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MOSS-IR: Multi-Ontology based Search System for Information Retrieval in E-health Domain

Viji Rajendran V[a 1] , Swamynathan S[b]

[a] Research Scholar, Dept. of IST, CEG Campus, Anna University, Chennai 600025
[b] Associate Professor, Dept. of IST, CEG Campus, Anna University, Chennai 600025

Abstract

With the development of the Semantic Web, ontology has become the crucial means for representing concepts in various domains of interest. Although the current search engines return results based on keyword search and page ranking, human intervention is still required to select the most relevant document. Hence to overcome the disadvantages with the current search scenario, this paper proposes search based on multiple ontologies to make information retrieval efficient. It rewrites the user query by adding semantic information, after consulting multiple ontologies.

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Keywords: Ontology; Semantic Web; Query expansion; Reasoning.

Introduction

1.1 Limitations of existing search techniques.

With the growth in digital literature, it is increasingly difficult for users to have effective search and retrieval of relevant documents particularly in the health care domain[15]. The top most pages returned by the search engines may not always be relevant. The medical domain offers controlled vocabularies and various tools for using them, such as the Unified Medical Language System (UMLS)[16]. UMLS meta thesaurus have

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* Corresponding author. Tel.: + 91- 044 - 2235 8571
E-mail address: vijirajv@gmail.com, vijirajendran@nssce.ac.in

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semantic information about various biomedical concepts, their semantic types and the relationships among them. In current standard web which is not supporting Semantic Web technology, information retrieval is essentially based on keyword-matching technologies[3]. The fact that individuals use different terminology to mean the same thing presents a challenge – especially in the healthcare industry. Healthcare is one of the best represented subject areas on the Semantic Web right now. In Medline[13], textual query is converted into a set of representative concepts and are matched to the indexed documents according to the MeSH conceptual hierarchy[12]. Such approaches, however, do not take advantage of the hierarchical relations among the concepts. End users generally have to search for appropriate documents manually. Since visiting all the web-page and manually analyzing data is nearly impossible, the identification of relevant information becomes a crucial task. Search is one of the key motivations behind semantic web.

1.2 Semantic Approaches.

Currently, as the web turn out to be more semantic, knowledge-based query expansion techniques become more accepted. It is harder for search engines to interpret user queries since, majority of them use popular or general terms[18]. Semantic approaches have established to be very successful in improving search processes. Intelligence should be embedded in search systems to manage efficient search and presenting relevant information. This can be done by information retrieval techniques based on ontology. Ontologies are useful for disambiguation in natural language. Natural language processing (NLP) tools can help in automating the translation of the existent natural language descriptions into semantically equivalent ones.

1.3 Role of ontologies.

The main advantage of using ontologies is the formalized semantics. Semantic web based search engines employ ontologies in a particular domain to enhance the performance of information retrieval process. The ability to deduce additional facts based on the axiomatic content of ontology can be important from a research point of view. A reasoner can automatically infer new statements without writing specific code. The use of ontologies in medicine is mainly focussed on the representation of medical terminologies. Medical professionals use them to represent knowledge about symptoms and treatments of diseases. Pharmaceutical companies use them to represent information about drugs, dosages, and allergies. On the other hand, the decentralized nature of the web makes it difficult to construct a single ontology. Although using a single ontology could make the task of integration and semantic interoperation easier, from the perspective of scalability, it is impractical to preserve global consistency with a single huge ontology. Therefore, integration of multiple ontologies is one of the key technologies that need to be developed for the Semantic Web. This paper proposes a Multiple Ontological Search System for Information Retrieval (MOSS-IR) to overcome this problem.

