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정보검색에서 자연어처리 응용효과 분석

Comparison of Application Effect of Natural Language Processing Techniques for Information Retrieval

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Abstract: In this paper, some applications of natural language processing techniques for information retrieval have been introduced, but the results are known not to be satisfied. In order to find the roles of some classical natural language processing techniques in information retrieval and to find which one is better we compared the effects with the various natural language techniques for information retrieval precision, and the experiment results show that basic natural language processing techniques with small calculated consumption and simple implementation help a small for information retrieval. Senior high complexity of natural language processing techniques with high calculated consumption and low precision can not help the information retrieval precision even harmful to it, so the role of natural language understanding may be larger in the question answering system, automatic abstract and information extraction.

Keywords: natural language processing, information retrieval, phrase identification, stemming

I. INTRODUCTION

IR (Information Retrieval) based on the full-text index has been developed more than 10 years. In this decade, researchers have been trying to use NLP (Natural Language Processing) techniques for information retrieval, but the result is not satisfied. Less complex basic natural language processing techniques with small calculated consumption and simple implementation help a small for information retrieval, which including stop words removal, word segmentation, stemming and so on. But some techniques are still recommended in the information retrieval experimental platform, which can improve the retrieval effect such as stop words removal and stemming etc. Senior high complexity of natural language processing techniques with high calculated consumption and low precision can not help the information retrieval even harmful to it, which including parsing, phrase identification, named entity recognition, concept extraction, anaphora resolution and WSD (Word Sense Disambiguation) and so on [1].

Therefore, through a comprehensive analysis of using natural language processing in information retrieval, we compare which one is the best IR method. This paper is organized as follows: It introduces the applications of natural language processing techniques in information retrieval in the second part; it compares the effects of NLP for IR precision (precision is the fraction of retrieved instances that are relevant.) in the third part; conclusions of natural language processing in information retrieval is in the fourth part.

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II. THE APPLICATIONS OF NLP IN INFORMATION RETRIEVAL

Natural language processing includes natural language processing technique and natural language processing resources. The technique can be divided into basic technique and advanced technique. The resources mainly refer to the dictionary that can be read by computer.

1. The Application of Basic NLP Technique

Basic natural language processing techniques include stop word removal, word segmentation, stemming and part-of-speech tagging etc.

1.1 Stop Word Removal

Stop word refers to the word that lacks actual meaning and appears lots of times in the document, such as most of English prepositions, articles and so on. Usually stop word removal is used in information retrieval system, which is as a step of document processing. Usually using a stop word list to filter stop words, and according to the actual collection of documents we can select the appropriate stop word list [1].

Because stop word removal technique has no substantial help to improve the retrieval effect, actual information retrieval systems such as Web search engines often do not use this technique. Moreover, using this technique could not lead to good results in dealing with some queries. The classic example is the query of “to be or not to be”. So stop word also has been reserved as index item in most actual retrieval system.

1.2 Word Segmentation

Word segmentation is a special problem in information retrieval of Asian languages such as Chinese and Japanese. Most of

European languages need not word segmentation. Word segmentation technique is widely used in Chinese information retrieval systems.

Peng et al. have made word segmentation and retrieve experiments in the Chinese data set of TREC5 (Text Retrieval Conference) and TREC6 (This collection of Chinese text consists of 164,768 documents and 139,801 articles selected from the People's Daily newspaper, and 24,988 articles selected from the Xinhua newswire.) [2]. Their experiments showed that word segmentation accuracy and retrieval effect is not the monotonous directly proportional. The best retrieval effect can be obtained when word segmentation accuracy is 70 % or so. If the Word segmentation accuracy is too high, it may lead to decline in retrieval effect [2]. The details of these algorithms and experimental results can be found in the given references.

Foo et al. obtained these conclusions through experiments as follows [3].

