A Survey of Query Expansion, Query Suggestion and Query Refinement Techniques

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Abstract—**The ineffectiveness of information retrieval systems often caused by the inaccurate use of keywords in a query. In order to solve the ineffectiveness problem in information retrieval systems, many solutions have been proposed over the years. The most common techniques are revolving around query modification techniques such as query expansion, query refinement, etc. Due to the high similarity in these query modification techniques, people are often confused about their differences. However, few existing survey papers compare their differences. Hence, in this paper, we first briefly discuss the basic technique of query expansion, query suggestion and query refinement, and then make a detailed comparison between these three techniques. We finally show the promising future research trend in the field of query modification.**

Keywords—query expansion; query refinement; query modification; query suggestion; information retrieval

I. INTRODUCTION

Internet has become one of the most important part of our daily life. One of the most common use of the internet is gathering information as the biggest advantage that offered by the internet is the tremendous amount of information. Almost any kind of information on any topic can be found on the internet. However, without the help of information retrieval systems, if a person wishes to retrieve any information from the internet, they have to know the precise web address of the web pages the information they needed from. Hence, it seems to be an impossible task.

Since the debut of information retrieval systems in the 1990s, it had become one of the most important and valuable aspect in the information technology field. 10 years ago, founder of the Northern Light search engine, David Seuss titled one of his talks as "Ten Years into the Web, and the Search Problem is Nowhere Near Solved" [1]. This sound rather pessimistic by that time. However, 10 years later, it is indeed that many problems of the information retrieval systems didn't solve yet. Much research has been done in order to improve the efficiency of the information retrieval systems. There are still many unsolved problems exist in the information retrieval systems.

This paper reviews the different approaches used in query expansion, query suggestion, query refinement and also the comparison between these three query modification techniques. Section 2 will outline the motivation and also the challenges in information retrieve. Section 3 is an introduction of query expansion and their approach. Section 4 we will discuss query suggestion and their techniques. In section 5, it will be a brief introduction about query refinement. We are going to discuss the differences between these query modification techniques in section 6. In section 7, we will discuss further study of this area. A small summary will be concluded in section 8.

II. CHALLENGES IN CURRENT INFORMATION RETRIEVAL SYSTEMS

Ineffectiveness of information retrieval systems often caused by the query inaccuracy. Retrieve information from the internet using an information retrieval systems often need precise keywords from multiple field to achieve the best result. This is because, information retrieval systems often need the exact keywords to return a high quality result list. Hundreds of thousands of irrelevant documents will be returned if the selected keywords are too general. This has become a problem for a user when they are not sure about the nature of the content they needed or the difficulties of describing the nature of the context of the information needed in just a few keywords.

Vocabulary mismatch is also one of the reasons for the ineffectiveness of the information retrieval systems. It is the fundamental problem for the information retrieval [2]. It is a common phenomenon that exists in natural language where a same concept or item was named differently. This may cause by the polysemy or synonym. Polysemy is the same word with different meanings such as a mouse, it could be an animal or it can also mean computer devices. On the other hand, synonyms is a word having the similar or nearly the same meaning as another word or other words for instance PC and computer.

Multiple approaches were proposed to solve the problems exist in the information retrieval systems, including word sense disambiguation, query expansion, query refinement and result clustering and re ranking. These techniques, tackle the problem of ineffectiveness in documents retrieval rate by modifying the query to improve the quality of the query since many believed that the inaccurate query is the major cause for the problem exists in information retrieval.

Several survey papers have been written for query expansion and query suggestion. In 2007, Bhogal, Macfarlance and Smith had written a review about ontology based query expansion. Even though this paper focus on query expansion that based on domain specific or general ontology, they also wrote an overview about different approach used for query expansion [3]. A few years later, Carpineto and Romano wrote a review about automatic query expansion in information retrieval, their approach, data sources and techniques [4]. 2014, Meng presented a general review on query suggestion, their approach and how to evaluate their performance [5].

Due to the similarity between the methods used in these query modification techniques, researcher, especially the new researcher often confuses about the differences between each query modification technique. Even though, there are quite a number of review papers have been written about the query modification techniques respectively, not a lot of review papers that discuss the overall methods and performance for query modification technique and their differences. Hence, in this paper, we would like to clarify the differences between several query improvement techniques and also summarises the various information about each technique.

III. QUERY EXPANSION

Query expansion is a process of reformulating a seed query to improve retrieval performance in information retrieval operations. There are quite a number of researchers firmly believe that inaccuracy of the query formed by a few keyword model that the actual user information need is the main reason for the ineffectiveness of information retrieval systems [4].

