International Journal of Information Science and Management
Vol. 15, No. 2, 2017, 123-134

Effect of Expansion and Reformulation of Query on Improved Precision of Retrieval Results

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Abstract

Expansion and reformulation of queries are among the most common strategies employed by users in retrieval of initial results to coordinate them with their needs. The present study examines the expansion and reformulation of queries and their impact on improving the precisionof the retrieval results.The analytical survey method was used to evaluate the relationship between the variables. The study was conducted on the MA students of the Information Science and Knowledgein Islamic Azad University of Ahvaz, Khuzestan Science and Research Branch, who had the seminar course(n=28). The data were collected using a researcher-made questionnaire. The results showed the lack of enough time to review all the retrieved results as the most important reason for the expansion and reformulation of queries (mean = 4.66). In addition, the users reported different perceived usefulness of the expansion and reformulation tools for the retrieval results where they perceived the reformulation strategy more useful (mean =3.781). Furthermore, the precision of the initial results was significantly increased using the reformulation tools. The tools including limiting the search terms by the resource title, subject, year, and searching the initial results enhance the overall precision of the initial results. However, for the expansion tools, using these limiting approaches resulted in no significant difference between the precision of initial results and the final retrieval results. The results show that using the expansion and reformulation tools to correct the initial search may have different reasons. Moreover, the use of these tools affects the precision of searches.

Keywords: Query Expansion, Query Reformulation, Retrieval Precision.

Introduction

Whenever a user is in need of information, he/ she has either to produce information or use the information produced by others (Babaee, 2003).A method of meeting information need is the use of databases. The databases are not a data warehouse; rather they contain different toolsin the form of searchinginterfacewhich can be used by individuals to satisfy their information needs. The different databases use a wide spectrum of tools and mechanisms to support the richness of results both from the recall and precisionviewpoint.

A main issue in aninformation retrieval is appropriate explain of the users' information need in the framework of query expressions;so that retrieval system is to be able to properly distinguish relevant documents from irrelevant ones (Salton and McGill, 1983). Eachinformation need should be expressed in the form of search terms, keywords, in order to be used in an information retrieval system. While keyword searches usually lead to a great amount of data, providing the results relevant to keyword queries is still a challenging issue (Liu, Natarajan and Chen, 2011). Appropriate use of query operators increases the web search efficiency, realized by increasing number of retrieved documents and relevant retrieved documents, or improving the ranking of documents (Eastman and Jansen, 2003).

Expansion and reformulation of queries are two majorstrategies used in different sources in various forms. However, He and Ounis (2009) reported that investigation of query circumstances has not been successful in all cases. The expansion and reformulation stages indicate the correction of initial query formulation manually or systematically (Huang and Efthimiadis, 2009; Mastora, Monopoli and Kapidakis, 2008) to improve information retrieval performance (Joshi and Doshi, 2013). Query expansion is a semi-automatic process for improving retrieval procedureby developing the new queries based on users' original query (Ma, Lin & Jin, 2010),that increase the probability of retrieval of more relevant documents (Alharoob, Khafajeh and Innab, 2013).

The use of the tools for the expansion and reformulationof queriesis influenced by some factors.The precision of initial resultsand users'perception of the usefulness of tools is some of these factors. Precision measures the accuracy of a search, defined as the ratio of retrieved relevant documents to all relevant and irrelevant retrieved documents, which is calculated using the Eq. 1 as follows (Davarpanah, 2003):

$$P = \frac{\text{Retrieved relevant documents}}{\text{All documents retrieved from a file}}$$

In addition, usefulness is the extent one believes the use of a certain system promotes his/her performance of a certain task (Davis, 1989; Mathwick and Malhotra, 2001); and user's perception of the outcome of an experience (Davis, Bagozzi and Warshaw, 1992). Therefore, in this study, these two factorswere investigated as independent variables influencingthe users' application of query tools.

