REVIEW ON WORDNET-BASED ONTOLOGY CONSTRUCTION IN CHINA

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Abstract-The problem of WordNet-based ontology construction was widely investigated and many effective methods have been proposed in China. The utilizations of the hierarchy structure of WordNet, the digraph structure of WordNet and auxiliary resources are main measures in the methods. Usually, the methods are facing three fundamental difficulties, the computation of semantic similarity, the construction of core ontology and the development of auxiliary resources. Through our reviews of previous researches, we find several inadequacies such as low utilization ratio of WordNet and the lack of standardized evaluation and give some suggestions for future works.

Index terms*:* Ontology construction, WordNet, semantics similarity, core ontology, auxiliary resource.

I. INTRODUCTION

The term Ontology has its origin in philosophy. Aristotle defined Ontology as the science of being [1]. In this sense, the Ontology tries to answer the question: "What is being?" or, in a meaningful reformulation: "What are the features common to all beings?" [2]. Nowadays, the connotation and denotation of Ontology are being developed greatly. In China, researchers even change the capital "O" into a small one "o" to distinguish the philosophical notion and its modern sense. The practical application of ontology has initially emerged in the artificial intelligence area last century. Today, a flood of literatures show that ontologies have been widely used in many domains. Various ontologies are being constructed within specific domains, such as linguistics [3], economics, and mechanical engineering [4] and so on.

In the present times, humans tend to be overloaded with information [5] and studies on information technology like the construction of ontology are drawing researchers' attention. As one of the common hotspots of computer science and information science, studies on construction of ontology are carried out lately. The most famous and widest accepted definition is made by Gruber: "ontology is an explicit specification of a conceptualization." [6]. Along with the mushroom development of information technology, numerous researchers focus on the study on ontological language, construction rules and application tools.

The fact that more than 500 papers focused on ontology have been published in China National Knowledge Infrastructure shows that the developing foreground of ontology is vast in China. The construction of fundamental engineering ontology like HowNet [7] or Chinese Concepts Dictionary [8] consumes a lot of money, time, manpower and material resource and that's why most of researchers choose to build task or domain ontologies. Researchers adopt different strategies, one of which is to build ontology based on WordNet [9]. As a semantic dictionary which is being constructed since 1985, WordNet has become the facto international standard after twenty years.

This paper finds that scholars from various institutions place a great importance on WordNet during the ontology construction and a trend of on WordNet- based ontology construction has been formed in China. In order to summarize research methods and create new ideas, this paper firmly believes that it is necessary to reassess ontology construction based on WordNet in China.

II. METHOD REVIEW

In China, studies on the construction of ontology involve complex tasks such as concepts mapping, text categorization, ontology matching, and framework integration. Various strategies are adopted by researchers in order to complete these tasks and three types of method has been formed [10] according to these strategies: firstly, based on the hierarchy structure of WordNet, concepts are extracted from WordNet and extended to the core ontology which is manually built; secondly, various auxiliary resources are utilized for extracting concepts and semantic relationships; thirdly, WordNet is used as digraph and the target ontology is built as a subgraph to which the directed edge learned from the initial graph is extended. Comparatively speaking, more researchers prefer to choose the first and second types rather than the third one.

a. Constructing ontology based on the hierarchy structure of WordNet

Following the psycholinguistic rules, WordNet is built by Princeton University and contains complex semantic relationships. Nowadays, WordNet has been reformed into ontology [11]. Some academics assume that WordNet is one rationally organized classification structure and they successfully construct ontology based on the hierarchy structure of WordNet [12].