- Although there is no direct relation between the Word segmentation accuracy and the retrieval results, different word segmentation approach is influential to retrieval results.
- Better retrieval effect can be obtained when we use a consistent approach in query and document. Consistency is more important than word segmentation accuracy for retrieval effect.
- Manual word segmentation can not obtain better retrieval effect than automatically word segmentation.
- It would get lots of unclear meaning words when using the simplest bigram word segmentation but this approach has not caused obvious bad effect for retrieval effect.

1.3 Stemming

Stemming can make the same stem word match the different form word. Rule-based stemming (e.g. Porter Stemmer) and dictionary-based stemming are commonly used methods.

Strzalkowski and Vauthey [4] applied the stemming method of dictionary-assisted in their retrieval system. The unreasonable states were improved in the results of stemming and the retrieval precision has 6 % to 8 % increase [4]. The corpus-based stemming approach improved the retrieval precision slightly to the Porter stemmer, which was put forward by Xu and Croft [5]. The details of these algorithms and experimental results can be found in the given references.

In practice, stemming technique is widely used in information retrieval system for its high availability although it can only improve the retrieval effect a little.

1.4 Part-of-Speech Tagging

There is no obvious usage about part-of-speech tagging to information retrieval. The biggest problem is that we do not know how to use it in retrieval even if it has a very high accuracy [10].

One approach is that only index the certain parts-of-speech. Kraaij and Pohlmann studied the importance of the different part-of-speech words to retrieval [6]. Their result is that 58 % are noun, 29 % are verb and 13 % are adjective among the document words that useful to retrieval. It can be found that 84 % are noun among the useful words if we only focus on those fronts of documents. Arampatzis et al. only used nouns to complete the experiment and the result showed that there was 4 % improvement compared with using all words [7].

Another use is to separate the different parts-of-speech of words. Let the words that have the same part-of-speech in the query and document can be matched. Using TREC7 and TREC8 data sets (TREC documents are distributed on CD-ROM's with approximately 1 GB of text on each, compressed to fit. For TREC-7, Disks 1-5 were all available as training material and Disks 4-5 were used for the ad hoc task.), Su Qi and others examined the retrieval effect of this use to the SMART system [8]. The results showed that if we can tag the words that have the same form but different part-of-speech we will improve retrieval accuracy and decrease the matching noise. The words that have the same meaning, the same stemming and different parts-of-speech have no match, leading to the decline of retrieval recall (recall is the fraction of relevant instances that are retrieved). The effect about part-of-speech tagging for information retrieval is related to the distribution of words in query and documents. Part-of-speech tagging can improve the retrieval effect, but only a little. Moreover, the selection of index weight may also affect the retrieval effect.

2. The Application of Advanced NLP Technique

Advanced natural language processing techniques include parsing, phrase identification, named entity recognition, concept extraction, anaphora resolution and word sense disambiguation etc.

2.1 Phrase Identification

We can resort to parsing technique or statistic methods when identifying the phrase of query and document. Phrase identification technique that is used in information retrieval mixes the results, largely depending on the specific recognition technology, the phrase type and the matching strategy [9-11]. In recent years the phrase recognition technique has some new progress.

Nie and Dufort made the phrase as an additional unit to combine with the traditional word-based index [12]. They placed the phrases and words in different vectors, calculated the similarity of the query and document and then added their weights [12]. The experimental results in TREC6 and TREC7 data sets showed that this approach can largely improve the retrieval accuracy.

2.2 Named Entity Extractions

Named entity is a special phrase that identifies a concept or entity, such as proper nouns, place names, organization name and so on. Obviously, the named entities express more accurate information than the general phrases.

But the application of named entity in information retrieval can not obtain the direct effect to retrieval result. On the one hand there also exists error in the named entity recognition technique itself, on the other hand, researchers have also confused that how to match the named entities. For example, "Bill Clinton" and "Clinton", what weights should assign to them? This is similar to the problem when using high word segmentation precision, therefore, we can try to use similar methods to solve it.

2.3 Concept Extractions

Concept is a more general special phrase than named entity. Named entity identifies a concept, so we can consider it belongs to the concept. Concept also includes other phrases that do not belong to the named entity, for example, “information retrieval”. However, the concept extraction also failed to improve the information retrieval effect.