The reformulation and expansion of query frequently as a research challenge is studied only in lab conditions. Because of Science Direct database has used these tools within a framework of its search user interface, we selected it as a natural condition that used this tools and investigate the usefulness and efficiency of expansion and reformulation tools based on users'

point of view. These tools require a study in realconditions. Therefore, this study aimed to investigate the usefulness of expansion and reformulation tools and their effect in improving the precision of initial retrieved results.The main contributions of this study are as follows:

- Research field is Science Direct database tools;
- Study the usefulness of both query expansion and reformulation tools;
- Analyzing the results step by step from initial query forming to using of tools individually.

The conceptual framework of this study is depicted in Figure 1.

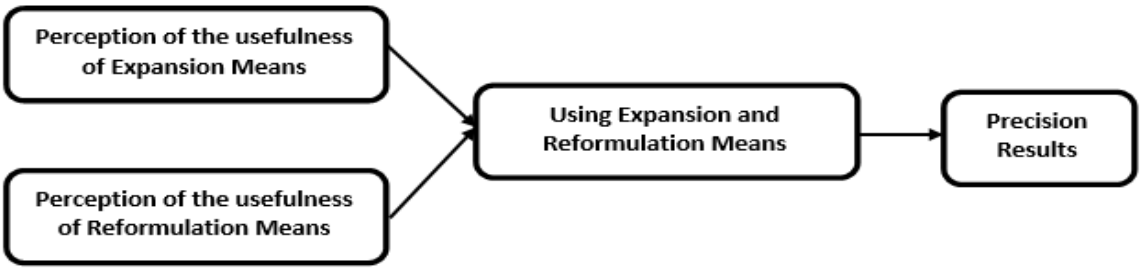

Figure1. Conceptual Framework

Literature Review

Majority of researches on query expansion and reformulation tools for search have focused on search strategies, web search engines, or offering automatically generated query suggestions to the user.

- **Search Strategy and Initial Query Status**

By development of the databases and the emergence of various search engines have necessitated the need for using different techniques and effective search approaches such as query expansion (Hayati and Shafiee, 2011).When users conduct information searches, they must have search strategies that combine the choice of search terms, operators, and tactics (Vakkari, 2003 cited in Rieh and Xie, 2006). Results of initial query can encourage users to redefine theirsearch strategy. Huang and Efthimiadis (2009) stated that the users often correct the previous search results in hope of retrieving better results. Then, users need supporting mechanisms while expressing their information needs through search queries.

- **Query Expansion and Reformulation Mechanisms**

Query expansion and reformulation are the two major mechanisms used for improving search performance. Salton and McGill (1983) indicated that users' attempt to greater retrieval of relevant documentsis the reason for query expansion and reformulation. Search expansion strategy can increase the precision (Fonseca, Golgher, Possas, Riberio-Neto and Ziviani, 2005; Lin, Wang and Chen, 2006; and Lioma and Ounis, 2008) and the relatedness in retrieved results in search engines (Fattahi, 2006). The success of query expansion depends on how the initial query is posed (Kekalainen and Jarvelin, 2000; Lesk's, 1969; and Voorhees's, 1994). Cao, *Nie, Gao and Robertson (2008)* demonstrated that good expansion expressions are to be known directly from their potential effect on retrieval usefulness.Huang and

Efthimiadis (2009) stated that users can also benefit from an improved search experience when performing reformulations. Although many studies have been conducted on query expansion or reformulation fields, challenges of improving precision and correctness in retrieving process still remain (Yoo and Choi, 2010). Considering the findings of previous studies, the present study was mainly aimed to investigate effectsof query expansion and reformulation procedures in improving the precision of results retrieved from the Science Direct database. Our specific purposes were: 1) to determineusers' reasons to use query expansion and reformulation,2)to determineusers' perceived usefulness of results retrieved using expansion and reformulation tools; and 3) to determine the difference between the precision of initial results and theprecision of query expansion and reformulation tools.Therefore,the following questions and hypotheses were posed:

Q1: What are the users'main reasons ofthe necessityof the query expansion and reformulation?

Q2: What is the users' perceived usefulness of the query expansion and reformulation tools?

H1: Users' perceived usefulness of results retrieved following the expansion and reformulation tools shows a significant difference.

H2: A significant difference exists between the precision of initial results and precision of retrieved results following reformulation and expansion tools.