1.4 Objective

An important motivation for using ontologies is the guarantee they hold for integrating information. Search is made possible by construction of a multiple ontology which forms the knowledge base. The objective is to enable users to perform queries without having to be familiar with ontology or concept hierarchies. In our proposed work, end user needs only to enter the keywords to perform his specific search. The purpose of this paper is to construct multiple ontologies and to develop an information extractor system that explores the use of semantic information to support more expressive queries. The orientation of this paper is to focus on refining the user queries i.e. include more relevant search terms in the query for improved retrieval results. For example, when users use irrelevant keywords, query expansion based on ontologies can improve retrieval accuracy by providing an intelligent information selection. The rest of this paper is organized as follows. Section 2 focuses on the motivation for this proposal in light of the limitations and imperfections of existing search systems. It addresses a general perceptive of what semantic search is and where we are standing in the evolution of semantic information retrieval. Section 3 illustrates the prototype of our proposed work. Section 4 presents the application of our model by taking health care system as case study.

2. Literature Survey

The development of effective retrieval techniques has been the core of IR research for more than 30 years. The main objective of IR is the retrieval of relevant information[10]. Users prefer to post queries in their native languages, while oftentimes queries in these human languages cannot be exactly understood by computers[17]. Queries expressed by means of keywords[3] are the least expressive one, since it is represented as a set of terms without any explicit relation between them. A prominent solution to these problems is to use ontology based information retrieval. The introduction of ontologies to enhance the capabilities of current search technologies has been portrayed in the area of semantic-based technologies since the late nineties[1]. Most approaches use large lexical ontologies like WordNet[20] because they are not domain specific. Although mapping of query keywords to WordNet synset is able to find the relations between the keyword, these are subjected to the limitations of lexical ontology[8]. SIEU[19] employs ontology as a knowledge base for the information retrieval process in University domain. The Google results are re-ranked for providing the relevant links. Their approach can be used as a prototype to the developers and researchers who work on semantic web information retrieval.

Some applications access the ontologies without regard to the heterogeneity and the dispersion of the ontologies. In order to support such a request, an efficient query processing over the distributed ontologies is essential. KAONP2P suggests the P2P-like architecture for query answering over distributed ontologies[6]. Query evaluation is performed against the virtual ontology generated from the target ontology to which the query is issued and the semantic mapping between the target and the other ontologies. Jihyun Lee[2] modelled a distributed query processing method considering models of the distributed ontology and the semantic mapping among distributed ontologies. Another significant phase that characterizes semantic search models is the way the user expresses his request. In information retrieval systems the relevancy of search results depends on the user's ability to represent her information needs in a query[11]. Natural language representation of query provides more information than the keyword-based approach since a linguistic analysis can be performed to mine syntactic information[4]. The semantic search requires knowledge about the data source schema and a user's proficiency with the syntax of the query language. Users cannot be expected to have an understanding of the knowledge structure nor mastering the formal query language construction. Therefore it is crucial to provide users a means of communicating with the data especially in natural language.

Query expansion is required due to the ambiguity of natural language. It improves information retrieval by expanding the query with terms related to the original query terms. The various query expansion approaches include relevance feedback, corpus dependent knowledge models and corpus independent knowledge models. The simplest way to develop a query is to navigate the ontology along different relationships. Query expansion with synonyms or hypernyms has a limited effect on web information retrieval performance. Before ontology is used in term selection, it must be processed by reasoners to make implicit knowledge available. Reasoning is a mechanism used for answering queries over ontology classes and instances[5]. Hence to overcome these limitations OWL-DL reasoner is used to compute explicit plus inferred equivalent classes for a concept in the query. These equivalent concepts are used as a basis for expansion. This paper thus addresses query expansion to include more relevant search terms in the query for improved retrieval results.

3. MOSS-IR Architecture

Multiple ontologies use the same description logic, even though the different vocabulary is used for representing the same concept. The aim is to create a collaborative system in which ontology co-operate with one another to answer questions about the information they have. Issues in interpreting a query from different ontologies include

- User queried keyword has to be decoded into ontology-centric vocabulary.
- Query response may require the merging of concepts from multiple ontologies.
- It is not possible to determine in advance which ontologies will be significant to a particular query.

