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Information Retrieval through Mobile Devices using Semantic Ontology

W. Aisha Banu, P. Sheik Abdul Khader and R. Shriram
School of Information and Computing Sciences, B.S. Abdur Rahman University,
Chennai, Tamil Nadu, India

Abstract: There has been a rapid growth in the number and volume of mobile devices. The growth rate of the mobile web usage has increased dramatically fuelled by the increasing availability and cheap cost. One of the promising areas of research is in improving the relevance of the results retrieved for search queries. Mobile web search has its own characteristics which is perhaps unique and in some ways different from search through computers. There is a need for fast, personal and effective information retrieval strategies. This study proposes a semantic ontology based approach for the information retrieval. The essential aspect of this study is to have a semantic fast snippet based re-ranking approach based on a powerful and vivid mobile ontology. The re-ranking process is carried out by the event control access system thus taking a step towards making the information retrieval system understand the information it processes. Experimental results validate the premise of this study. The overall design of the ontological system, re-ranking system and the reasoning mechanism is described in this study.

Key words: Mobile computing, ontologies, information retrieval, semantic web, snippet reordering technique, context, personalization

INTRODUCTION

Improving the dimensions of search operations has been a focus of much research study like that of Bedi and Chawla (2010). This is even more relevant in a mobile phone context. All the information in the world is available in our fingertips literally through a mobile phone. Amershi and Morris (2008) have stated that large populations of the developed world have access to a mobile phone. There is also an explosive growth in the developing countries. But, the usage of the device for the search process is often frustrating to users (Arias *et al*., 2008). When a user seeks information from the Web, the process starts with a keyword being typed in the search field of the search engine. The search engine's software program then utilizes algorithmic functions and criteria to find keyword matches in the information stored in the databases. The vast amount of information leads to information overload according to Tsai (2010). Now, software applications such as by Banu and Khader (2010) have been developed that use the results of the web contents and further provide a prioritized results to the user based on relevancy of the Web page in terms of various criteria.

Developing search applications for the mobile phones is exacerbated by the nature of the domain with its small size screen, limited processing power and communication speeds. Also, methods for handling the content in various file formats of the web in mobile phones are severely limited. The need of the hour is for methods that do not rely on complex data manipulation as the overheads of the data manipulation will add to the bad user experiences. Hence, fast and effective and personalized information access methods are the need of the hour. Personalized information access methods provide an alternative to the one size fits all approach of the web. In a truly personal device like the mobile phone with a single person using the system always, this is (Bouidghaghen *et al*., 2009) perhaps the need of the hour. The various Information Retrieval models have been given by Prasannakumari (2010).

In general, Kastrinakis and Tzitzikas (2010) state that web search can be improved through the improvement of the query, use of ontologies for query processing (Corby *et al*., 2006) and context based approaches. In a mobile phone based context, the web usage is personal in nature, Kamvar and Baluja (2007) state that the searching consists of short queries and demands results that are most relevant to the user There is a need for methods that are relevant and also understandable to the users. In a mobile context, various methods have been proposed to improve the quality of the web search. This study proposes to use an ontology based model for the re-ranking process. An event condition action system is proposed for the reasoning process.

Corresponding Author: W. Aisha Banu, School of Information and Computing Sciences, B.S. Abdur Rahman University, Chennai, Tamil Nadu, India

The solutions for improving the quality of results in the mobile phones are constrained by the limitations of the domain. There have been many approaches in the semantic aspects. A semantic web based local search system was proposed by Jeon and Lee (2007). This study was implemented in data in a simulator based local setting. A methodology for personalizing the search results using ontologies where an intermediate server was placed between the mobile client and the web was discussed by Goenka *et al.* (2010). A framework for web data management using ontologies was described by Huo *et al.* (2009). The use of event condition action languages using semantic web has been described in detail (Papamarkos *et al*., 2003). A variation of the rules for the mobile context in an ontological form has been applied in this study. Knowledge representation and reasoning on this knowledge are the two main components of Semantic web (Ilyas *et al*., 2004).

A genetic algorithm using ontologies has been explained by Bergstrom *et al.* (2000) and Mao (2010). This study uses a reasoning mechanism that uses a complex reasoning system and is based on nested term document pairs. The ontology follows the properties of inheritance. The awareness of a specific situation is called context awareness as per Liao and Tu (2007). This can be used in mobile phones to restrict the granularity of the information served.