Methodology

This study was aimed to investigate the relationships between the variables; thus, the analytical survey methodwas used. For this purpose, using patterns of similar previous studies (Hendrickson, Massey and Cronan, 1993) a researcher-made questionnaire was designed.The validity of the questionnaire was officially confirmed by the faculty board members of the Information Science and Knowledge department (Ahvaz Azad University). In addition, its reliability was confirmed using Cronbach's alpha values of 0.966. The study population was MA studentsof the Information and Knowledge Sciencesstudying the researchseminarcourse.They all hadspecificinformation needsinthe form ofthekeyword expression. Therefore, people participated in the research process over the six steps, as follows:

Due to limitations in the number of students studying the Information Science and Knowledgein Islamic Azad University of Ahvaz taking a seminar in a research course,the population consistedof only 28 students (n=28). In the second step, students were taught on how to use Science Directdatabase and its various tools. In the third step, the participantsperformedthe initial search andthe results were arranged based on the relevancy and they selected relevant documents from retrieval results. In the fourth step, students were asked to answer the questions in the relevant part if they needed to expand and reformulate the results. In the fifth step, they were required to repeat the various expansions and/or reformulation tools based on the number of tools; and each time they were required to evaluate their relevance feedback (Precision Coefficient). In the sixth step, users evaluated the perceived usefulness of each tool.

In this study three types of tools were used for data collection: 1) A researcher-made questionnaire; 2) Ashampoo Snap 4 webcam capturing software (for filming the desktop screen while being used by participants and only used to make sure of search process or double check the vague or suspicious cases); and 3) Researcher's direct observation of the search process.

Results

Research Question 1: What are the users' main reasons of the necessity of the query expansion and reformulation?

The Friedman's test was used to identify the users' most important reasons for query expansion and reformulation tools (Table 1).

Table1

Descriptive statistics of Friedman's tests on the users' the most important reasons for their need to use query expansion and reformulation tools.

Users' reasons for their need to query expansion and reformulation	Number	Mean	SD	Min	Max	Mean of Ranks
Not having enough time for evaluating all retrieved results	28	3.57	1.200	1	5	4.66
Lack of relationship between results and information need	28	3.64	1.162	1	5	4.63
Least amount of retrieved results	28	2.64	1.367	1	5	3.20
Great amount of retrieved results	28	3.36	1.496	1	5	4.29
Difficulty of finding relevant information	28	3.18	1.188	1	5	3.82
Being boring evaluation of this amount of retrieved results	28	3.25	1.295	1	5	3.93
Being frustratingresults retrieved based on document relevance characteristics	28	2.89	0.994	1	5	3.48

The rank of each variable was assessed using the Friedman's Test (Table 1). A significant difference exists between the mean scores of variables: "least amount of retrieved results" variable has the lowest score(M=2.64), compared to other variables.Results of Friedman's Variance Analysis showed that chi-square test (x^2 = 13.47, df = 6 and P-Value=0.036) is significant and this analysis is acceptable. In other words, the mean rank of "Not having enough time for evaluating all retrieved results" (mean of rank =4.66)which isthe users' most important reason for using the query expansion and reformulation tools. Furthermore, the "Least amount of retrieved results" (mean of rank = of 3.20)was in the last rank order.

Research question 2: What is the users' perceived usefulness of the query expansion and reformulation tools?

In the Science Direct database, the query expansion tools include "recommended articles tool", and "relevant reference work tools" and the query reformulation tools include "search revision", "limiting to the type of publications", "limiting to the subject", "limiting tothe year", and "limiting tosearch in the results".

