Quality Aspects in Ontology-Based Information Retrieval

Darijus Strasunskas, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway; E-mail: dstrasun@idi.ntnu.no
Stein L. Tomassen, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway; E-mail: steint@idi.ntnu.no

ABSTRACT

Ontologies are increasingly used in various applications (e.g., semantic interoperability, data integration). One of the reasons is that ontologies are seen as a means to improve qualitative characteristics of applications. In particular, there is an intensive on-going research on ontology-based information retrieval. Typically, ontology usage in information retrieval adds another level of complexity; therefore we propose a holistic method for evaluation of ontology-based information retrieval systems as well as define a set of essential features for ontology-based information retrieval tools.

INTRODUCTION

In this article we investigate the application of ontology to enhance Information Retrieval (IR). Since information quality is critical for organizations, ontologies have been used in a number of information retrieval systems (Aitken & Reid, 2000; Brasethvik, 2004; Ciorascu et al., 2003; Nagypal, 2005; Suomela & Kekalainen, 2005; Vallet et al., 2005) in order to improve their performance.

There are sparse evaluations of ontology-based information retrieval (ObIR) tools (e.g., Aitken & Reid, 2000; Brasethvik, 2004; Suomela & Kekalainen, 2005; Vallet et al., 2005), and they report improvement compared to a traditional IR systems. However, it is not clear whether this improvement is optimal, i.e. how could ontology properties enhance IR.

Furthermore, IR evaluation methods are mainly based on relevance of retrieved information. However, additional sophistication of ObIR tools adds complexity on user interaction to reach improved results. Therefore, standard IR metrics as recall and precision are not feasible to measure user satisfaction because of complexity and effort needed to use the ObIR systems. Furthermore, evaluation methods based on recall and precision do not indicate the causes for variation in different retrieval results (Alemayehu, 2003). There are other factors that influence the performance of ontology-based information retrieval, such as query quality, ontology quality, complexity of user interaction, etc.

We investigate quality aspects essential for improvement of information retrieval. This paper tries to answer two following questions. How can we enhance ObIR performance? How should an ObIR system be evaluated?

Related work comes from several areas. Consequently, in next section we first take a look at ontology-based IR systems and then we proceed with an overview of IR systems and ontology evaluation methods and metrics. Then we discuss essential features of ObIR systems relating these features to users' experience and present a holistic evaluation model for ObIR quality assessment. In last section we conclude the paper and outline future work.

RELATED WORK

First, we summarize ontology-based information retrieval (ObIR) approaches, classifying them according complexity of user interaction. Second, we survey the IR evaluation methods and metrics, pointing out their weakness in analyzing the cause of variation in results. Third, we take a look at ontology evaluation, as ontology plays one of the central roles in ObIR systems.

Ontology-based Information Retrieval

An increasing number of recent information retrieval systems make use of ontologies to help the users clarify their information needs and come up with semantic representations of documents. While general assumption of ObIR is as follows. If a person is interested in information about *B*, its likely that she will find information about *A* interesting, with a condition that *A* and *B* are closely related terms/concepts in the ontology. Then user provided query is expanded by hypernyms (superclasses) or hyponyms (subclasses) or other related concepts (sibling concepts or other neighborhood concepts).

Furthermore, approaches to ontology-based information retrieval can further be categorized according to the complexity of required user interaction: a) simple keywords based entry into text field; b) multi-optional specification of search parameters; c) advance interaction through a specific ontology query language. Approaches belonging to the first category allow user to enter keywords in a simple text field. The provided query is expanded using an ontology without any further interaction from the user (e.g., Ciorascu et al., 2003). The second category of ObIR systems spans more diverse range of approaches. The approaches here require more interaction by the user. Nagypal (2005) uses ontology to disambiguate queries. Simple text search is run on the concepts' labels and users are asked to choose the proper term interpretation. Tomassen and Strasunskas (2006) discuss four abstraction levels of query terms, where users are allowed to specify the granularity of information needed. Other approaches let users to browse the provided ontology and select relevant concepts (e.g., Suomela & Kekalainen, 2005). Approaches in the latter category typically adopt knowledge base approach to interact with the information using reasoning mechanism and ontological query languages (e.g., SPARQL, RDQL, OWL-QL) to retrieve instances. Documents are treated either as instances or are annotated using ontology instances (Ciorascu et al., 2003; Kiryakov et al., 2005; Rocha et al., 2004; Vallet et al., 2005). These approaches require advanced knowledge of ontology query languages and target professional users.