Lane *et al.* (2010) shows that the personal context of the user plays an important role in the web search outcomes. In this study, the personal context of the usage is maintained in the personalized ontological model. The intermediate server model has also be used (Carpineto *et al*., 2009) for evaluation of the results using re-ranking algorithms. At this stage, our study does not involve the use of any intermediate server and instead focuses on re-ranking algorithms.

The visualization of search interface queries has been explored by Church and Smyth (2009). A complex and comprehensive method incorporating summarization, visualization and clustering is explained by Machado *et al.* (2009), Van den Bergh *et al.* (2010) mentions that consistency in user interaction operation is a big need for users. This feature is what is of primary importance over other aspects. A method for transforming web pages is explained in Xiao *et al.* (2009). The method is important in the search and display of the contents and will be a part of our future study. A model that adapts itself based on the trends in search of the users has been described (Ruvini, 2003). In our method the adaptation strategy is in the updates of the ontologies. The log based manipulation can be applied in the future. The relevance feedback method outlined in Vinay *et al.* (2005) is adapted and applied in our study. The important difference is that only the results at the website level are considered.

While the above approaches show the depth of the study in the domain, our study is unique in its expressive nature of the ontology, intuitive and feedback based re-ranking algorithm and support for clustering. The study also uses the database centric approach for ontologies thus making it generalizable and extensible. This study uses the snippet clustering approach for ranking the results. The content based clustering for the documents will need a Document object model for the content extraction thus proving to be time consuming.

The contributions of this study are: (1) A fast snippet manipulation method for mobile web search is proposed, (2) A study that shows that using the fast snippet manipulation method increases the accuracy over using a distance function alone and (3) A study of the effectiveness of the ontology construction system over other methods.

Thus, the major objective of the paper was to demonstrate the usage of an ontological mechanism for information retrieval from mobile phones.

MOBILE ONTOLOGIES

The central aspect of this system lies in the mobile ontological system. In general, the use of ontologies provides a mechanism to allow inference on the data, such that an inference engine, in combination with rules, can derive new facts and conclusions implicitly represented in the data. In general, ontology is a formal description of entities and their properties, relationships, constraints, behaviors. This study uses a bottom up approach to the problem of building the ontologies. For the test cases, a domain independent set of constructs were built and the data populated. The system is modeled in terms of its objects, attributes and relations. A mobile ontology has been defined as a machine readable schema that can be used for sharing knowledge and exchanging information across people, services and mobile communications. A variant of the DCS schema (Ercan, 2011) is used in the mobile phones and represented in a database oriented approach. The usage of advanced methods for indexing the contents of the ontology will be a part of our future study. The user has the option of specifying the meanings and category of the relevant measure and the ontological structure grows with time. The ontological structure is represented (Table 1) in an indexed and cross linked database approach and consists of the following constructs. Thus the + symbol stands for related terms, the - symbol stands for opposites, the * symbol stands

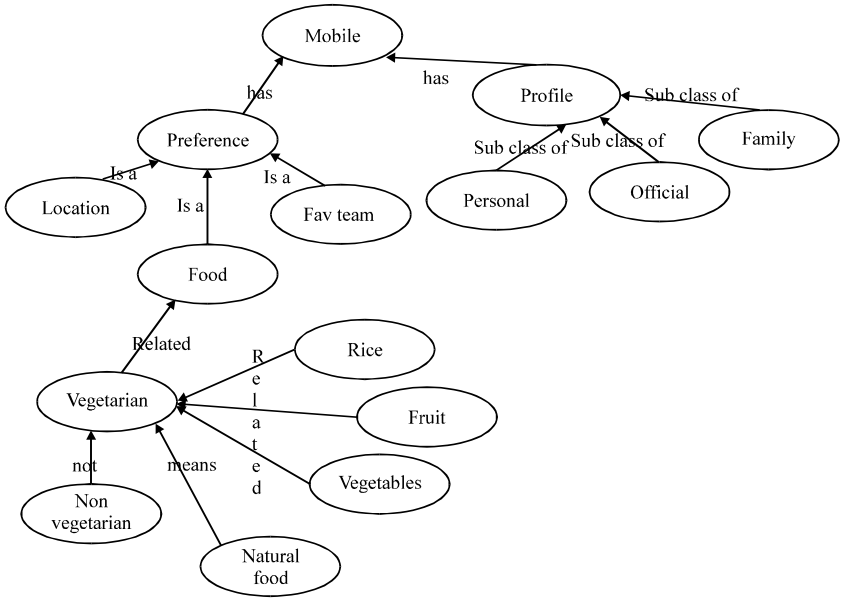

Fig. 1: Example of ontological structure

Table 1: Generalized ontological structure

Word	Wordand	Meaning 2	Meaning 3	…..
Word	-word 1	-word 2	- word 3	……
Word	+ term 1	+ term 2	+ terms 3	…..
Word	* pair 1	* pair 2	* pair 3	…..
Word	and word 1	and word 2	&Word 3	
^word	Word 1	Word 2		