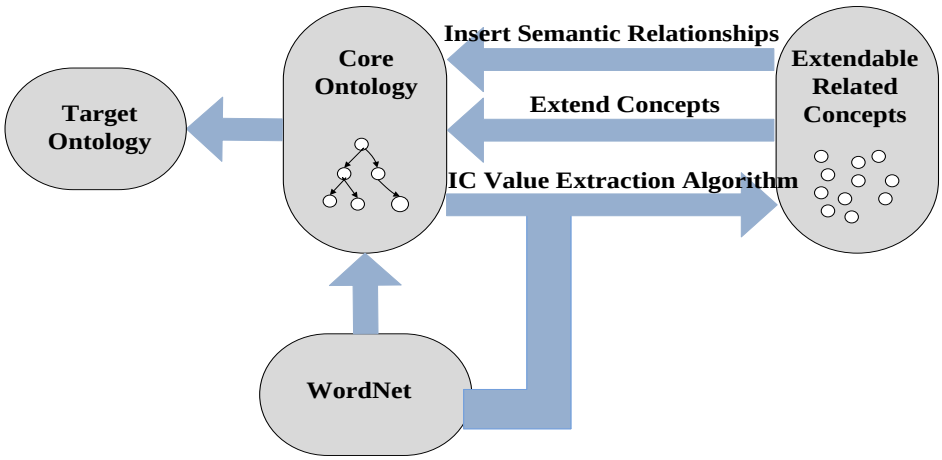

Figure 1. Frame diagram of ontology construction based on the hierarchy structure of WordNet

Taking the hierarchy structure of WordNet as the starting point, previous researchers extend related concepts through semantic similarity after counting the Information Content (IC) Value

and successfully construct the Information Content Security Ontology [12]. Moreover, researchers also add semantic relationships to the ontology through counting the IC Value. The basic idea of this method can be described as: manually select the core concepts from WordNet for building initial core ontology, and then extend related concepts to core ontology through semantic similarity algorithm which is based on the IC Value. Finally, researchers add semantic relationships among concepts to construct the target ontology. Figure 1 shows the frame diagram of ontology construction based on the hierarchy structure of WordNet.

Actually, similar idea has long been there and more supplementary means had been adopted. For example, besides the IC Value, previous researchers choose focused crawler to be another tool for counting semantic similarity while extending the related concepts [13]. The focused crawler collects web resources, establishes database and counts the semantic similarity between words by counting co-occurrence frequency of words.

b. Obtaining concepts and semantic relationships through auxiliary resource

When there are more than one programs running in parallel, each of them has specific features of its own [14]. Similar as the theory of affordance, researchers will choose different methods during the WordNet-based ontology construction to adapt themselves to the realistic conditions [15]. However, some fundamental research steps could be identified in nearly all the researches. As a fundamental step during constructing ontology, the acquisition of concepts and semantic relationships is the key point. One important strategy adopted by a number of researchers is to extract concepts and semantic relationships from auxiliary resources besides WordNet.

In their paper, Wu and his colleagues construct a patent ontology and the research focuses on building the database which is used as the auxiliary resource [10]. Researchers select a number of patent abstracts and establish their database for extracting concepts [10]. Based on the already chosen core concepts from WordNet, researchers obtain the related concepts mainly from database. By the way, all the concepts extracted from database also belong to WordNet. Researchers discover the semantic relationships in WordNet and copy that into the patent ontology. Finally, researchers successfully transform the database into engineering ontology which is constructed in the OWL. Figure 2 shows the main procedure of constructing mentioned patent ontology as well as partly reveals the framework of obtaining concepts and semantic relationships through auxiliary resource.

