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User Interface Tactics in Ontology-Based Information Seeking

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ABSTRACT

Ontology-based information seeking is one of the most promising approaches to enhance existing search interfaces with features enabling users to better express their information needs or to improve exploratory search styles. This entails the interaction of users with concepts and relations embodied in ontologies in a dialogue process that can be interpreted as a query or used as a sign to suggest other paths that could lead to casual encounters. In this paper, we describe a number of ontology-enabled search tactics that have been experienced in prototype experiments, along with other possible techniques that would eventually be useful, as pointed out by existing research on information seeking models.

Keywords: *information seeking, ontology search tactics, interfaces.*

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1. Introduction

Information seeking (IS) on hypermedia systems – and especially on the Web – is a complex human activity that originates from an information need and entails some form of strategy, in some cases including search and browsing on several disparate information sources. A number of behavioural models have been proposed for such activities. For example, the model proposed by Choo, Detlor and Turnbull (2000) includes four main models of information seeking on the Web: undirected viewing, conditioned viewing, informal search, and formal search, and a number of different *moves,* like chaining, browsing or monitoring. These characteristics entail that interfaces for search engines and other applications should explore new query formulation

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paradigms that enable interacting with users to a higher extent than current query-formulation interfaces, which are mainly based on typing words and matching word indexes. In addition, studies on Web search behaviour through conventional search engines have pointed out that most people use few search terms, and they rarely use advanced search capabilities (Spink *et al.*, 2001).

If we consider the richness of information seeking modes and behaviours together with the relatively simple query formulation usage patterns of search interfaces on the Web, it becomes clear a need to support diverse seeking moves or tactics in Web user interfaces, but without increasing their complexity or overcrowding them with facilities that will be rarely used. These somewhat conflicting requirements call for a new research agenda in user interface design that takes as a point of departure existing research on information seeking models and also on the human factors-oriented branch of information retrieval (Robins, 2000), often referred to as *interactive information retrieval* (IIR).

Every model of information seeking provides an account of what the concept of information need, which originates the seeking or search process. From a cognitive perspective, those needs – which are in many cases vague – can be expressed through high-level concepts (Sutcliffe & Ennis, 1998), which in turn are connected to other concepts that pertain to a given domain or the intersection of a small number of them. Thus, computer-based conceptualizations appear as a promising approach to guide search, both for the fulfilment of information needs and also for serendipitous or casual discovery of interesting information connected to the current search process. From among the knowledge representation formalisms (Davis, Shrobe, & Szolovits, 1993) that have been proposed and applied in the last years, ontologies have become the most interesting one from the perspective of developing Web applications. This is due to the fact that modern ontology description languages (Fensel, 2002) are prepared for interoperation on the Web through XML formats, and the logics that underlie them (Baader *et al.*, 2003), have been carefully selected to provide a good compromise between richness and computational complexity.

In this paper, we review the different kind of user interface tactics that can be implemented with the help of ontologies in the context of information seeking, along with some of the conceptual and technical issues that surround them. The issues described here are based or similar to experiences reported elsewhere about ontology-based search interfaces (García & Sicilia, 2003; Sicilia *et al.*, 2003), search based on thesauri

(Papazoglou, Porpoer & Yang, 2001) and also other specialized search interfaces like (Jacenek & Pu, 2003).

The rest of this paper is structured as follows. Section 2 introduces the context, motivations and assumptions for ontology-based search. Then Section 3 provides the description of tactics that can be supported by ontologies. Finally, conclusions and prospective future research directions are provided in Section 4.

2. Assumptions and Rationale for Ontology-based Information Seeking

Ontologies *per se* are structured knowledge representations in the sense given by (Davis, Shrobe & Szolovits, 1993). But the concept of shared ontology, as envisioned by researchers on the so-called *Semantic Web* (Berners-Lee, Hendler & Lassila, 2001) goes further by considering that those representations are available for use in the Web, and they represent the consensual vision of a group or community of individuals. Some public ontology repositories like the *DAML Ontology Library*[2] already exist, and their number, quality and the range of domains they support can be expected to grow in the near future. This will eventually result in a coverage of domains with enough depth to enable the *annotation* of the vast majority of the resources available through the Web. These annotations would provide the basis for new search and browsing functionalities that will be able to take advantage form precise statements regarding document contents. For example, it could be possible to state that a given document provides "*details about*" linear regression, while other provides "*examples*" or "*a SPSS tool description*" regarding the same topic. Furthermore, applications could use ontologies to retrieve the fact that linear regression is a concrete form of "*regression*", and that even that it is usually "*taught in statistic courses*". Virtually any fact in the scope of ontologies will be available to diverse search and browsing tools. This vision subsumes also previous attempts to provide semantic types to links in hypermedia systems (Trigg & Weiser, 1986), since annotations can be used to automatically generate links (Carr *et al.*, 2001).