Table 2: Example ontology

## Mobile	#has	Profile	Preference	
& Profile	Official &	Friends &	Family &	
## Preference	# Isa	Location	Food	Fav team^
Food	Vegetarian			
Vegetarian	-Non vegetarian	Natural food		
Vegetarian	Rice	Fruits	Vegetables	

for the relevant terms. The symbol ^ unites the keywords. These categories (meaning, opposite, relevant & related) can then be used to compute the distance measures. The '&' symbol is used for high level linkages and representing sub category pairs. The 'and' before word represents its sub category and after it represents the super category.

The example of the ontological structure is shown above in Fig. 1 and Table 2. The ontology structure is expressive and generalizable. While the structure and framework are similar to the general ontology structure of RDF (Resource Description Framework) and OWL (Web Ontology Language), the implementation is tailored towards mobile based systems. In general the RDF and OWL are the standards for the Ontology design. But, such as system may not study in a mobile setting due to the restrictive nature of the content storage system in the mobile platform. When the node for "mobile" is created, the bi-connectional nodes for the related terms are created similarly. So, when "mobile" is related to "communication" and "mobility" and "on the move", the reverse case also holds good. Thus, "mobility" also related to "mobile" at the same time. The similarity case does not hold good here. "On the move "cannot be called as related to "communication" unless an explicit link is created. When the user encounters the word "mobility" now, the node for the related term is already in the system. This is a pre-emptive and proactive approach towards data management.

FAST SNIPPET MANIPULATION METHOD

The model proposed in this study was based on the following assumptions:

- Need of the hour is for fast algorithms
- Application in the mobile phones cannot store and manipulate the contents of web pages retrieved by the search engines due to this need for speed
- Snippet contents are used as input for the re-ranking and
- The personalized ontological structure is used for the process

In the web search, it has been observed that majority of the snippet contents contained the search term. Hence methods to manipulate the results based on the snippets must also take into account the linkages of the search term in the context of the snippet, thus needing the ontology.

The snippets are assigned a rank based on the inter-term relationships in an organized set of steps. Thus each term processing is considered as a step in the computation of the information gain and the consolidated information gain tfij is calculated for the entire snippet contents. Here the notation tfij represent a term 't' in the snippet 'f'. The term 'i' stands for the snippet value and the term 'j' stands for the term in the snippet. Each snippet is randomly chosen from among the search results. The terms visited in each snippet can be written as tfi1, tfi2, tfi3,... For each term in the snippet the distance vector measure is calculated in terms of the term-relationship frequency α where the term relationship frequency is calculated as the measure of how much each term is related to the search term. The value β is a measure of the distance vector of the term to the query word. The trust value of the web site from which the content is retrieved is also given a proportional importance γ.

$$tfij = (\alpha\sum fi+\beta\sum di +\gamma\sum ti)/\sum tfij \text{ ---------} \quad (1)$$

Here for a given term, the ontological structure will give the term relationship frequency as a fuzzy measure which will consist of the following characteristics: meaning, related, relevant, no measure and opposite. For each of these the value of ? will differ. These fuzzy measures are intended to help the user categorize the relevance of terms in a realizable manner. For the new instance of the word being encountered, the user would be prompted to enter the information. This ensures that a personal and local view of the world that the user has is captured in the system. Our experiments show that over time these words that are formed show a significant difference from user to user and reflect their context.

The distance vector of the term with the query term will give an idea of how relevant the search term is and needs to be considered for the ranking aspect. The computation of the distance vector is done by computing the shortest path between the query term and the term encountered in the snippet. As of now, the distance is taken as the hop count.