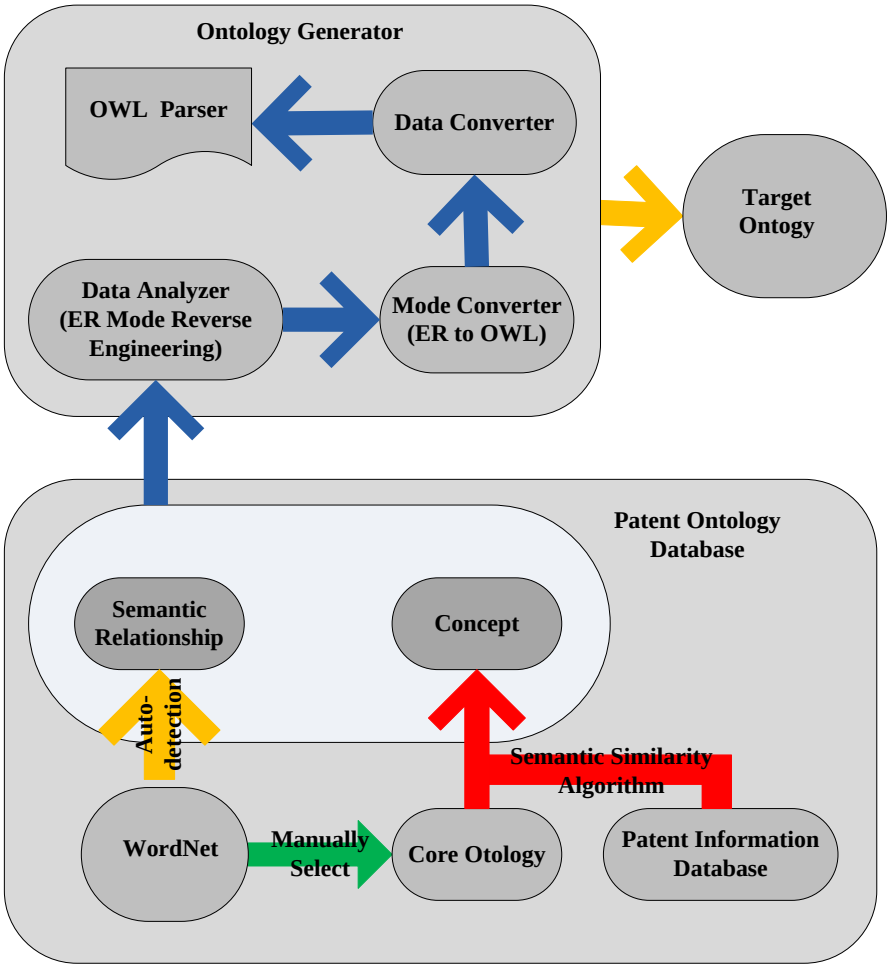

Figure 2. Frame diagram of patent ontology construction

Compare with the above research in which domain literatures are used as auxiliary resource, the research of medical ontology by previous researchers [16] assets greater emphasis on auxiliary resource. This research selects 8000 abstracts from different medical magazines and builds one relationship database for storing semantic units by natural language processing technologies. A representative core concept in medical domain is chosen and all the concepts which are directly related to the core one will be processed as candidates. Moreover, those candidate concepts which exist in the semantic unites are mean to be extended to ontology. Besides the concept issues, auxiliary resource could provide nearly all the semantic relationships.

Auxiliary resources play an important role in the construction of ontology nowadays. We investigate five typical researches on the construction of ontology based on WordNet. They are

[16], [11], [17], [12] and [18]. For a better understanding, we call the concepts extracted from auxiliary resource as auxiliary resource concepts. We find out the number of auxiliary resource concepts in each research and carry out a contrast experiment which shows the percentage of auxiliary resource concepts in each ontology. The outcome of this experiment is shown by the following figure.