The main motivation of query expansion is to add meaningful terms that will help the user to remove the ambiguity of the natural language and also express the information concept in a more detailed way into original query [6]. By adding related words to the original query can also increase the number of relevant documents identified, hence increase the chances of relevant document discovery.

Adding additional terms into query can either be automatic, manual or user-assisted. Manual query expansion depends on user input to decide which terms will be added to the original query while automatic query expansion is a technique that relies on the terms weighing. Terms with the highest weight will be added to the original query. A proper weight is needed in order to receive a useful result.

A. Query expansion using corpus dependent knowledge model

Between late 60s to early 70s, a series of researches had been carried out to investigate the effectiveness of query expansion using term clustering. Researchers believed that the pairs of words that often occur together in the documents are about the same subject [7]. Similar documents are placed in a cluster. With the previous assumption, if the query terms are mapped into one or more than one cluster(s), terms in the cluster can be used as the terms to expand the original query.

Thesaurus used for query expansion can be either hand crafted or build automatically. Building a hand crafted thesaurus is a tedious process. One of the most well-known thesauri is WordNet [8]. The downside of the hand crafted thesauri is the domain specific hand crafted thesauri must be paired closely to domain-specific document collection in order to receive good result [9]. Another drawback for the hand crafted thesauri is that it is too general or lack of the ability to include new words. Hence, it is more suitable for static document collection instead of web documents.

Traditional automatic thesaurus gather words together based on their occurrence pattern in a cluster [10]. One of the in-adequateness of corpus based query expansion is when user's query is not listed in the thesaurus, the process of query expansion cannot be completed. Another weakness of corpus-based query expansion the inability to determine term relationships which occur between words which are used in the corpus and those that are used in different community [11].

In 2003, Vechtomova, Robertson and Jones proposed two novel approach of query expansion using two types of long-span collocates, global and local [12]. In global collocates, query terms are extracted from the entire collection while in local collocates, query terms are only extracted from a sub net of retrieved documents. The experiments show that the approach using global collocation analysis are worse than the original query. The terms extracted globally are too general may be one of the reasons for the poor experiment result. Local collocations received a better result in this experiment.

B. Query expansion using relevance feedback

Relevance feedback is a well establish approaches for expanding query by choosing important terms or expression, attached to documents retrieved from original query that had been identified as relevant by the users or the system assume the top ranked documents as relevant [13].

In order to make a successful expansion, a few assumptions must be made. First, the user must have sufficient knowledge about the document they desire to compose the initial query. Misspelling, cross-language information retrieval, and also mismatch of searcher's vocabulary versus collection vocabulary cannot be solved just using relevance feedback [14]. There are three different types of feedback, ad hoc or blind feedback, implicit feedback and explicit feedback.

1) Ad hoc (blink) feedback

Blink feedback or ad hoc feedback is based on the assumption of top ranked documents return by information retrieval systems is relevant to the document desire by the user [15]. Users often provide terms that are not suitable for the relevance judgements. In this situation, blind or ad hoc feedback is used to expand the initial query. Terms are

extracted from top ranked documents retrieved by a user's initial query for the query expansion.

Effectiveness of ad hoc feedback is based on the quality of the initial top ranked documents retrieved by the original query. Query drift occurs when the initial top ranked documents retrieved is not the most ideal. This is a situation where the alteration of the focus of a search topic caused by improper expansion. It has become one of the major drawbacks in ad hoc feedback [16]. Much research had been done to prevent or minimize query drift such as predicting the query effectiveness, or estimating query drift.

Cao, Nie, Gao, and Robertson proposed to use supervised learning for selecting the terms for expanding the query [17]. In their experiment, they notice that the lack of effectiveness in the traditional way of selecting expansion terms. Only a very small proportion of the terms suggested are useful and the supervised learning term selecting methods achieve a slightly better result than the traditional methods.

2) Explicit feedback.
In explicit feedback system, feedback is obtained by the explicit evidence showing the relevance of a document [18]. Graded or binary relevance are often used in an explicit feedback system. Graded relevance feedback presents the relevance of a document to a query using numbers, letters or any other form of marking appointed by the researcher. The proper scale to rate the document in order to receive the best result remain unclear even after numerous research studied on this topic [19]. On the other hand, each document in the query only needed to be marked as relevant or irrelevant to the original query in binary feedback. Binary feedback assume that all the documents are equally important to the users. Both methods need the input from the user to provide feedback which may be an additional burden for the user. Hence, despite the improvement in the retrieval effectiveness of explicit feedback, it does not always reliable or is applicable in the query expansion.