Classical information retrieval (IR) algorithms are based on the assumption that information items (or documents) are modelled logically by keywords pertaining to some natural language (perhaps considering also some lexical or even syntactical structures in some cases). But the Semantic Web essentially advocates "crossing the chasm" from

[2] http://www.daml.org/ontologies/

unstructured keyword-based models to richer logic-based annotations that would eventually provide a basis for reasoning. This entails that the logical model of a document becomes a set of logical assertions (annotations) about its contents (and perhaps also about its physical structure, its relationships with other documents and other meta-information). In addition, the form of the queries becomes a logic expression with an arbitrary level of complexity in its structure. It should be noted that the use of ontologies for the annotation of Web resources is not limited to categorization processes, as those that have been extensively used in Web catalogues like the popular *Yahoo!* (Labrou & Finin, 1999).

Ontologies can be use for the purpose of search in several ways. One of the possible approaches is the use of an interface in which users type terms – like in *Ontoquery* (Andreasen, Fischer-Nilsson & Erdman-Thomsen, 2000) –, and use ontologies later for the expansion of the query. In consequence, these approaches still rely in natural language processing, and gives no advanced search control features to the user. Other designs expose the technical structure of the ontologies in the user interface – like the OntoBroker query interface (Fensel *et al.*, 1998) –, thus hampering their usability for non-specialist audiences.

Our approach for ontology-based search interfaces is based on a number of assumptions about the evolution of *Semantic Web* technology, combined with an attempt to investigate the provision of user features to control the search process, as described by Bates (1990). It is assumed that a large number of annotated Web resources will be available in the future, and that such resources will be properly annotated by using logical assertions that relate them to terms or concepts in ontologies in semantically precise ways. In addition, it is also assumed that *description logic* languages (Baader *et al*, 2003) like those currently available will be used. The query formulation process is intentionally *iterative*, since the main point of the paradigm describes here is that search proceeds through guided navigation of the knowledge stored in ontologies. That is, the relationships among terms in the ontologies are used to build the user interface, and the system gets actively involved in suggesting alternative paths or possibilities that end up in a query comprised by the navigation and selections of the user.

In the Figure 1, a classical IR view is depicted, in which document representations (e.g. indexes) are used to match a query formulated after some given information need, usually in textual form.

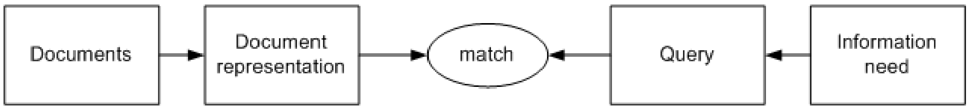

Figure 1: Classical IR model

Figure 2 depicts how the availability of shared ontologies changes both the query formulation and document representation parts of the IR process. On the one hand, the query formulation process can be supported by interacting with one or several ontologies, initially selected according to the domain of the information need – an important element in Bates' model described in (Bates, 1989) –. On the other hand, the representation of the document includes logical assertions that make it an integrated part of the ontological structure. This way, the matching process can be generalized to an exploration process that can be implemented in a number of different ways, depending on the form and logical interpretation of the query.