Table2

Frequency distribution for users' perceived usefulness from query expansion and formulation and reformulation tools

Tools	Factor/ usefulness	N	M	SD	SEM
Query expansion tools	Users' perception of the suggested article tools	28	3.46	1.06	0.202
	Users' perception of relevant reference works tools	28	3.34	1.08	0.204
	Sum (Users' perception of query expansiontools)	28	3.40	0.915	0.173
Query reformulation tools	Users' perception of search revision tools	28	3.87	0.655	0.123
	Users' perceived usefulness of limiting to the type of publication	28	3.70	0.917	0.173
	Users' perceived usefulness of tools for limiting to the source' name	28	3.91	0.758	0.143
	Users' perceived usefulness of tools for limiting to the subject	28	3.92	0.849	0.160
	Users' perceived usefulness of tools for limiting to a year	28	3.63	0.954	0.180
	Users' perceived usefulness of search in results tools	28	3.64	1.01	0.191
	Sum (Users' perceived usefulness of query reformulation)	28	3.78	0.650	0.122

The mean Sum score of the query expansion tools item is 3.40, which is greater than average (Table 2). Accordingly, the highest and lowest perceived usefulness by users is for the "tools of recommended article" and "tools of related reference works" items, respectively. The mean score of the responses fluctuated between 3.34 and 3.46 indicating the appropriateness of query reformulation tools for users. In addition, mean Sum score of the query reformulation tools item is 3.78 which is higher than mean andat an appropriate level. Therefore, the highest and lowest perceived usefulness of query reformulation tool by users is for the "limiting to subject tools" and "limiting to year" items, respectively. The average score of responses fluctuates between 3.63 and 3.92 indicatingthe usefulness of the query reformulation tools for users.

Table3

One-tailed T-test for users' perceived usefulness

Theoretical Mean= 3						
	T	Df	Sig.	Mean Differences	Confidence Interval 99%	
					Min	Max
Users' perception of query expansion tool	2.339	27	0.027	0.404	0.049	0.759
Users' perception of query reformulation tool	6.355	27	0.000	0.780	0.528	1.032

The t-test analyses showed the mean scoreof the users' perceived usefulness of query expansion tools (Table 2) is 3.40. In addition, the calculated T is 2.339 (for$\alpha = 0.05$) whichis smaller than the critical *T*. Therefore, the mean calculated difference and the theoretical meanis not significant indicating that the perceived usefulness of users of query expansion tools is at a medium level (P=0.05). In addition, the mean score for the perceived usefulness of users of query reformulation tools (Table 2)is 3.78. Furthermore, the obtained *T*(6.355 at the level of $\alpha = 0.05$) is greater than the critical *T* and the difference is statistically significant. Therefore, while the perceived usefulness of users of query reformulation tools is higher than average indicating the users considered it useful (P= 0.05).

Hypothesis 1: Users' perceived usefulness of results retrieved following the expansion and reformulation tools shows a significant difference.

In order to test the first hypothesis, the respondents were required to reply the following usefulness statements"Use of this tool helped me to faster find the results, compared to initial results, use of this tool had more successful results for me, Use of this tool helped me to save time; Use of this tool helped me to qualitatively obtain more relevant results according to the ideal expected results;This tool is user-friendly; Considering retrieved relevant results, I believe it is a useful tool. A5-point Likert scale (very much, much, medium, little, and very little) was used to investigate the usefulness of query expansion and reformulation tools.

Table4

Correlated t-test results of users' perceived usefulness of results retrieved during the use of expansion and reformulation tools

Dichotomous Comparisons	Descriptive Statistic				Differences between dichotomies		Correlated t-test		
	M	N	SD	SEM	M	SD	t	Df	Sig.
Reformulation Usefulness	3.781	28	0.650	0.123	0.376	0.838	2.375	27	0.025
Expansion Usefulness	3.405	28	0.916	0.173					

A significant difference existsbetween the users' perceived usefulness of retrieved results following the tools (Table 4). A significant difference existsbetween "reformulation usefulness" and "expansion usefulness" tools (hypothesis 1)(p-value ≤ 0.05, df = 27 and t = 2.375).The mean score of users' perceived usefulness of query reformulation is3.781, whereas for the expansion tools is 3.405 which is statistically significant difference (P=0.05) (Fig. 2).