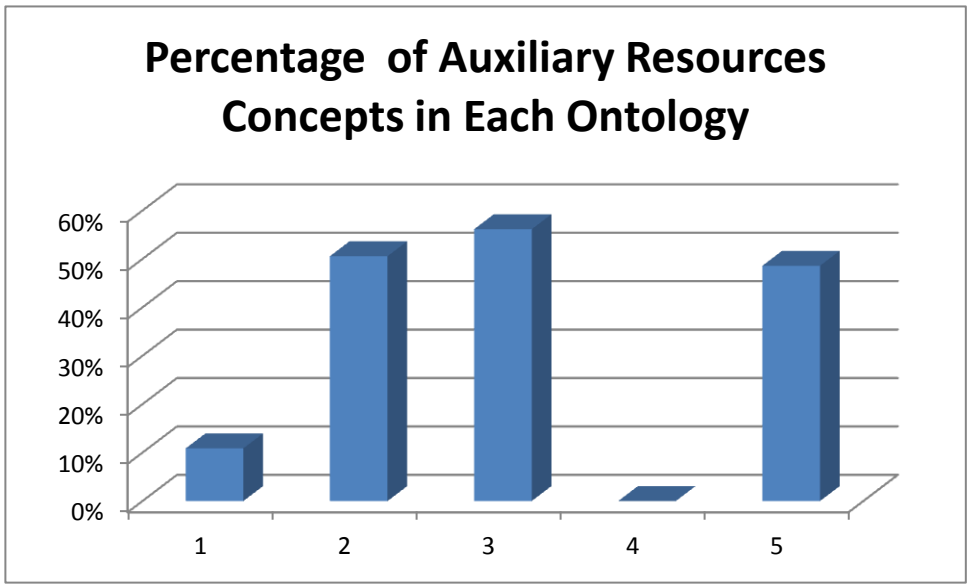

Figure 3. Percentage of Auxiliary Resources Concepts in Each Ontology

As we see, the fourth result which is carried out by Zhou and Wang [12] is quite different from the other ones for they did not use any auxiliary and all the 201 concepts of their ontology are extracted from WordNet. In the first research, Xu [16] obtained 78 concepts from auxiliary resource while 639 concepts from WordNet that means that his percentage is nearly 10%. In this experiment, it is clearly shown that Zhao [11], Bi [17] and Yuan [18] made full use of the auxiliary resource for they obtained approximately 50% concepts from the auxiliary resource.

c. Constructing ontology based on the digraph structure of WordNet

As the basement for extending concepts, all the mentioned researches begin the construction work with building initial core ontology. However, method of digraph is quite different from the others for the core ontology that functions as the existing knowledge base [19] is no more useful. For example, during the construction of military domain ontology, Zhao treats WordNet as a digraph and the key issue is to delete those useless nodes and edges [11].

Zhao and his colleagues regard the concepts, instances and semantic relationships in WordNet as network structure. Therefore, WordNet is abstracted as diagraph. Domain ontology constructed based on WordNet could be considered as a subgraph of WordNet. Researchers focus on the deletion of useless nodes and edges. However, a major difficult in this research is that direct deletion of edges could lead to large numbers of isolated nodes. Aiming at solving this problem, the research puts forward a strategy for utilizing transitivity of semantic relationships in ontology construction. Let's take hyponym which is a transitive relationship as an example. Supposing that superior node N_s is connected with sub-node N_j through intermediate node N_i by hyponym relationship, N_s and N_j will be directly jointed after the deletion of N_i. Algorithm developed by this research could be described as follows:

1) Find out all the useless nodes and delete them;
2) Find out all the useless edges and delete them;
3) Add those edges that represent the transitive relationship;
4) Extract the subgraph.

Furthermore, this research obtains a number of concepts and semantic relationships from terminological dictionary and manually defines several relationships for military concepts. The function of auxiliary resource will be discussed in details below.

III. FEATURES AND INADEQUACIES OF THE CONSTRUCTION OF ONTOLOGY BASED ON WORDNET

This paper finds that all the involved researches aiming at different domains adopt different strategies and emphasize different start points. As former researchers mentioned, each research method has its advantages and disadvantages [20]. An overall review of differences between the former researches of ontology construction is quite necessary. Therefore, this paper believes that the summarization of features and inadequacies of existing researches will be helpful for future works. Moreover, three common features and inadequacies could be discovered through a reassessment.

a. Semiautomatic construction

The fact that the main methods for constructing ontology could be summarized as a semiautomatic one lies in three respects: all the core ontologies are manually built; following the iteration rules, most of concepts and semantic relationships could be automatically obtained; and concepts from the auxiliary resources are automatically extracted by natural language processing technologies.