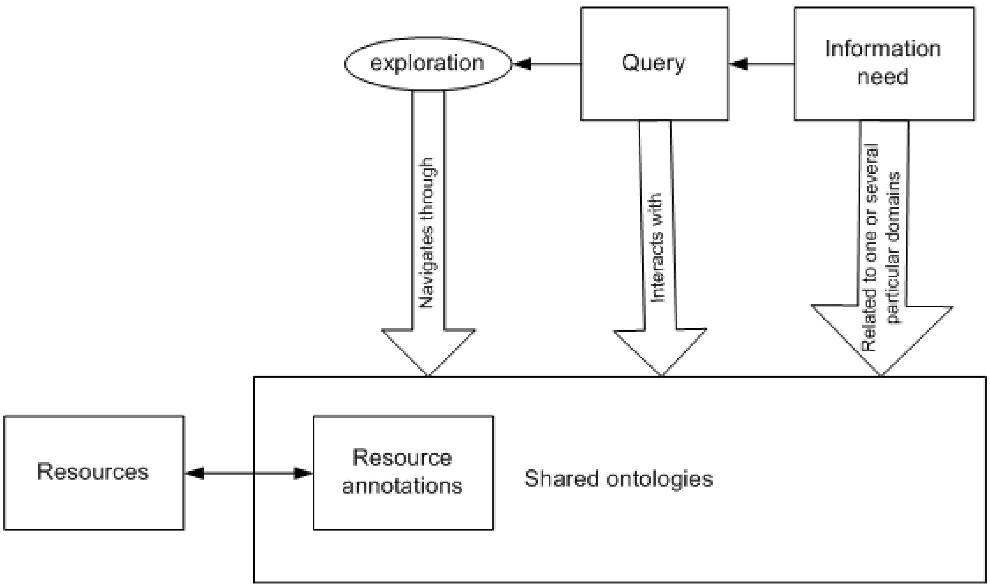

Figure 2: Ontology-based IR model.

3. Ontology-Enabled Search Tactics

As pointed out by Bates (1990), sometimes the user prefers to control the search process to some extent, according to certain search strategies and tactics that can be effectively supported in user interfaces. Tactics are defined by Bates as “one or a handful of moves made to further a search”, and include, for example, changing a term by a more specific one or adding similar terms. Strategies are entire plans for search that may comprise several tactics and have a far-reaching scope. Ontologies can be used to give direct support to tactics, and user models can be used to represent and reason about strategies. Here we focus on the former, since they constitute a more specific level, and tactic support can be used effectively even with anonymous users about which the system do not carry out any kind of profiling activity.

Table 1 provides a summary of some of the tactics described in (Bates, 1990) that can be effectively supported by ontologies, along with the move/s inside the ontology required to implement them. A simple notation is used to describe implementations, where capital letters are used to denote terms (A, B, C), the subset symbol is used to denote subsumption.

Tactic	Bates’ description	Ontology-Based Implementation	Example
SUPER	To move upward hierarchically to a broader (superordinate) term.	Change B by A, where $B \subseteq A$.	Move from *Siamese_Cat* to *Cat*
SUB	To move downward hierarchically to a more specific (subordinate) term.	Change A by B, where $B \subseteq A$.	Move from *Cat* to *Siamese_Cat*
RELATE	To move sideways hierarchically to a coordinate term.	Change B by C, where there exist a concept A such that $B \subseteq A$, $C \subseteq A$ (“directly”).	Move from *Siamese_Cat* to *Angora_Cat* (through *Cat*).
CONTRARY	To search for the term logically opposite from that describing the desired information.	Change B by C, where $B \cap C = \emptyset$ (*at least*)	Move from *LateHarvest* to *EarlyHarvest* (as wine categories)
RECORD	To keep track of trails one has followed and of desirable trails not followed up or not completed.	Store ontology traversal paths while browsing.	The path *Pet* → *Cat* →*SiameseCat* is recorded, so that the system may later suggest other traversals.
SELECT	To break complex search queries down into sub-problems and work on one problem at a time.	Split the ongoing search, pruning some branches that can be joined later.	When searching for information on *softwareTestMethods*, split on the different techniques (unit, integration, etc.)

PARALLEL	To make the search formulation broad (or broader) by including synonyms or otherwise conceptually parallel terms.	Add term *C* where *C* is similar to any of the terms that form part of the current navigation.	When searching for information on *softwareInspection* include also *softwareReview*.
PINPOINT	To make the search formulation precise by minimizing (or reducing) the number of parallel terms, retaining the more perfectly descriptive terms.	The inverse of PARALLEL.	-
SPECIFY	To search on terms that are as specific as the information desired.	Allow for stepwise refinement by going to the more specific in the subsumption hierarchy, combining several terms with "and"-like semantics.	(later explained as the main guiding design principle of *OntoIR*)
EXHAUST	To include most or all elements of the query in the initial search formulation; to add one or more of the query elements to an already-prepared search formulation.	Allow for multiple selection of terms and "or"-like semantics.	(later explained as a feature of *OntoIR*)

Table 1: Ontology support for search tactics

The SUPER and SUB tactics are straightforward navigations through the generalization-specialization hierarchy of the ontology, and have been applied yet in a number of systems like in (Papazoglou, Porpoer & Yang, 2001). The RELATE tactic involves "crawling" the generalization line of the concept up to its immediate covering concept (possibly more than one), and then deciding which specialization is closer to the original one. The "immediate" covering concept can be computed in some way by ordering the covering concepts by extent size, but deciding where to move up and down where several alternatives are available is not a simple decision. Models of "resemblance" or distance from concepts to super and sub-concepts have been developed elsewhere (Sicilia *et al.*, 2003), but such meta-information requires an elaboration of the ontology that virtually none current ontology provides. Providing a systematic account of the CONTRARY tactic is a challenge in the general case, provided that ontologies are not lexical thesauri, and thus antonyms (which represent relations between words) are not often explicitly stated. An approximation to this tactic may be that of using the disjointWith predicates that are included in the OWL[3] ontology language, but the changes would not always be useful, e.g. changing general concepts, like Male by Female, rarely would produce meaningful results. Once again, a