Ontologies in the same domain may have difference in the level of details. This poses further challenges to choose the potential ontology that has the precise concept coverage. Ontology selection is the process of identifying one or more ontologies that satisfy certain criteria. These criteria can be related to topic coverage of the ontology. The actual process of inspecting whether ontology satisfies certain criteria is fundamentally an ontology evaluation task. In this approach ontology concepts are compared to a set of query terms that represent the domain. It first tries to determine ontologies that contain the given keyword. If no matches are found, it queries for the synonyms of the term and then for its hypernyms. The ontology selection process returns combinations of ontologies that jointly satisfy a certain information need. Whether a user query fits in the domain underlying ontology is a vital issue to ontology-based query rewriting. This paper assumes that the user queries are within a particular domain so that the ontologies can be directly utilized.

There is a user interface that allows the consumer to enter queries in natural language (NL). The natural language query is sent to NL Processing engine where it is processed and is converted to Description Logic (DL) query. Stop words are stripped off the queries. NL-DL query convertor comprise of several natural language processing tools such as the Stanford Parser for creating the parse tree while WordNet can be utilized to account for syntactic variability by finding synonymous words. The query processor's task is providing the user with the best answer to the question from the ontology. High level architecture of the model is shown in figure 1.

Query processor system parses the query and interprets the meaning of the end-user's query terms. This enables the construction of a meaningful query. Before any actual query re-formulation, the mapping between the vocabulary of the ontologies and the query is required. The mapping is indispensable for retrieval improvement using ontology based query approaches. The first step of the processor is to identify the set of ontologies likely to provide the information requested by the user. Hence it searches for near syntactic matches within the ontology indexes, using lexically related words obtained from WordNet and from the ontologies, used as background knowledge source. It makes out the subject, predicate and object, which is used to create the DL query and runs it against the ontology to attempt to answer it from existing knowledge. Query expansion is a query reformulation technique that appends to query Q a (possibly empty) set of keywords $\{K_i, . . . , K_{i+j}\}$ while retaining the semantics of Q, for some positive integers i and j. Query expansion does not mean to expand concepts implicit in a query but to supplement the keyword set by including terms more relevant to the concepts such that the query purpose becomes more concrete to search engines. The consequential query is the disjunction of the original query concept and the concepts intensifying it, formed using the Boolean operation OR. Only a few web users employ advanced searching options, e.g., Boolean operators, in query formulation.

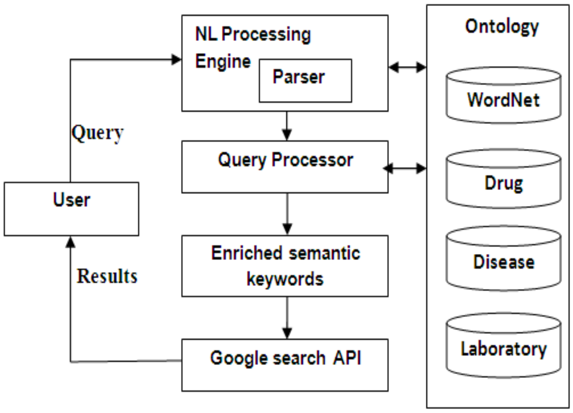

Fig 1: High level architecture of MOSS-IR

Query expansion has some intrinsic dangers like query drift, that is moving the query in a direction away from the user's intention[17]. This occurs normally when the query is ambiguous. The concerns addressed with query expansion are the selection and the weighting of added search terms. Instead of choosing phrases that are similar to the query terms, they are expanded by adding those terms that are equivalent to the concept of the query. The semantically related keywords in the ontology are retrieved to form the refined query. Hence these refined queries have more semantic relevance. The refined queries are sent to Google search API which fetches the web links related to the user query. The result(s) are returned to the end user. The log details of the processed query are stored in log file for future reference. There are several tools available for developing the ontologies like OntoEdit, WebODE and Protege. In the proposed work, Protege[14] is used as the tool for developing ontology. Protégé allows the support of web ontology language (OWL) and export Protégé ontologies into a variety of other formats such as RDF/S and XML Schema. Besides that, it has plug-in, which include ontology visualization (OntoViz) and OntoGraph, and interfaces with rule engines and formalisms such as SWRL (Semantic Web Rule Language) [7].