The semiautomatic construction strategy is in keeping with the main trend of constructing methods. Manual method totally relies on the analysis of domain experts and provides well-structured engineering ontology. However, the manual method which cost too much money, time and man power cannot meet the requirement for constructing ontology in the informational age. Although the automatic method provides an efficient way for constructing, its low accuracy and rationality limit its functions for application. Nowadays, the semiautomatic one seems to the best choice.

Aiming at the concrete practical application, all the involved researches are oriented towards specific domain, including information contents, medicine, and agriculture and so on. Therefore, WordNet turns out to be the knowledge database from which the concepts and semantic relationships are extracted. The fact that most of existing researches are lack of macroscopic perspective results in the inadequate utilization of WordNet.

b. Low utilization ratio of WordNet

Low utilization ratio of WordNet lies in three respects: the WordNet edition that is being researched is stored in the original data memory structure; most of the application oriented ontologies constructed based on WordNet are still small scale ones; and the semantic relationships extracted from WordNet are insufficient.

Princeton University initially stores WordNet in the form of semantic dictionary in which two kinds of files are contained, “index.*” and “data.*”. The former is an index file while the later contains all the synsets. Lately, researchers realized that WordNet was quite useful for constructing engineering ontology and reforming it would be necessary. Nowadays, some research group like World Wide Web Consortium (W3C) has reformed WordNet into RDF and OWL. This paper finds that only one research makes use of the new formed WordNet instead of the original one in China. This fact shows that most of the researchers regard WordNet as primitive language resource rather than an engineering ontology.

Generally speaking, numbers of concepts extracted from WordNet in researches in China are not large ones. For example, 201 concepts are extracted by the mentioned information content security ontology [12], and for the medical one, the number is 639 [16]. The reason for it may be that all the ontologies are designed to be small scale ones. Another reason is that most of concepts are ordinary ones rather than high domain professional ones in WordNet. The research status shows that academics should pay more attention to the non-professional concepts which is the major part of WordNet.

Semantic relationships among concepts in WordNet are quite valuable. No doubt that the problem how to obtain semantic relationships from language resource catches researchers' attention. Nearly all the researches treat this problem as a key issue. Actually speaking, semantic relationships extracted from WordNet are far from enough. For example, the above mentioned information content security ontology extracts only one semantic relationship "is-a" from WordNet [12] while Fei selects only inheritance relationship in constructing the Shanghai Expo ontology [13].

A typical example comes from the medical ontology [16]. Table 1 shows the result of concepts and semantic relationships extracted both from WordNet and auxiliary resources in this research. Comparing with WordNet, auxiliary resources seems contribute more to the construction of target ontology. On one hand, the number of concepts obtained from WordNet is 639 while the number of concepts extracted from auxiliary resources is 78. Concepts come from WordNet are 8 times more than that come from auxiliary resources. On the other hand, the number of semantic relationships is 4 from WordNet while their number is 457 from auxiliary resources. Semantic relationships come from auxiliary resources are 114 times more than that come from WordNet.

Table 1: Extract result in the medical ontology construction

	Extract result of semantic relationships	**Extract result of concepts**
WordNet	4	639
Auxiliary resource	457	78

Except for the original data memory structure, WordNet does not establish supremacy over auxiliary resource in providing concepts. For a better understanding, we call the concepts extracted from WordNet as WordNet concepts. We test the percentage of WordNet concepts in

the total WordNet in five typical researches. Five researches that had been tested are [16], [11], [17], [12] and [18]. The outcome of this test is shown by the following figure.