The trust value of the web site is computed in the following manner. Whenever the user selects a website from the list of available terms, the trust rating of the web site is updated. The user also has the option of updating the information in the next run of the interface and in that case, the URL is stored and then the value asked in the next instance. If a web site content is trusted (like wikis), the results are given a higher preference than new web content sites. Once web site content is declared trusted, the user has the option of editing the preference and downgrading the trust values. There is a maximum vale that the websites can reach .The website trust values are also personal and may differ from user to user.

After finding the information gain for each snippet, the similarity measure of the snippets is also found. The similarity measure of the snippets are found by the formula:

$$Sim (tfi,tfi+1) = |tf'i \cup tf'i+1|/|tf'i \cap tf'i+1| \quad (2)$$

where, the set tf'i is the set of non-stop words of snippet tfi. Thus the snippets which are most similar are clustered together and shown to the user as such. Overall, the ranking for the entire search results is found and the results re-ranked. The biggest difference between this approach and the term frequency methods lies in the fact that the entire search results are processed in one single parse operation. Also, the ontological contents which are personal to the users' guide the operation.

Overall the system uses a personalized, adaptive, context-based, intuitive algorithm for re-ranking the web content. There is a need for powerful reasoning system to support this operation. The reasoning system is explained in the next section.

REASONING SYSTEM

The reasoning system is implemented as event condition action systems. The overall process consists of application of rules for the event conditions. Each rule in the system is deemed to be an ECA rule which is defined over the relevant information attributes:

- Every rule uses the event language, one or more words and an action language for the respective components:
    - {The language components are described by the ontology,}
- {there is a well-defined interface for communication}

The system consists of a protocol for handling the rules and conditions. The rule element in the schema model has a set of attributes and that each element in the schema is made up of a sequence of a combination of attributes and other elements. The schema model allows ECA rules to be specified as part of a set or a part of a protocol. The reasoning system is modeled after the event condition action. The rule schema consists of elements (*name* and *body*). The name is the identifier of the rule. Examples of the identifier are {Information gain, re-rank, retrieve, snippet-relationship, term frequency, etc). The

body consists of elements (Event, Condition and Action). For e.g., for the identifier Information gain, Event is local or global, condition is a number on i where i is a finite value and the action is calculate-information-gain (snippeti). The referencing system has both global and local scope .For example the distance vector calculation system will study in a set of nested queries that iteratively compute the connectivity of the terms till it reaches the goal. The best first approach is used in this case with a computational limit of twelve (Maximum Bound). This means that if a word is more than twelve nodes removed from another word, then the relationship between the words is minimal. This is an example of a local scope structure. The cluster similarity measure is an example of the global scope system as it takes as input the entire stream of data and works on individual sub-components. The global and local scope delimits the inference rules and is imbibed in the conditional structure.

EXPERIMENTAL SETUP and RESULTS

In an information retrieval context, there are two major metrics used: precision and recall. In this system, we have tested for the recall efficiency by comparing the outcome of the web search results with that of our system. The quality of the retrieved results is an important measure. The other aspect tested here is the time taken for getting the results. The time taken for getting the first query output and the time taken for the desired output is plotted separately. The distinction is because on an average the users parse the system for 2-3 pages till they get the outcome. The time taken for the first query outcome and the desired query will show the overhead of our system better.

The application was designed using J2ME and implemented in Nokia mobile phones. The ontology contained a set of 600 indexed and cross referenced terms at the beginning of the process. The users were post graduate students of computer science and totally 4 users participated in the process. The testing was done in the last week of March 2011. Around 40 queries were tested using the system. The Bing Search interface was used to fetch the results from the web and the comparison was done between the search interface's results and the mobile search interface's results. The users entered the query in parallel in the systems (with Bing interface and with the search application) at the same time and saw the results. The validation was empirical and measured the relevance of each result to the query. Three unbiased users were given the interfaces at conclusion of the retrieval process and asked to validate the results.

The results of the testing process over 40 queries were analysed. The queries were marked in the X- αAxis and the improvement in efficiency in the Y axis. The results (Fig. 2) showed that the system showed an average improvement of around 16.23% over the conventional system. This is a significant development and is consistent with similar results in the domain.

There were cases where our systems study was not efficient and cases where the prediction of our system and the conventional system were the same. The overhead in the system due to the time for processing was plotted next. This was a calculated by using a timer and plotted as a composite parameter for 40 queries. The results are shown in Fig. 3. The key factor here is the fact that the average taken by our system for the first retrieval is around 29.2 sec whereas that for conventional search methods is 16.95 sec.