4 Case Study

Several use case scenarios that will profit from the proposed method can be mentioned. In this paper, health care system has been taken as the case study. Ontologies can assist constructing more powerful and more interoperable information systems in healthcare. The terms for query expansion are taken from dispersed ontologies. The objective of this paper is to find a solution to improve the lack of standards in the health care system and provide an efficient query processing over the distributed ontologies. A simple lexical matching technique is used to obtain overlap between the matching ontologies and the background knowledge. Protégé 4.3 is used for creating OWL ontologies. Three kinds of inter relationships are used in the creation of ontologies: is-a, instance-of, and part-of. The class hierarchy represents an "is-a" relation: a class A is a subclass of B if every instance of B is also an instance of A. Part-of represents the primary compositional relationship whereas instance-of represents the individuals of a class. OWL 2 supports a number of important automatic DL inference services, which can be provided by different DL reasoners including HermiT[23], Pellet[22], Fact++[21] or Racer[24]. The reasoner helps to maintain the hierarchy correctly. In the proposed work Pellet, which interfaces in the Manchester OWL-API, is used for reasoning. It provides all the standard inference services that are traditionally provided by DL reasoners. Pellet has an implementation of a direct tableau algorithm for a DL-safe rules extension to OWL-DL. This implementation allows loading and reasoning with DL-safe rules encoded in Semantic Web Rule language (SWRL). SWRL may be considered as a blend of rules and ontology, through which the relationships and terms described in the ontology can be used directly when writing rules. SWRL is a combination of OWL DL and first order Horn like rules. OWL DL is equivalent to DL SHOIN (D). Currently, there is no complete implementation for SWRL. Yet, human readable syntax may be used to formulate queries to simulate SWRL queries. OWL API is employed to access the ontology model. In addition, other tools like WordNet and Java Wordnet Library(JWNL) are analyzed and integrated.