Information Retrieval Evaluation

When evaluating information retrieval systems retrieved information is typically assessed by its relevance or non-relevance to the users' information needs. Then IR systems are compared based on their ability to retrieve and rank relevant information. Evaluation methods in information retrieval are focused on precision and recall metrics (Baeza-Yates & Ribeiro-Neto, 1999). Furthermore, there are a number of other similar metrics derived from the precision and recall metrics such as *novelty*, *coverage*, *the E measure*, *Harmonic mean* (a.k.a. *F – measure*) (Baeza-Yates & Ribeiro-Neto, 1999). Korfhage (1993) discussed *satisfaction* and *frustration* metrics, where satisfaction metric takes into account only relevant documents, while frustration – non relevant documents.

Important information that indicates the causes for variation of different retrieval results remains hidden under the average recall and precision figures (Alemayehu, 2003). Gao et al. (2004) argue that there are other factors than IR system that needs to be considered in the evaluation. These factors are as follows (Gao et al., 2004): indexing and searching methods; difficulty of a searching topic with respect to retrieval; and quality of a query. The detail analysis on how these factors and their interactions affect a retrieval process can help to dramatically improve retrieval methods or processes. In fact, it is widely acknowledged that factors external to an IR system can affect retrieval result significantly and examination of these factors is essential to the improvement of IR systems (Alemayehu, 2003; Gao et al., 2004; Jansen & Pooch, 2001; Kim & Allen, 2002; Zins, 2000).

Ontology Evaluation

The ontology's ability to capture the content of the universe of discourse at the appropriate level of granularity and precision and offer the application understandable correct information are important features that are addressed in many ontology/model quality frameworks (e.g., Burton-Jones et al., 2005; Gangemi et al., 2005; Lindland et al., 1994; Tartir et al., 2005). Most of them are generic quality evaluation frameworks, which do not take into account ontology applications (i.e. metrics are not defined for task specific usage of ontology). For instance, Ontometric (Lozano-Tello & Gomez-Perez, 2004) methodology defines Reference Ontology that consists of metrics to evaluate ontology, methodology, language and a tool used to develop ontology.

Brak et al. (2004) summarize main perspectives of ontology evaluation. Below we comment applicability of the evaluation perspectives for ontology evaluation in ObIR.

- *Lexical, vocabulary, or data layer*. Checks the vocabulary used to represent concepts. Ontology best fits to a particular domain when its vocabulary corresponds to the vocabulary used by a user and terminology in a document collection.
- *Hierarchical or taxonomical relations vs. other semantic relations*. Some methods evaluate the ratio of IsA relationships and other semantic relationships in ontologies, where the presence of various semantic relationships identifies the richness of an ontology. This perspective is important for ObIR systems, since higher richness (i.e. more diverse relationships) allows better matching of the provided query in a form of triples, which results in better performance.
- *Context and application level*. Here it is evaluated how the results of an application are affected by the use of an ontology. However, in the case of ObIR, adding an ontology into a system changes its architecture and the way of interacting with the system. As well it is difficult to create an experimental environment where no other factors but the ontology influence the performance of the application.
- *Syntactic level*. Since ontologies are created in particular languages, the ontology specification needs to match the required syntax of the language. This ontology quality is a precondition for any ontology usage, including ObIR.
- *Structure, architecture, design*. Ontologies need to meet certain predefined design principles. Parts of a domain may be badly specified therefore the ontology may need maintenance.

Figure 1. Essential features of ObIR systems depending on users' experience

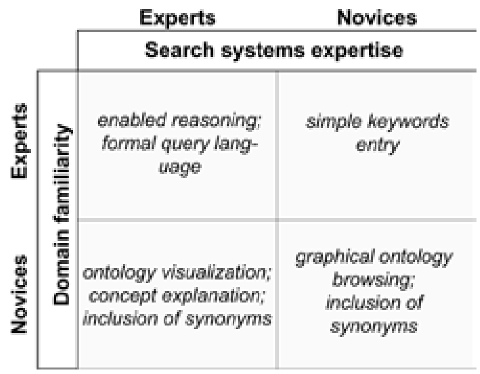
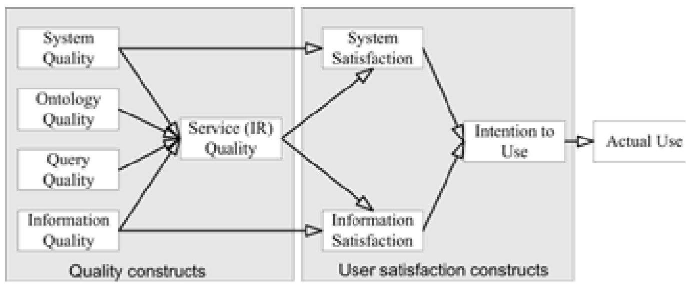