[3] http://www.w3.org/TR/owl-ref/

supplement to ontological structures should be designed for more effective tactic application. The PARALLEL tactic exhibits similar difficulties, since synonymy is in general not inferable from the ontology. Concrete cases for PARALLEL include the trivial situation in which C is completely equivalent (for example, owl:equivalentClass statements) to any of the terms in the current navigation, and also entity similarity measures that have been proposed elsewhere (Rodríguez, & Egenhofer, 2003). PINPOINT operates on the same information, but in this case allowing the user to eliminate some terms that are marked by the system as parallel.

The RECORD tactic requires user profiling, storing the traversal paths inside the ontology. Paths include both subsumption but also any arbitrary relation among concepts. Since the number of unexplored alternatives may grow significantly when interacting with large ontologies, it makes sense to left the decision of what tracks to store to the user, in a sort of “bookmarking” of ontology branches.

The SELECT technique can be implementing by using a child browser window for each branch, thus maintaining the link with the original one for an eventual re-joining. SPECIFY and EXHAUST indicate the need for “and”-like and “or”-like semantics for query formulations including several terms, so that more specificity or flexibility in selecting search results is provided.

Some of the ideas described so far have actually been implemented in several prototype-Web tools described elsewhere (Sicilia *et al.*, 2003; García, Sicilia, Díaz & Aedo, 2003; García & Sicilia, 2003). Figure 3 provides a screenshot of the OntoIR tool, illustrating the interface design of some tactics. OntoIR enables ontology-based search on collection of annotated resources by stepwise refinement of the query, according to the subsumption structure of the ontology. Since its main interaction mean is selecting terms presented to the user, two actions are required before starting the search:

- Domain selection. This entails selecting a concrete domain (ontology) to initiate the search. Nonetheless, ontologies in Web languages can be linked arbitrarily to reuse existing concepts, so that the search process may eventually jump to terms in other related ontologies.

- Presentation of the higher-level concepts (entry points) for the given domain. These are typically the higher level and more common concepts of the ontology, and will ideally be marked in the ontology, and later personalized according to the history of each user. It’s important that the selected collection of entry points for a given domain covers completely the terms in the domain, that is, that every term can be reached eventually by traversing some term relation (or several).

It is important to remark that not every concept included in an ontology is appropriate for user selection in this kind of interfaces. Concretely, terms in “upper ontologies” are often excessively abstract to be recognizable by users as indicators of information needs. For example, concepts in the “upper” part of the *Cyc* ontology (Lenat, 1995) like *Thing*, *SetOrCollection* or *TemporalStuffType* are useful for the purpose of internal representation inside the ontology, but they are seldom used as a concept in a search process, since they are excessively general to become representations of meaningful information needs.