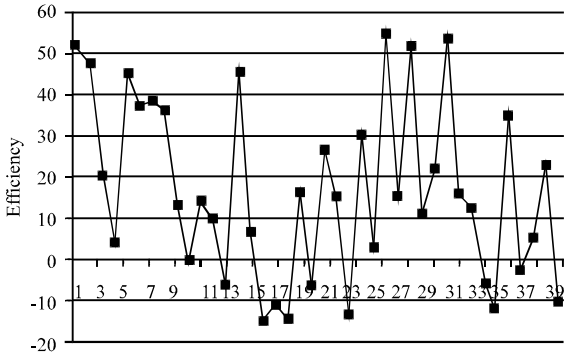

Fig. 2: Improvement in Efficiency of the system

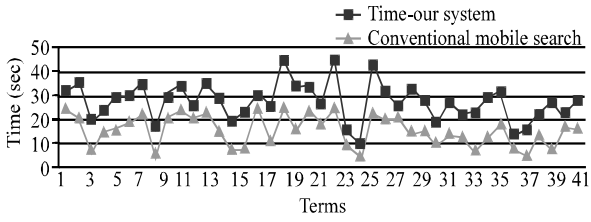

Fig. 3: Time taken for first query output

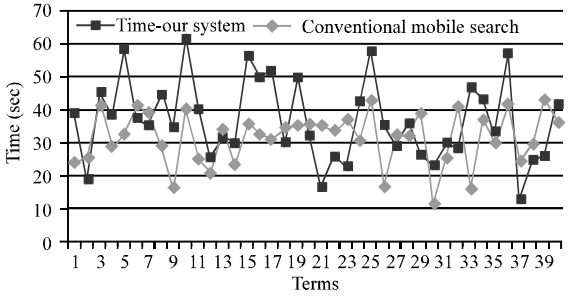

Fig. 4: Comparison of our system and the conventional system

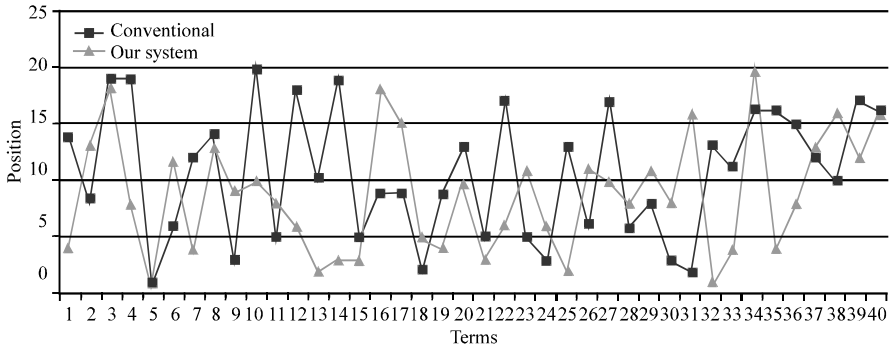

Fig. 5: Recall characteristic of the system

The time taken for search the average time taken for the completion of the task is shown in Fig. 4. The average time taken by our system for query completion was 31 sec and the conventional system 35 sec. This shows that while our system imposes an overhead due to the processing, the overall performance of the system is better than conventional systems.

The position of the desired website was plotted next in Fig. 5. The comparison was made between the existing and conventional system and it was found that for simple queries the efficiency of the proposed model was better than the conventional interface system. This can be inferred from the fact that for the majority if the queries, the proposed model's position is better than the conventional system. However, more detailed tests are needed to validate the system further.

CONCLUSIONS AND FUTURE WORK

This study has described a methodology for improving the quality of the web search in mobile phones. The methodology comprises of a mobile ontology, reasoning system and a re-ranking algorithm. The system was validated empirically and show considerable promise. The major contribution of this study is in the presentation of a comprehensive ontology based fast snippet manipulation method for mobile information retrieval. The study is unique and shows considerable promise. However, the study needs more testing and deployment in a range of devices and with large number of users. As the size of the ontology grows, there is a need for complex indexing mechanisms to be implemented. This will speed up the process of re-ranking. Also, methods to increase the size of ontology (download and plugin) may be needed for large scale deployment. This will be a focus in the future. The re-ranking method uses a combination of parameters. These parameters are presently configurable by the users. In future, a model for automatic learning based on the selections made by the user or explicit methods of ranking the contents (supervisory approach) will be a focus of this study. Notwithstanding all these factors, the basic structure of the study shows considerable promise.

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