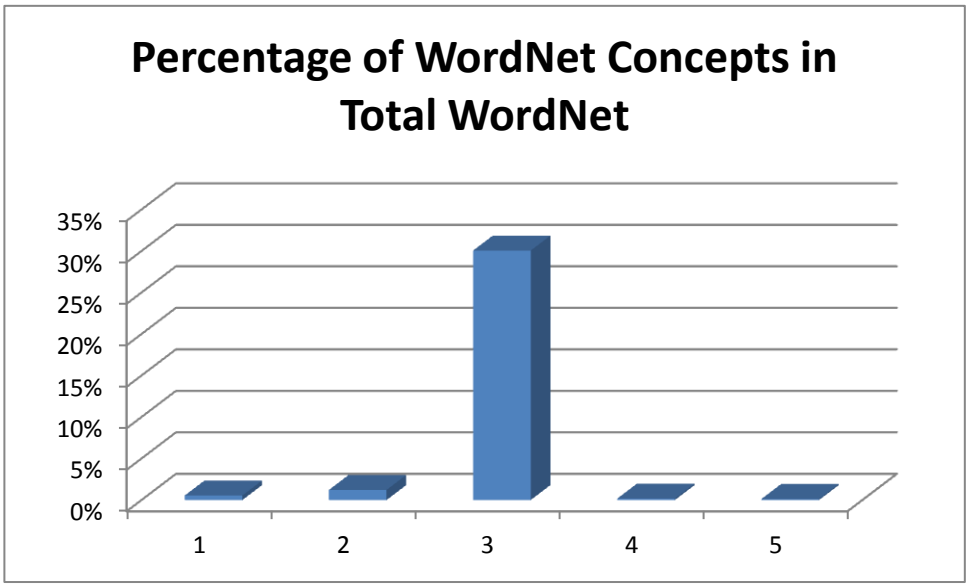

Figure 4. Percentage of WordNet Concepts in Total WordNet

The above chart clearly shows that only the third research which is done by Bi [17] used nearly 30% concepts of WordNet to construct the ontology. Among the other four researches, only the second one which is done by Zhao [11] used nearly 1% concepts of WordNet to construct the ontology. All the rest of researches obtained less than 1% concepts in WordNet for the construction of ontology.

c. Lack of standardized evaluation

Among the five major researches mentioned above, one tests the semantic similarity algorithm, one evaluates the usage of its ontology through the practical application, one does not evaluate its results, and the other two literally describe their results. The lack of standardized evaluation is obviously a common feature for the construction of ontology based on WordNet.

Different from the information retrieval and machine translation, ontology construction has no international evaluation conference which could provide the evaluation standard and testing corpus for the construction of ontology. However, early in 1995, Gruber put forth five basic principles for the evaluation of ontology: clarity, coherence, extendibility, minimal encoding bias and so on [6]. These five principles tell us that the refinery structure of ontology is more

important than the number of concepts or semantic relationships. Unfortunately, researchers nowadays attach more importance to the number of concepts and semantic relationships. As a matter of fact, the lack of concrete and technological standard cannot lead researchers into a right direction.

IV. KEY ISSUE FOR THE CONSTRUCTION OF ONTOLOGY BASED ON WORDNET

Although the strategies adopted in the construction researches are quite different from each other, all of them have successfully built the application oriented ontology. This paper finds that three key issues on which all the researches focus could be summarized: computation of semantic similarity, construction of core ontology, and development of auxiliary resource.

a. Computation of semantic similarity

If researchers do not treat WordNet as a digraph, then the main strategy for obtaining concepts is semantic similarity computation. After manually selecting those domain core concepts, the acquisition of new concepts totally relies on the semantic similarity computation in most of researches. During the construction of Shanghai Expo ontology, semantic similarity is counted based on Lin Algorithm and the co-occurrence of target term in selected web texts [13]. The semantic similarity algorithm is one of the most important innovations in the research of information content security ontology for the researchers' main job is to refine the existing algorithm which is based on the hierarchy structure of WordNet [12]. Furthermore, semantic similarity computation plays a supporting role while the patent ontology is being constructed [10].