Chapelle, Zhang, Grinspan and Metzler proposed a novel evaluation metric for information retrieval called expected reciprocal rank [20]. The metric measures the expected effort required to satisfy a user's information need. Their experimental results suggest that the expected reciprocal rank real user browsing behaviour better and quantifies user satisfaction more accurately than other editorial metric.

3) Implicit feedback
To overcome the problem exists in explicit feedback, implicit feedback was proposed. Implicit feedback understand user interest and preference by observing user behaviour [21]. Information needed for implicit feedback can be collected in a lower cost and also without the burden on the user in the retrieval system [22]. However, information collected is harder to understand and potentially noisy. Systems can only make assumption about user behaviour and motive from the collected data.

C. Query expansion using language model
Another famous approach for query expansion is to build a statistical language model for the query, specifying a probability distribution over terms [4]. Terms used for query expansion are selected according to the probability in the language model. Those with the highest probabilities are often selected. Language modelling not only produce promising results in the experiment, it also provides a solid theoretical setting [23]. Due to the increasing number of successful experiments and also the intuitiveness of the model formulation, query expansion using language model has rapidly become a preferable choice over probabilistic and vector space models.

Buscher, Dengel, Biedert and Elst determine that there's a good relation between relevance and gazed based measure and also validated them into their experiment [24]. Also, the variation of gaze measure varied between individual and also the difficulties of the task. However, they discover that popular measures of "fixation duration" does not seem related to perceived relevance.

IV. QUERY SUGGESTION

Another approach to solve the ambiguity and inaccuracy in the information retrieval system is query suggestion. It is very common for a user to reformulate their query when they didn't receive ideal result from their original query. The system can improve the user's searching effort by providing suggestions by guessing the user intention, according to users past behaviour [25]. A series of experiments on man-machine interaction of information retrieval system indicate that instead of automatic query expansion, users prefer to use query suggestion to improve the effectiveness of their original query [5]. Providing effective and useful query suggestion is the most important motivation for query suggestion.

A. Click-through based query suggestion
Click-through based query suggestion focus on mining user's click pattern in a search log. Traces of the click-through for each query are recorded. The clicked URL can be used to exploit the relationship between different queries [5]. If the queries in the same cluster are classified as the same or similar topic, the queries within the same cluster will be used as the query suggestion.

Leung, Ng and Lee proposed a method that provides personalization query suggestion based on a personalized concept based clustering technique [26]. Instead of providing similar suggestion to every user, they clustered user click-through data to predict user intention and preference. A personalized query suggestion was given to every user based on their past behaviour.

B. Session based query suggestion
Session based query suggestion based on the assumption on every search query in the same session is related to each other in one way or another [27]. A few assumptions can be made regarding session based query suggestion. (1) When a number of queries in the same session in a short time are usually submitted by the same user. (2) In a same session, the user often tried to change their query or try a new query to get a better result. (3) Query submitted by a user in the same session usually are about a single topic.

Cucerzan and White make use of the user past searching experience to generate query suggestion for the new user [28]. This experiment suggests the result list to another user when the user's initial search fulfil the rules determine by Cucerzan and White, which is when user's need are satisfied by the information retrieval systems, whereas the use of query sessions captures mostly the other cases, in which users refine queries to direct the information retrieval systems into a new result space because they were not completely satisfied with the results for the original query.

V. QUERY REFINEMENT

Query refinement is a process of transforming a query into a new query that reflect the user information need in a higher accuracy [29]. Research about query refinement is not as prevailing as query expansion or query suggestion.

A. Query Refinement using relevance feedback

One of the most well studied approach for query refinement is the use of interactive relevance feedback where the term suggestion are based on the user feedback about the previous retrieved documents [30]. However, due to the user reluctant in making prerequisite document relevance judgements, this method does not widely implement in practice, even though it has received a high recall rate and also improve on the precision of the subsequent search [31]. Generating terms suggestion from the top rank documents regardless of its relevance has been one of the approach to solve this problem.

Sadikov, Madhavan, Wang and Halevy proposed an approach for query refinement by occurrences within user search sessions, which received an effective result for the query that are unrelated content wise. However, their effort of grouping the queries based on their respected search result such as grouping the queries that shared many similar clicked from the result list or the vocabulary of the clicked documents does not receive any decent result [32].