2.4 Anaphora and Co-references

An anaphora and co-references technique is to find the actual things for the pronoun or the unknown phrase that appear in the document. For example, “Mr. President” used to refer to “Bill Clinton”, “he” in the “He denied all responsibility”, can be given a detailed explanation using the anaphora resolution technique. This technique seems to have contribution to the information retrieval since it is able to eliminate the unclear expression in the document. However, the truth is not the case. Anaphora and co-references also can not improve information retrieval effect. On the one hand anaphora resolution still has more errors; on the other hand pronoun and the unknown phrase do not actually affect the results of information retrieval [14].

2.5 Word Sense Disambiguation

Word sense disambiguation is a natural language processing technique that researchers have been trying to apply it to the Information Retrieval. It tries to find the actual meaning for each word which in the specific context for the “the single word can express some meanings” problems existing in the natural language.

2.5.1 Word sense index

Voorhees [13] used the word sense disambiguation technique in treating word sense as an index item. Voohees’ experimental results showed that the effect for using word sense index is not better than directly using the words after stemming. Moreover, sometimes even worse, the decrease is 6 % to 40 %. It is found that some queries can indeed benefit from the word sense index, however more decline after individually analyzing retrieval results of each query. Almost all the declines are because of the match failure of those words that should be matched between queries and documents, since word sense index is used.

Then what word sense disambiguation accurate could help the information retrieval? The answer is 90 %, which is given by Sanderson [15]. In his experiment he found that the improvement of succeeded disambiguation for retrieval would be offset by the negative effects of failed disambiguation if there was 20 % to 30 % error rate of word sense disambiguation.

The word can be insured that it has no ambiguity in the context because there are many words in the document. Word sense disambiguation will become useless in information retrieval only if the query length is not too short (for example, only one word).

2.5.2 Progress using WSD in information retrieval

Stokoe et al. used Semcor corpus which released with WordNet training the word sense disambiguation system. Part-of-speech and co-occurrence relationship information is combined in the disambiguation system. The failed words among disambiguation would be assigned to the meaning of the highest frequency that appeared in the WordNet [16]. Although the accuracy of the word sense disambiguation was only 62 %, the experimental results which completed in TREC9 data showed that this disambiguation method can relatively improve the retrieval effect 45 %. However, their retrieval results are still worse than the best result of TREC9 even if there is more improvement about retrieval accuracy because the performance of the benchmark system used in their experiments is poor.

Kim et al. used a particular word sense disambiguation technique. They only considered the 25 most original word meanings of a word in the WordNet and then assigned a meaning to a word, which can insure the accuracy of WSD [17]. Although they did not give the accuracy of disambiguation, the experimental results in TREC7 and TREC8 data showed that the disambiguation method can increase the retrieval effect more than 10 %.

3. Adding Natural Language Processing Technique into Language Model

In recent years researchers have tried to add the natural language processing to language model. Good progress has been achieved. The nature of the language model is to determine the relevance between the query and document by computing the probability of generating the query from the document.

Kumaran and Allan [18] joined the stemming technique in the language model. They thought that stemming can be regarded as smoothing. They proposed a generative model. In this model, they thought that it can be divided into two steps from d (d is document d) to w (w is query word w). Firstly, d generates c (c is a set of which has same stem of w), and then c generates w. This assumption comes from the writer writing. When writers select the words they usually think to a meaning and then select the word with correct form. Experimental results showed that the average retrieval accuracy of the new model had increased about 10 %.

4. The Application Effect of NLP Technique in Information Retrieval

TREC5 NLP evaluation results showed that query expansion, phrase identification, terminology, stemming and other natural language processing techniques used in information retrieval can obtain better effect than the word-based retrieval system. These systems are still not better than the systems based on statistical, in which applied these technologies [19].

