Fig. 8: in "企业战略性改组"(strategic reorganization of enterprises), "企业"(enterprise) and "战略性"(strategic) are respectively an agent and a modifier of the predicate "改组"(reorganization). Such examples are, "政权和平转移" (peaceful transfer of power), and "国家经费投入" (national fund input).

5.3 Predicate Is at the Beginning of the phrase

In this category, we have three different situations. The first type is that the predicate and the component after it are more related semantically and they modify the root together. This is illustrated in Fig. 9: "团队" (team) is the agent of the predicate "竞选"(campaign). Such examples are "创作歌手形象"(the image of singer-songwriter), and "零售商品总额" (volume of retail sales).

The second type is that all the words before the root directly modify it. The root can be an argument of the predicate or a component modified by the predicate as illustrated in Fig. 10 "驻京", "外资", and "金融" all directly modify the root "机构". Other examples are "独资船务公司" (sole-investment shipping company) and "合资建筑企业" (joint-venture construction enterprise).
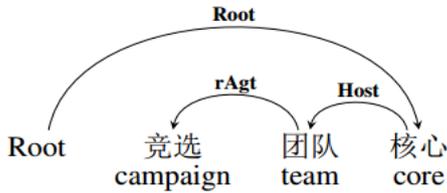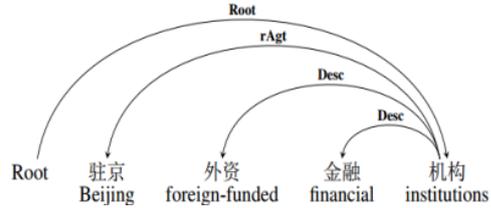

Fig. 9. Type 5.   Fig. 10. Type 6.

The last type is that the predicate and the components after it constitute a predicate-argument structure that modifies the root. As is illustrated in Fig. 11, compared with Type 5, the feature of this type is that the components between the predicate and the root are more semantically related to the predicate, so we make the dependency arc point from the root to the predicate instead of the nouns. Such examples are "利用外资渠道" (channel for utilizing foreign investment), and "接卸集装箱能力"(ability of unloading container).
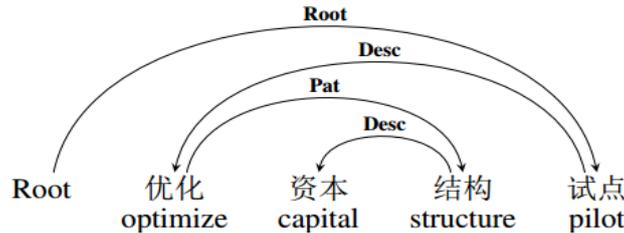

Fig. 11. Type 7.

From the study above, we can see that no matter what position the predicate is, there are two kinds of dependency arcs (the last category has three). Knowing this is helpful for the machine understanding of natural language. For example, "一份学习文件" (a learning document) and "正在学习文件"(be learning document) [23], we can distinguish these two structures according to the dependency arcs. Fig. 12 is a noun phrase because its root is nominal and the predicate "学习"(learn) is a modifier of root "文件"(document). Fig. 13 is a verbal phrase because the root "学习"(study) is a verb and "文件" (document) is its object. In fact, not only noun phrases with predicate but also noun phrases without predicate have these two kinds of dependency arcs.
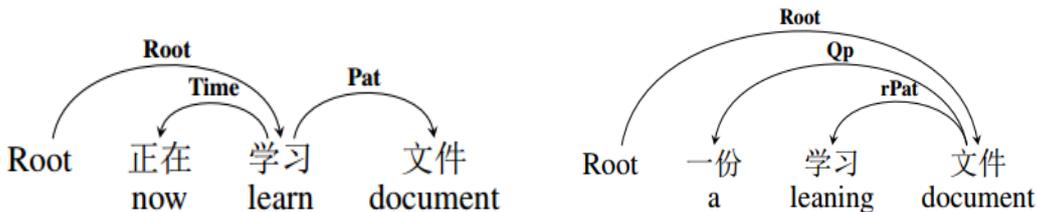
Fig. 12. Type 8.   Fig. 13.Type 9.

6 Annotation of Noun Phrases Without Predicate

The noun phrases here refer to the ones consist of +multi nouns or adjectives such as "世界先进水平" (world advanced level), "工业经济总体效益" (overall efficiency of industrial economy), "境内外资金融机构" (domestic foreign-funded financial institutions). It is worth noting that the adjectives in this kind of structure only function as modifiers, while in noun phrases with predicate adjective is the core of the phrase. For example: "密集" ("intensive) of "资本密集产业" (capital intensive industry) is defined as a predicate because it takes an argument and plays a key role in the structure.

To annotate this structure the first step is to figure out how many parts it has, and then determine their relationship with the root and then each other. This kind of noun phrases also have two kinds of dependency arcs. The first type is that the component1 modifies the component2 that directly modifies the root such as "有色金属公司" (nonferrous metal company),"搜索引擎功能"(search engine function) and "海外市场前景"(the prospect of overseas market). As is shown in Fig. 14: "海外"(overseas) modifies "市场"(market) that directly modifies the root "前景"(prospect).
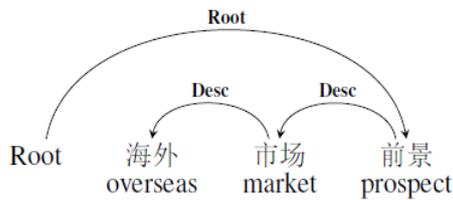
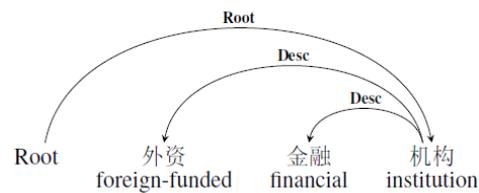Fig. 14.Type 10   Fig. 15. Type 11.

The second type is that all the components directly modify the root. Such examples are "消费类电子产品"(consumer electronics), "中国保险产业"(Chinese insurance industry), and "外资金融机构" (foreign-funded financial institution). This is illustrated in Fig. 15: "外资"(foreign-funded) and "金融"(financial) directly modify the root "机构"(institution). The proportion of different types of noun phrases is shown in Table 1 and Table 2.

Table 2. Proportion of Noun Phrases With Predicate

Type	Quantity	Proportion
Type 1with predicate in the middle	418	58%
Type 2 of predicate in the middle	63	9%
Type 3 of predicate at the end	123	17%

Type 4 of predicate at the end	61	9%
Type 5of predicate at the beginning	26	4%
Type 6 of predicate at the beginning	17	2%
Type 7 of predicate at the beginning	10	1%
Total	718	

Table 3. Proportion of Noun Phrases Without Predicate

Type	**Quantity**	**Proportion**
Type1 without predicate	455	40%
Type 2 without predicate	657	60%
Total	1112	

7   Conclusion

From the data we can see that no matter whether a noun phrase contains predicate or not, it has two kinds of dependency arcs. We find that predicates in noun phrases are more likely to be the connection of the root and other components, while in noun phrases without predicate all the words are more likely to directly modify the root. The annotation scheme of noun phrases can improve the accuracy of automatic semantic analysis, and also provides theoretical support to other fields of natural language processing. First of all, the labeled corpus can provide materials for machine learning, which is helpful to the development of automatic semantic analyzer. Besides, it can be useful in other fields such as nominal predicate recognition, information extraction and machine translation, etc.

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