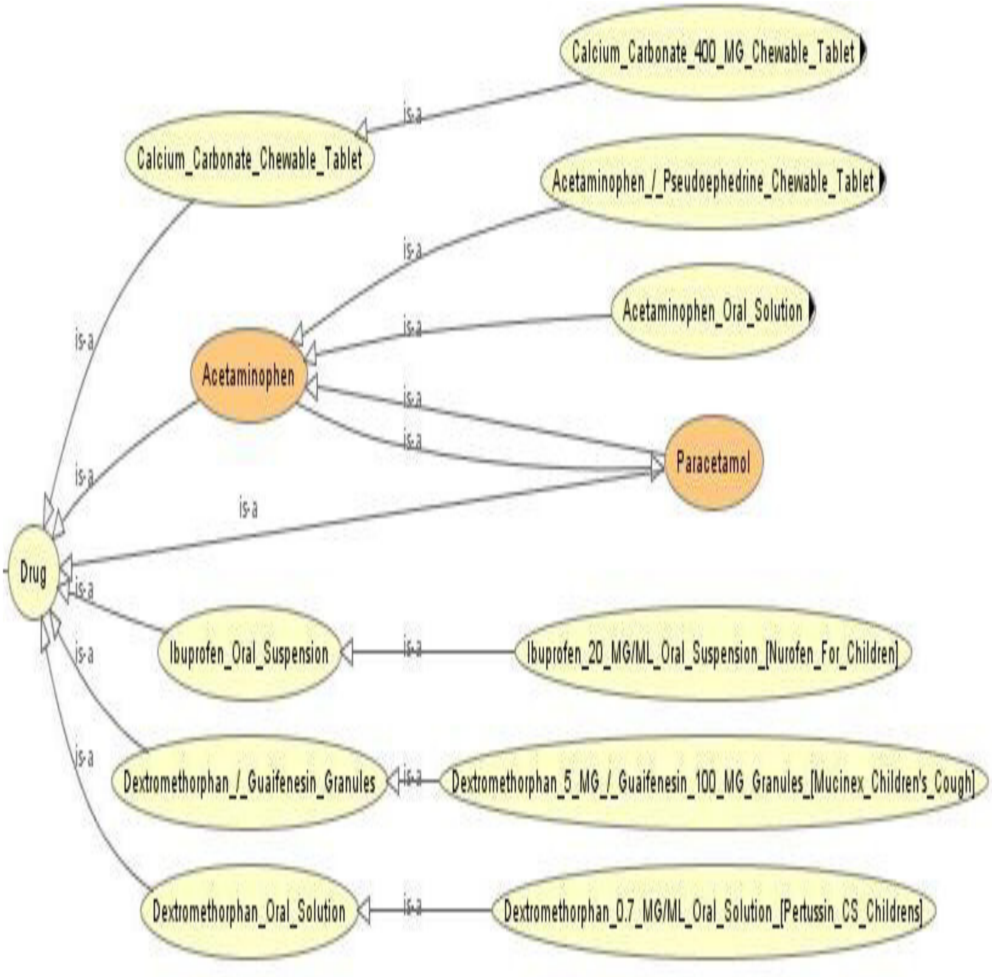

Fig 2: Snapshot of Drug Ontology

Common diseases and their symptoms are incorporated in disease ontology. These information were collected from various resources like Bioportal and Open Biomedical Ontologies Foundary[18]. Disease Ontology (DO) and UMLS vocabularies (SNOMED-CT, NCI, MeSH, and ICD-9) were used as controlled vocabulary for disease names. Various drugs, their usage and side effects are included in drug ontology whereas common tests done for various diseases are dealt in laboratory ontology. Figure 2 presents the some of the drugs used in children from drug ontology using OWLViz tool in Protégé 4.3. OWLViz tool shows the graphical representation of the class subsumption hierarchy. Axioms can be used for defining complex relationships or obtaining new information. SWRL adds rules to OWL DL and they provide more expressive power to Description Logic. Some of the sample rules from laboratory ontology are given in figure 3.

Patient(?p),hasDisease(?p,Pancreatic_Disorder)→ doTest(?p,Amylase_Test)
Patient(?p),hasDisease(?p,Diabetes)→ doTest(?p,HbAIC)
Patient(?p),hasDisease(?p,Bristle_ Asthma),hasSymptom(?p,fever)→doTest(?p,Blood_Test)
Patient(?p),hasSymptom(?p,anemia)→doTest(?p,CBC)
Patient(?p),hasSymptom(?p,inflammation),hasSymptom(?p,muscle_pPain)→doTest(?p,ESR)
Patient(?p),hasSymptom(?p,mononucleosis)→doTest(?p,Mono)
Patient(?p),hasDisease(?p, Hypothyroidism),hasSymptom(?p,thyroid_disorder)→ doTest(?p,TSH)
Patient(?p),hasSymptom(?p,UTI)→doTest(?p,Urine_Culture)
Patient(?p),hasSymptom(?p,blood_in_urine),hasSymptom(?p,abdominal_pain)→ doTest(?p,Urinalysis)
Patient(?p),hasDisease(?p,Diabetes),hasSymptom(?p,hypertension),hasSymptom(?p,kidney_disorder)→
doTest(?p,Microalbumin)

Fig 3: Some SWRL rules in Laboratory ontology

Table 1 gives the restrictions used in description logic and the corresponding Manchester syntax. Keyword "some" or existential restrictions describes classes of individuals that participate in at least one relationship along a specified property to individuals that are members of a specified class. "Only" or universal restriction is used to describe classes of individuals that for a given property only have relationships along this property to individuals that are members of a specified class.