Wang analyzed the roles of natural language processing techniques in Web Retrieval [19]. He believed that the phrase after parsing was helpful to the retrieval effect, but the phrase that was obtained by statistical method almost achieved the same effect, and the latter had been applied to the systems. In fact, Web retrieval technique has gained more progress through Web link analysis techniques and AnchorText. AnchorText is synonyms information provided by manual actually. Web links created by web site builder and Web users’ click behavior provided information that they thought important to search engine. Obviously, human intelligence is always better than artificial intelligence.

5. The Application of NLP Resources in Information Retrieval

Natural language processing resources refer to the dictionary such as WordNet and HowNet.

Smeaton experimented with WordNet after the failure that using natural language technique to retrieval experiment such as parsing [20]. He used synonym sets of WordNet to calculate the semantic distance and semantic similarity between words. The semantic similarity calculated had nearly 80 % accuracy through manual evaluation [20].

WordNet is also frequently used for query expansion. In many cases it was helpful to the retrieval results. Zhang et al. also improved the retrieval effect for used WordNet in query expansion [21], but the level of increase was not better than the query expansion based statistical methods.

In addition, as mentioned above, WordNet is a commonly tools used in word sense disambiguation.

Natural language processing resource is constructed manually or revised manually after generated by machine. It has a very high accuracy and it is suitable to be used in information retrieval. We should use it according to the actual situation for different problems.

III. COMPARISON OF DIFFERENT NLP TECHNIQUES APPLIED IN IR SYSTEMS

According to some researchers' experiments on TREC data by using Chinese corpus, we summarize the natural language processing evaluation results in Tables 1 and 2. Of course, they used different data sets and also the data sets are not proper to each kind of case. So the average precision and R precision are not the same standard between these methods. But for some method we can see the relative result of the average precision and R precision.

Here, precision is the fraction of retrieved instances that are relevant.

$$precision = \frac{|\{relevant\,documents\} \cap \{retrieved\,documents\}|}{|\{retrieved\,documents\}|}$$

Avg.Prec. denotes the average precision, and R.Prec. denotes the precision of retrieving R documents. No use means this technique wasn't used in this experiment.

The detailed algorithm description of each technology is given in corresponding references.

These tables show that phrase identification, part-of-speech tagging, stemming and other natural language processing techniques used in information retrieval can obtain better effects than the word-based retrieval system.

Most of the trials had no good effect, which try to use natural language processing in information retrieval, even had some little help, it was not satisfied for people.

The negative impact is bigger than positive impact for using it in the information retrieval because natural language processing is highly relevant areas and poor migration. Information retrieval effect depends on the nature of the query, but the actual query is very difficult for natural language processing and information retrieval. It is difficult to avoid that most of the user's queries are not clear, professional and integrity. It is possible that the user does not know their own needs clearly before retrieval, sometimes very difficult to express the query, let alone a clear description.

표 1. 정보검색에서 기본적인 NLP 기법의 실험결과.

Table 1. The experimental results of basic NLP techniques used in IR systems.

	TREC-5		TREC-6	
	Avg.Prec.	R.Prec.	Avg.Prec.	R.Prec.
Stop word removal	No use	No use	No use	No use
Word segmentation	0.3721	0.3988	0.5044	0.5072
Stemming	0.328	0.356	0.273	0.304
Part-of-speech tagging	0.4632	0.4804	0.2692	0.2712

표 2. 정보검색에서 진화된 NLP 기법의 실험결과.

Table 2. The experimental results of advanced NLP techniques used in IR systems.

	TREC-5		TREC-6	
	Avg.Prec.	R.Prec.	Avg.Prec.	R.Prec.
Phrase identification	0.2347	0.2939	0.2434	0.2574
Named entity extraction	0.2860	0.2835	0.1961	0.2014
Concept extraction	0.2613	0.2545	0.3346	0.3321
Anaphora co-references	0.2998	0.2876	0.3261	0.3211
Word sense disambiguation	0.3291	0.1994	0.2426	0.1980

We think that there are the following obstacles about using natural language processing in the information retrieval: robustness and efficiency of natural language processing need to be improved; the natural language processing results are too complicated; lack of a well information retrieval model of using natural language processing.