Figure 2. Holistic evaluation model for ontology-based information retrieval system



EVALUATION MODEL FOR ONTOLOGY-BASED INFORMATION RETRIEVAL

An important factor in search is the experience of the users. Expertise in this area is often considered along two dimensions, namely, domain expertise and search expertise (Jenkins et al., 2003). The former subjects are knowledgeable about a particular domain, while the latter have experience in using search engines and tools. Domain experts evaluate search results more closely as well as web search experts investigate results deeply, while search novices use breadth-first search strategy (Jenkins et al., 2003). Surprisingly enough, even the experienced users (computer specialists) are using 3 words on average in query to specify their information needs (Fox et al., 2005), and that seems to be valid for web search in general (Gulla et al., 2002). This important aspect demonstrates a certain need for query expansion by certain means.

Choice of search strategies depends on the level of experience as well as level of sophisticated interaction with ontology-based information retrieval systems (see Figure 1). Evaluation of some ObIR systems indicates that ontology based IR systems perform better for more generic queries (Brasethvik, 2004; Suomela & Kekalainen, 2005). Inexperienced users find ontologies helpful in comprehending domains by familiarizing themselves with the terminology and formulating queries (Brasethvik, 2004; Suomela & Kekalainen, 2005). Therefore, in these cases a graphical visualization of the ontology is a certain quality. In addition, it was found that linguistic enhancements (inclusion of synonyms) close the gap between ontology concepts and documents, and enable ObIR to perform better for queries that are required to find only a small number of documents (Aitken & Reid, 2000; Brasethvik, 2004). Furthermore, inclusion of synonyms facilitates mapping between user's query and ontology concepts (i.e. it eases query processing in ObIR). However, domain experts prefer to specify terms/concepts directly in a search field, instead of browsing an ontology (Suomela & Kekalainen, 2005).

However, the complete quality of the ontology-based information retrieval system needs to be seen as a composition of various qualities, where all these qualities contribute to final user satisfaction. We define a holistic evaluation model for the ontology-based information retrieval systems (see Figure 2). The model is inspired by Technology Acceptance Model (Davis, 1989) - a model for explaining and predicting user acceptance of information technology. The arrows in the figure depict dependency between the model constructs.

The constructs of the holistic ObIR evaluation model are defined as follows. *System Quality* concerns indexing, ranking and user interface implementation qualities. Some value-adding aspects of user interaction with an ObIR system are presented in Figure 1. *Ontology Quality* aspects have been discussed above; though need to be elaborated further and related to a particular ontology usage scenario in an ObIR tool. *Query Quality* really depends on the users' experience in the domain and information seeking per se. Figure 1 deploys ways to help to specify more precise information needs. *Information Quality* is external to an ObIR system, and can be partially compensated by good ranking algorithms. Furthermore, information quality is a research topic itself and for more details the reader is referred, for instance, to Eppler (2006). Quality of these four components directly impacts *Service Quality* that can be measured using traditional (i.e. recall and precision based) methods.

System Satisfaction denotes the degree to which a user perceives the use of a system being effortless. *Information Satisfaction* is the degree to which a user believes that retrieved information would be useful. System and information satisfactions are determined by quality of corresponding components of an ObIR system and a service quality. *Intention to Use* is the degree to which a user intends to use a system and that depends on both, system and information satisfaction. Intention to use determines *Actual Use* that can be observed in longer period of time.

CONCLUSIONS AND FUTURE WORK

In this paper we have focused on quality aspects of ontology-based information retrieval (ObIR). We have argued about added complexity to interaction with information retrieval systems by employing ontologies. Consequently, we have related a set of vital features of ObIR depending on users' experience.

Furthermore, we have argued inadequacy of traditional information retrieval evaluation methods to assess ObIR quality and potential adoption by the users. We have presented a holistic evaluation model for ObIR tools. We will need to conduct a series of empirical evaluation of ObIR systems in order to test our holistic evaluation model and reconfirm dependencies between constructs defined there.

Ontology quality aspects have been overviewed; though need to be elaborated further, since the value of specific ontology properties depends on the actual use of the ontology in these systems. Therefore, major future work is to define specific application scenarios of ontology in IR and accordingly relate required ontology properties.

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