Table 1: *Manchester Syntax Restrictions*

Description Logic		*Manchester Syntax Restrictions*
Some		$\exists$
Only		$\forall$
Value		$\ni$
Min		$\geq$
exactly		$=$
Max		$\leq$
Boolean Concept Constructors	*And*	$\sqcap$
	Or	$\sqcup$
	Not	$\neg$

Table 2: sample of ontology selection criteria

Disease Ontology	Drug Ontology	Lab Ontology
Complicated by	Drug	Diagnoses
Symptom	Disease	Test
Occurs with	Overdose	X ray
Results in	Side effect	Scan
Transmitted by	Therapy	Result
Vital Signs	DbXref	Screening
Treatment	Medication	Normal range
Cure	Potency	Percentage deviation

Query reformulation can be abridged in three steps:

1) Identify the key ontology concepts in the query: The input query keywords were used to choose the most related group and the domain ontology associated with selected group was used to identify the associated concepts for the expansion of the user query. So the choice of ontology is based on query phrases. A sample of ontology selection criteria is given in the table 2 and sample query is given in table 3.
2) Concept expansion: Input query is semantically expanded in ontology based information retrieval. The phrase concepts are not split into single terms because single terms are likely to be semantically different than their associated phrase concepts (e.g. "sleep walking disorder"). Moreover expanding concepts by their superclass concepts is avoided because broader concepts are more likely to compromise precision and cause query drift. Hence the detected ontology term is expanded by its equivalent concept. For each identified ontology concept, estimate its weight using the log file created.
3) Aggregation of concepts: merge lists of expansion terms for each concept into one final expansion list. The query is finalized by ORing the query term with the set of expansion terms obtained and then ANDing the query with the semantic type retrieved from UMLS thesaurus. Normally ORing the terms with its synonyms will not have considerable impact on the precision of top 10 results. ANDing semantic

type of the query term with the expanded query increases the precision of the top 10 search results in most cases.

Table 3: Sample query

Query	# of ontology involved	Ontologies used
What is Disease_X ?	Single	Disease
What are the preconditions for doing test_A?	Single	Laboratory
How can drug_X be used in the treatment of disease_Y?	Multiple	Disease and drug
How can test_U be used in the diagnosis of disease_V?	Multiple	Laboratory and disease
Causes and treatments of mental deterioration like Alzheimer?	Multiple	Disease, drug and laboratory

It is necessary that there should be good coordination between multiple ontologies. Multiple distributed queries need to be generated from an original query to obtain results from dispersed ontologies. Some examples of query expansion are illustrated below.

Case 1: input with multiple query term.

Typically users submit short queries resulting in poor recall and precision [25]. Moreover, the keyword queries that users submit are inherently ambiguous. Some drug like Triall is ambiguous. Even if "drug triall" is given as the query term in Google, it shows the result of clinical drug trial instead of drug triall. But according to National library of medicine in RxNorm, triall has RxNorm 745619. When given to our system it returns Chlorpheniramine (trade name) as query refining term. Hence precision is enhanced.

Case 2: input with phrase or a sentence.

The query "symptoms of liver failure due to paracetamol overdose" to Google search engine retrieves more than 160,000 pages which include both relevant and irrelevant pages. User will be willing, typically, to look at only a few of these pages. But most of the medical journals use the term acetaminophen or tylenol instead of the term paracetamol. When the query is given to our system (figure 4), it parses the input and identifies the key terms in the query, which when consulted with WordNet and ontologies, return Acetaminophen as equivalent term for paracetamol from drug ontology (figure 5).