Some researchers think that it can help to improve the effect of the information retrieval for no errors and almost perfect natural language processing technique, but obviously the present situation can not reach this level. They also think that the information retrieval technique of not using natural language processing may get good effect is because these technique themselves have already contained the linguistic knowledge.

For example, word sense disambiguation mentioned above, in actual application, polysemy is not the main reason of leading to the retrieval failure unless the query is very short (only one word). If there are enough words can be matched between the query and documents and the similarity is high, then the context of the same words is often similar and ambiguous words generally express the same meaning. Thus, we can guarantee that these documents are related by returning the high similarity documents basically, which have the same meaning of the words in the query, as long as the users' less recall. So the word sense disambiguation can be implemented automatically.

Generally speaking, less complex basic natural language processing techniques with small calculated consumption and simple implementation help a small for information retrieval, which including stop words removal, word segmentation, stemming etc. But some techniques are still recommended in the

information retrieval experimental platform, which can improve the retrieval effect such as stop words removal and stemming etc. Senior high complexity of natural language processing techniques with high calculated consumption and low precision can not help the information retrieval even harmful to it, which including parsing, phrase identification, named entity recognition, concept extraction, anaphora resolution and WSD etc.

Researchers analyzed this phenomenon and thought that the reason of natural language processing useless in information retrieval is as follows: on the one hand, there are some errors in the low precision natural language processing technique even if there are some positive effects, which will be over shadowed by the negative impact; on the other hand, those methods can largely improve the effect of information retrieval which do not use natural language processing, such as statistical methods, since it already contains the linguistic knowledge, and those problems is relatively easy to solved, leaving the more difficult problems to natural language processing.

IV. CONCLUSIONS

This paper aims to find some proper natural language processing technologies which can be applied to information retrieval. By comparing the related researchers' experimental results the following conclusions can be drawn.

Simple natural language processing can often improve the information retrieval effect, although not much helps, such as stop word removal and stemming etc. Complex natural language processing basically can not achieve any positive effect, or even harmful for search results, such as WSD and anaphora resolution and so on. Complex approach usually would increase the processing and storage consumption. Therefore, natural language processing needs to be optimized for the information retrieval task in order to reduce complexity and improve the effect of information retrieval.

Those natural language processing techniques which directly designed for improving the information retrieval effect are often effective. The technique is usually not successful, which independent of the retrieval task and purely a linguistic method. Porter Stemmer is an efficient stemming algorithm specifically for information retrieval. It provides help for the information retrieval even though there are some linguistic errors in the query results. The statistical methods also have been succeeded, which optimized for information retrieval tasks, although a lot of "phrase" it gains are considered as violation of linguistic knowledge. WSD was not originally designed for the retrieval, and it is not helpful even harmful for the retrieval. If we can optimize it for the special field we may improve the retrieval effect.

It is found that a modest benefit of NLP techniques in IR. However, this benefit comes with large computational costs, and non-NLP techniques tend to yield greater improvements. Small positive effects often seem to be a superposition of positive and negative effects. Automatically separating positive and negative instances would help a lot. Such a separation would require a joint focus on natural language processing and retrieval, not to build a natural language processing system and then apply it to retrieval more or less as a black box.

The information retrieval mentioned in this paper is the narrow sense, referring to the document retrieval. The general information retrieval include passage retrieval, question answering system and information extraction etc. in addition to document retrieval. For a long time, the development of natural language processing is to be applied to the tasks which need precise results such as machine translation, so the role of natural language understanding may be larger in the question answering system, automatic abstract and information extraction. In face, in these tasks, we have achieved good results through the interaction between the natural language processing and the information retrieval. The results of TREC also show that natural language processing can improve the effect of these tasks.

Natural language processing has played a significant role in other systems in addition to narrow sense information retrieval (document retrieval), such as question answering system and information extraction. It will be one of development direction about natural language processing in the future. The researchers also suggested that optimize the natural language processing techniques for information retrieval tasks, for example, using it in intelligent display of retrieval result or in capturing the context information of user's query in order to return the best result to users.

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