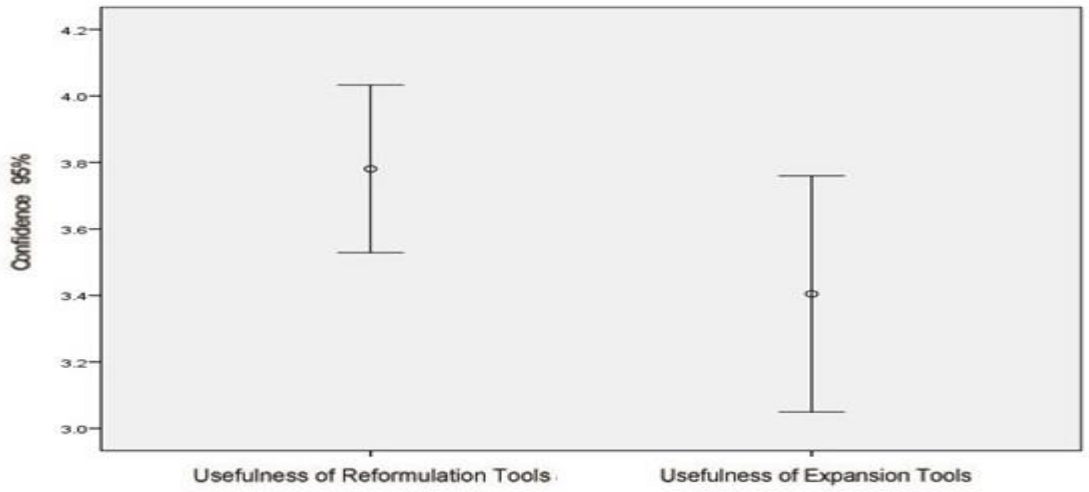

Figure2. The users' perceived usefulness of the results retrieved for the query expansion and reformulation tools (data are presented as mean ±SD).

Hypothesis 2: A significant difference exists between the precision of initial results and the precision of the retrieved results following query expansion and reformulation tools.
This hypothesis is proposed and tested as two separate hypotheses as H2 (a) & H2 (b).
$H_{2\,(a)}$: A significant difference exists between the precision of initial results and the precision of query reformulation.

Table5
The results of correlated t-test for precision of initial results and precision of query reformulation

Dichotomous Comparisons	Descriptive Statistic				Differences between dichotomies		Correlated t-test		
	M	N	SD	SEM	M	SD	T	Df	Sig.
Precision of initial results	8.51	28	10.04	1.898	-5.85	20.19	-1.532	27	0.137
Precision of search revision tools	14.36	28	20.92	3.954					
Precision of tools of limiting to type of publication	9.57	28	11.23	2.122	-1.05	11.30	-0.492	27	0.627
Precision of tools of limiting to the title of source	18.93	28	19.83	3.747	-10.41	23.68	-2.33	27	0.028
Precision of tools of limiting to the subject	33.61	28	35.51	6.711	-25.09	35.46	-3.74	27	0.001
Precision of tools of limiting to the year	20.36	28	26.12	4.94	-11.85	26.74	-2.34	27	0.027
Precision of tools of limiting to the search in results	21.88	28	24.95	4.72	-13.37	24.65	-2.87	27	0.008

The precision of initial results was significantly different from the precision of reformulation tools ($P \leq 0.05$) (Table 5). This difference was observed for the four reformulation tools including "limiting to the source's title", "limiting to subject", "limiting to

year", and "limiting to the search in results"($P \leq 0.05$). However, the other two tools including "search revision tools" and "limiting to publication tools" showed no significant difference.

$H_{2\,(b)}$: A significant difference exists between the precision of initial results and the precision of query expansion tools.

Table6

The results of correlated t-test for precision of initial results and precision of query expansion

Dichotomous Comparisons	Descriptive Statistic				Differences between dichotomies		Correlated T-test		
	M	N	SD	SEM	M	SD	t	df	Sig.
Precision of initial results	8.51	28	10.04	1.898	1.419	14.72	0.510	27	0.614
Precision of recommended articles tools	7.09	28	10.675	2.017					
Precision of relevant reference works	10.94	28	20.09	3.797	-2.427	23.50	-0.546	27	0.589

No significant difference ($p \geq 0.05$) exists between the initial results' precision and the expansion toolsprecision(Table 6).In other words, use of expansion tools did not improve initial precision.