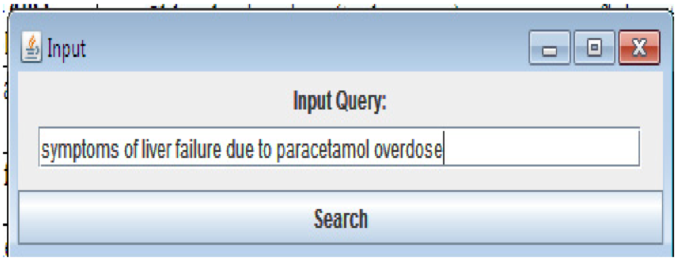

Fig 4: sample input query to MOSS-IR

Generally, query expansion is realized by adding new terms to the initial query using the OR operator to broaden a query as shown in figure 6. Semantic type information for acetaminophen, T109 (Organic Chemical) and T121 (Pharmacologic Substance), is retrieved from UMLS vocabulary MeSH. This refined query is then issued on search engine through Google API to retrieve the search results. Unlike the convention search, this enhanced search result comprises information from eMedicine world medical library, MedlinePlus medical encyclopedia and US national library of medicine in the top 10 pages of result. Hence the ability to retrieve top-ranked documents that are mostly relevant is high. Accordingly, query expansion is primarily associated with its potential to induce increases in precision and recall.

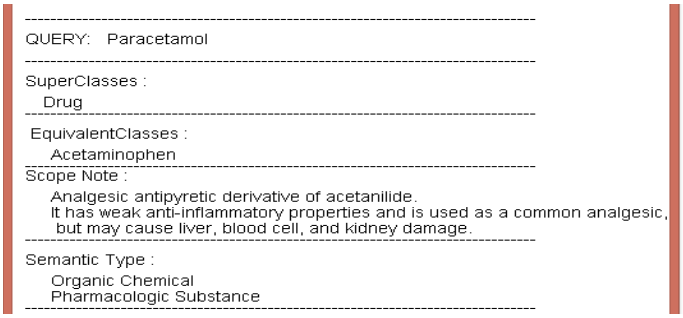

Fig 5: Snapshot of intermediate result of query processor

Evaluation Measures: Precision@k is a measure for evaluating top k positions of a ranked list. $precision@k = \frac{1}{k}\sum_{j=1}^{k} r_j$, where k = the truncation position, r_j =1 if the document in the j^{th} position is relevant and zero otherwise. Precision@10 measures the proportion of relevant documents among the top 10 retrieved. This metric is particularly important for search engines, because most users won't browse beyond the first 10 pages of results. Table 4 shows that precision is enhanced when query is given through MOSS-IR.

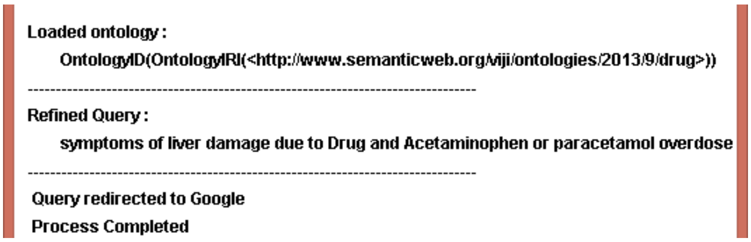

Fig 6: Snapshot of refined query after query processing

5 Conclusion

This paper has presented a multiple ontology query processing method and analyzed case studies on domain-specific ontology based query expansion. Use of ontologies for information retrieval, in particular their use in the area of query expansion is presented. Concept-based query expansion retaining original keywords yields more desirable and useful results. The process of query expansion that is based on ontologies and WordNet benefits short query statement more than long statement. Query expansion makes little difference in retrieval efficacy for long queries as they typically have a full description of the information required. Compound words add complexity to the query expansion, however further research experiments are desirable to study the effects of using ontology for query expansion. Finally further research is outlined for the exploit of ontology based information retrieval in Cloud.

Table 4: Comparison of precision of query with and without query processing.

Query	P@10 conventional search	P@10 MOSS-IR
How can we avoid camp fever?	0.45	0.90
What are the causes and treatment of dairy fever?	0.80	0.95
How can we diagnose “bronze john” disease?	0.75	0.90
Which health policies cover treatment of American plague?	0.35	0.50
How can we detect ‘bad blood’ disease in children?	0.55	0.80

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