Through an overall reassessment of existing researches, this paper finds that researchers in China still have a long way to go in the area of semantic similarity algorithm. In the present times, the main basements of semantic similarity algorithm in ontology construction are co-occurrence of target terms and the structure of WordNet. The former is easy for practical manipulation while cannot provide valuable results. As a matter of fact, researchers have not made great progress for the later one.

b. Construction of core ontology

As the initial step for the ontology construction, the construction of core ontology provides the basement for the extraction of concepts and semantic relationships that come from both WordNet and auxiliary resources. Concepts contained in the core ontology should be the most typical and ones for a specific domain. Figure 5 shows the basic situation of core ontology construction.

Figure 5. Basic Situation of Core Ontology Construction

As the basement of whole research, the quality of core ontology determines the successful construction of ontology. That is the reason why all the researches choose to build core ontology manually. As a matter of fact, the construction of core ontology is easy to implementation and that is the second reason why it is manually constructed. For example, core ontology in the construction of information content security ontology contains only ten concepts and one inheritance relationship [12]. The research of the mentioned medical ontology extends its concepts based on only one concept “medicine” [16]. Similar situation happens in the researches of Shanghai Expo and agriculture patent ontology. This paper believes the core ontology must be constructed manually in the foreseeable future.

c. Development of auxiliary resources

Auxiliary resources which come from diversified sources are playing an important role in most of the existing researches of constructing ontology based on WordNet. For example, text database made up of texts collected from internet is established to play a supporting role for counting semantic similarity [13]. A better example comes from the research of patent ontology. Previous researchers establish their auxiliary resource by collecting journal abstracts and extract semantic units[10]. Their auxiliary resource plays a fundamental role in the procedure of obtaining concepts and semantic relationships.

In the sense of extracting concepts, auxiliary resources are performing the same function as WordNet. More evidences could be discovered in the construction of military ontology [11]. Zhao and other researchers regard WordNet as digraph and extract subgraph for the construction of military ontology. After that, researchers choose the Military Terminological Dictionary (MTD) to be the auxiliary resource [11]. In order to construct a large scale military ontology, they extract concepts both from WordNet and the auxiliary resource. Table 1 and 2 give a detailed description of result about extracting concepts from WordNet and auxiliary resource.

On one hand, researchers obtain six types of elements from WordNet, namely word object, noun, verb, adverb, adjective and adjective satellite. The number of concepts they extract from WordNet is 3059 while the total number of words in WordNet is 251693. Their extract ratio is 12‰. On the other hand, researchers obtain single word terminology and compound word terminology from Military Terminological Dictionary which is auxiliary resource in this research. The number of concepts they extract from the auxiliary resource is 3129 while the total number of terminologies in the auxiliary resource is 5776. Their extract ratio is 542‰. These numbers tell that auxiliary resource and WordNet are performing almost the same function in the WordNet-based ontology construction.

Table 2: Extract result of concepts in WordNet

	Word object	**Noun**	**Verb**	**Adverb**	**Adjective**	**Adjective satellite**	**Total**
WordNet	140470	75804	13214	3629	7345	11231	251693
Target ontology	685	1528	600	9	65	172	3059
Extract ratio	5‰	20‰	45‰	2‰	9‰	15‰	12‰

Table 3: Extract result of concepts in Military Terminological Dictionary

	Single word terminology	Compound word terminology	Total
MTD	2511	3261	5776
Target ontology	2286	843	3129
Extract ratio	910‰	259‰	542‰

Words description may not be enough to explain the importance of auxiliary resource during the construction of ontology based on WordNet. This paper keeps track of the progress of the related research in the past six years and the contribution rate is studied. The contribution rate means the proportion of concepts obtained from the auxiliary resource. In the past six years, seven independent typical researches on the construction of ontology based on WordNet are made in the China. Two of them have not published their concrete data. The contribution rate trend of auxiliary resources in the rest five ones which are published in [16], [11], [17], [12] and [18] are studied with statistics. The contribution rate trend of auxiliary resources in the past six years is clearly shown by the following figure.