Discussion and Conclusion

Users employ query expansion and reformulation tools after theirevaluation of initial retrieved results. Query expansion and reformulation tools moderate retrieval results. The users' dissatisfaction with the initial search results is the main cause for using query reformulation and expansion tools. They try to reorganize the initial results to achieve a satisfactory result. Our results showed the most important reasonsforusing query expansion and reformulation tools by the users were respectively 1) lack of relationship between initial search results and information needs,2) lack of enough time to evaluate all retrieved results,3) time consuminganalysis of the great amount of data to find the relevant information, and, 4) disappointing results retrieved based on the relevance of document characteristics and little amount of retrieved results (Table 1). Our finding on dissatisfaction withthe results as the main reason for using query expansion and reformulation tools is consistent with the findings of Voorhees(1994), Hayati and Shafiee (2011),and Salton and McGill (1983).If the initial query is a full description of information need, it does not improve the query expansion technology of relevant documents. However, the questions which have not been initially well defined, can achieve the appropriate results with this method. Therefore, the initial search in Science Direct does not provide satisfactory results, which might be rooted in users' disability, deficiency of search system of database, or deficiency of the representation method of documents. Lack of relationship between results and information need is the first reason reported by userfor query expansion and reformulation. Therefore, in indexing documents of the Science Direct database, the tendency was toward holistic approach which decreased precision. The smallamount of retrieved results also confirms this result as users perceived the initial search results as inappropriate. The findings of our study showed that perceived

usefulness of query expansion tools by users was at anaverage level (Table2) so that they reported them as useful. In addition,theperceived usefulness of reformulation tools was higher than average and the users perceived them as useful (Table 2). This finding is in agreement with the findings of Mastora et al.(2008), and Huang and Efthimiadis (2009).

The findings also showed a significant difference between the users' perceived usefulness of query expansion and reformulation tools. It is claimed that the perceived usefulness by users of retrieved results showed a significant difference during the use of the query expansion and reformulation tools (Table 4).No previous studies have indicatedthe perceived usefulness of users of results retrieved during the use of query expansion and reformulation. Our findings demonstrated that the usefulness perception is not the same for all tools. In addition, a statistically significant difference was observedbetween the initial result's precision and the reformulation tool's precision ($P \leq 0.05$) for four tools and the usefulness of query reformulation tools (Table 5). This finding supports the findings of Huang and Efthimiadis(2009) and Yoo and Choi (2010).

We found no significant difference between the precision of initial results and precision of expansion tools (Table 6). Use of expansion tools did not improve precision of initial results. These findings contrast the findings of Hayati and Shafiee(2011), Fonseca et al. (2005) and Lin et al. (2006).Interestingly, although the difference between the initial precision and the precision mediatedthrough two expansion tools was not significant, the query expansion tools were useful and satisfactory. Using reformulation strategies will always decrease the number of documents, compared to the initial search results, whereas the expansion tools do not yield permanent improvement. Furthermore, using expansion tools probably increases the number of retrieved documents, compared to the initial retrieved documents which in turn affectprecision.

Our findings showed that query expansion and reformulation tools are usefulness.Previous studies have indicated that good expansion strategies must be directly identified according to their potential effect on the retrieval usefulness (Cao *et al*., 2008). On the other hand, a part of the usefulness of the query expansion and reformulation tools is because of the rates of precision and recall from information retrieval systems increases during the process.

Applying query expansion tools in developing user interface databases can accelerate and simplify searching and finding the appropriate results. Furthermore, when users are not able to usevarious strategies for re-preparation of query, query expansion approach enhances the searching efficiency through improving searching function and helps them to retrieve more relevant results. Users' perception of usefulness of query expansion and reformulation tools can lead to useful and satisfactory use of databases. In addition, this improvedperception can increase the users' benefit from the results. However, perceived usefulness is not the same for all tools and requires revision. Inappropriate acquaintance with using the tools and their efficiency for various searches and topics in a database can lead to a different usefulness rate. Finally, based on the findings of this study,the key conclusions are as follows:

- Considering specificity in documents indexing can improve the initial queries' result.
- Usingquery expansion and reformulation tools can significantly improve search results and the precision rate.

- Search skills of users must be improved to use best search strategies and query expansion and reformulation tools.

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