VI. COMPARISON BETWEEN QUERY EXPANSION, QUERY SUGGESTION AND QUERY REFINEMENT

Query modification is a modification applied in a query in order to improve the accuracy, retrieval rate of its previous search result and also removing the ambiguity in the original query. It revolved around the same problem. (1) Ambiguity in query. (2) Vocabulary problem that commonly exists in most of the information retrieval systems. (3) Vagueness in the query. Every techniques are trying to solve the same problems with a slightly different approach.

Query expansion, query suggestion and query refinement are some of the most well-known query modification techniques. Due to the nature of these techniques and their application methods such as these techniques are built based on the modification of the query or they are based on the user feedback or the result list of the previous query, the real differences between the techniques are often confused by the researchers especially those who are new.

The similarities between these techniques are they are all with a same motivation, which is improving the information retrieval rate as we mentioned before and they are also based on the modification of the query. Query expansion and query refinement are more similar in the sense of query modification than query suggestion. Query expansion is a method of expanding the user's original query to improve the retrieval number from the information retrieval system in hope of increasing the chances of relevance documents discovery. This is a fairly well-used technique in the early days of information retrieval system. Much research has been done and many aspects of how to achieve the ideal result has been proposed. Mitra et al. proposed their query expansion method by using relevance feedback [33]. Using a manually formulated Boolean filter, documents used for relevant feedback had been filtered and this has proven that it prevented query drift that are often found in query expansion based on relevance feedback. They also make use of term co-occurrence information to estimate the connection between the text in a query and their concept to automatically predict the terms of query expansion. Many commercial information retrieval system had given the user the chances to include query expansion in their searching.

On the other hand, query refinement transforms a query into a new query that will retrieve the user's desired documents with a higher accuracy instead of adding relevance query as query expansion has done. In a research done by Velez et al., RMAP was introduced [29]. RMAP is an algorithm that dynamically combining precomputed suggestions for single term queries in order to refine multiple term queries. In this paper, they also proposed an experimental framework to predict the effectiveness of a suggested query by an algorithm. Query refinement often modified the original query based on the feedback provided by the user. It is not as renowned as query expansion most likely due to the high dependent on user feedback.

Although query refinement provides a new query to the user based on their past query history, it does not give the user choices in what terms to replace the original query. They acted on behalf of the user based on their assumption on the user's need and purpose. This has an obvious drawback where the user input regarding their interest and opinion on the relevance documents is not considered when a new query is generated.

Query suggestion provided a solution for this disadvantage in query refinement by suggesting several queries that the system deem related to the user's interest according to the assumption made by the information retrieval system based on the user past behaviour. Users are able to select which terms they would like to replace the original query if the original are not what they expect. This has become a preferable method compare to query expansion and query refinement for improving the result list retrieval rate for the relevant documents. Many commercial browsers nowadays had adopted this technique in their searching algorithm as this has provided a higher flexibility for the user in improving their query.

A context aware query suggestion approach was suggested by Cao et al. [25]. By clustering a click-through bipartite, queries were summarised into different concept during the offline model learning step. Later on, a concept sequence suffix tree was created according to the query suggestion model. The suggested query was generated according to the sequence

suffix tree mentioned above. Experimental result shown that, this method was better in both coverage and quality.

In the table below we will show a small comparison chart of these three techniques.

TABLE I.   Comparison table for query modification techniques

	Generate new query	Expand original query	User feedback before modification	User feedback for final modification
Query Expansion		✓	✓	
Query refinement	✓		✓	
Query suggestion	✓			✓

VII. FURTHER RESEARCH

Even though that, much research has been done, numerous approaches were proposed to improve the effectiveness of information retrieval system, clarify the ambiguity in the query. The solutions are not perfect yet. The ambiguities of queries still exist in most of the information retrieval systems. There are some methods that are being more favour than another. However, the accuracy of these methods still heavily relies on the user input query. Modification in the query can be done in a more intelligent way. Instead of severely based on the user's original query, it can be more predictable on what the user need and their intention. A more diversify query terms can be suggested to the user instead of the rigid, routines suggestion. There was some research that has been done to diversify the query suggestion. However, it didn't receive any significant result yet.

VIII. CONCLUSION

This paper looks at the differences between query expansion, query suggestion, and query refinement. It analyse different method such as relevance feedback, language model, corpus dependent model that the researcher use in approaching these problems. This paper also analysis case studies on every different method. A small summary of the differences between these techniques are also presented in this paper.

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