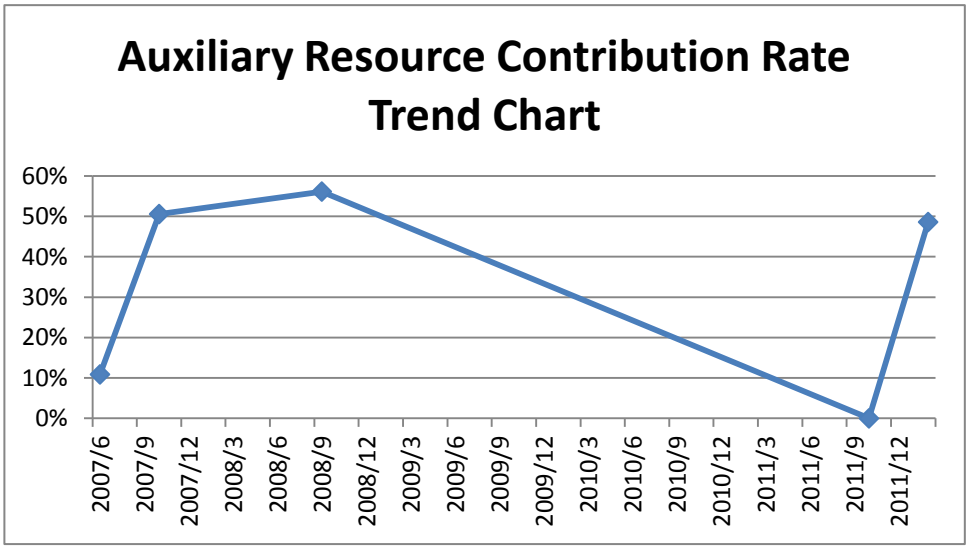

Figure 6. Auxiliary Resource Contribution Rate Trend Chart

The abscissa shows the time of each research while the ordinate shows the contribution rate. According to the contribution rate trend chart, we cannot summarize regular patterns. However, except for the research took place in 2011 which is done by Zhou [12], the rest of researches did make full use of the auxiliary resources and the trend chart shows that the contribute rate increase with time.

As the language resources from which the concepts and semantic relationships are extracted, the auxiliary resources perform the same function as WordNet. Actually, auxiliary resources are doing better than WordNet in some aspects. The major difference between them is quite obvious. WordNet is well-formalized and refined structured. Auxiliary resources which are established based on internet texts, journal abstracts and terminology dictionary are not structured language resources. This paper believes that the accumulation of structured auxiliary resources is quite important for future construction of ontology.

V. CONCLUSIONS AND PROSPECTS

This paper makes an overall reassessment on several researches of the construction of ontology based on WordNet in China. In order to successfully construct the ontology, three key issues which are computation of semantic similarity, construction of core ontology and development of auxiliary resources should be emphasized. Furthermore, this paper finds that some common features and inadequacies like semiautomatic construction, low utilization ratio of WordNet and the lack of standardized evaluation could also be summarized through this reassessment.

Furthermore, this paper puts forwards some research suggestions for the future work:

1) Researchers should emphasize the development of semantic similarity algorithm which could be based on structure of WordNet or co-occurrence of target terms.
2) Based on the task oriented construction of ontology, researchers should enlarge the scale of target ontology.
3) Utilization of WordNet and auxiliary resource should not be limited to extracting concepts and semantic relationships. Aiming at the construction of well-structured and clearly defined ontology, all the language resources should be made full use of.
4) Researchers should pay attention to the accumulation of auxiliary resources. Academics should realize that WordNet is not the only basement for constructing ontology. Structured and semi-structured language resources will provide more choices for researchers.

Looking into the future, three research trends could be revealed. Firstly, the fact that technology for constructing ontology is being innovated and WordNet itself is being updated forces researchers to adapt themselves to the new conditions. In other words, the dynamic research requirements drive researchers to constantly modify their strategies. Secondly, Chinese

researchers should pay more attention to the problem of constructing ontology in Chinese rather than English based on WordNet which is the English language resource. Finally, there is no concrete and technological standard for the ontology construction. This paper believes the study on evaluation standards should be another focus for the future work.

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