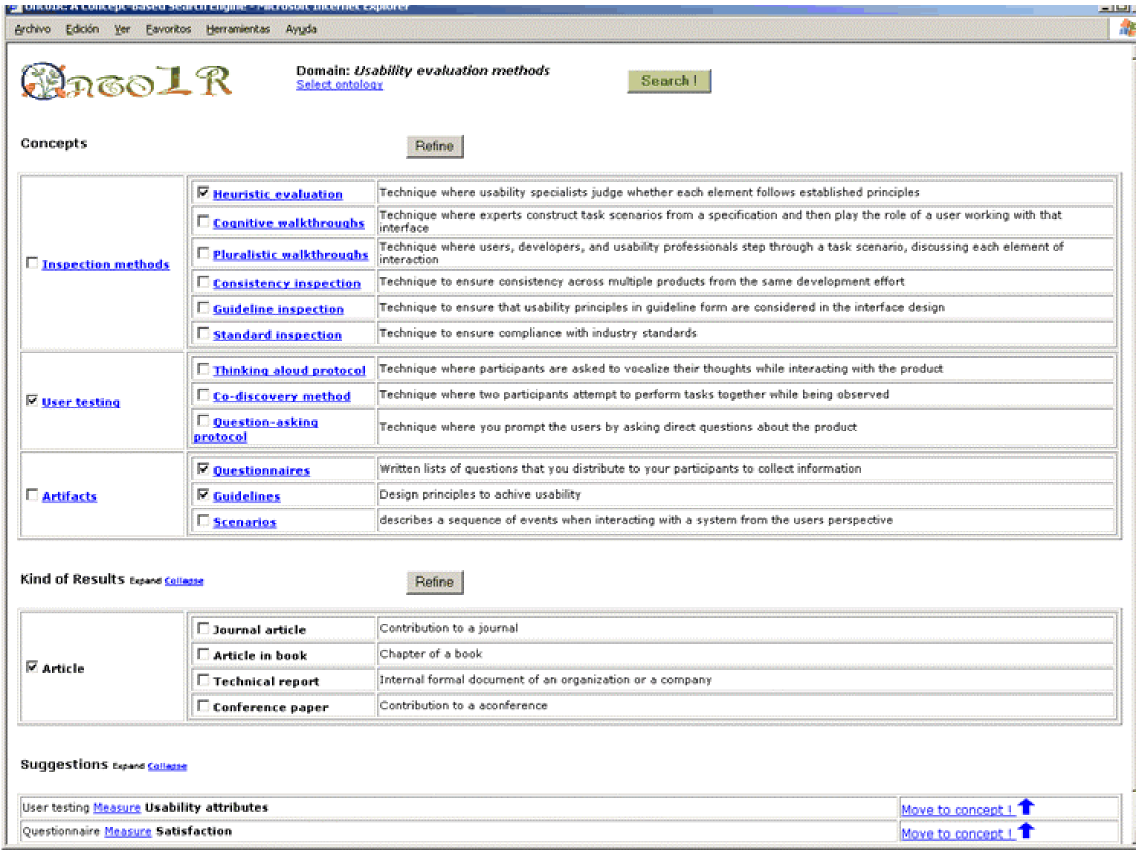

Figure 3: OntoIR ontology-based query formulation

OntoIR implements a number of tactics from among those described in Table 1. Concretely, its progressive refinement philosophy is based on the SUB and SPECIFY tactics, in an attempt to give the user the choice to specify queries to a large extent of detail. To do so, *OntoIR* allows the navigation from the entry points to lower levels of the subsumption hierarchy, pruning the branches that are not explicitly selected (checkboxes and the “Refine” button in Figure 3). The same stepwise philosophy is applied to the type of documents to be retrieved (“Kind of results” section in Figure 3), so that the form of the results can be pre-determined if desired, independently of the concepts that represent the information need. In addition, a form of the RELATE tactic is supported by the section “Suggestions” (at the bottom of Figure 3), that dynamically traverse the relations applicable to concepts currently selected, in an attempt to widen allow the user to widen the query (by “moving up” the concept with the corresponding link), thus providing a sort of modified EXHAUST technique, that eventually jumps to other ontologies not initially selected.

Once the user considers that his/her navigation through the ontology is finished, the results are obtained by exploring the resources annotated with the ontology. The current interpretation of the results of the navigation is described in detail in (García & Sicilia, 2003), that provides an “or-like” behaviour, but with an additional ordering or relevance of resources designed to show first the items that are heuristically considered more appropriate.

The OntoIR design interface represents an attempt to find a balance among common usability design guidelines and the potential contents of ontologies. First, the interface has intentionally avoided typing terms to eliminate errors coming from natural language interpretation, although it may be eventually convenient to produce a hybrid of the two approaches. Second, a necessary balance among interface readability (i.e. minimizing scrolling and not overcrowding the screen) and richness of the available paths is required, specially when traversing arbitrary relations to provide suggestions, since many terms large ontologies are often equipped with dozens of relations, many of them inherited from upper level terms, and thus of little relevance to the current context. And third, the assumption that users prefer a two-step process has been made, i.e., the user first elaborates the needed concepts, and then the system provides the results, just like in most conventional Web search engines. Breaking this assumption may lead to richer models, but they were not considered for the sake of simplicity and memorability. In addition, the evaluation of OntoIR has suggested the convenience of expanding its range of supporting practices to include others, like SUPER as a way to “backtrack” from explorations, i.e. supporting also RECORD for the previous traversal steps.

An additional important element of OntoIR is its intentional restricted support for casual discovery (Toms, 2000), somewhat provided through the “Suggestions” section, but also available in the results page, that list existing related information about each resource and also enables the initiation of additional queries, as showed in Figure 3.

Figure 3. Example OntoIR result *snippet*

4. Conclusions and Outlook

Ontologies are shared formal conceptualizations that can be used to support a range of well-known user interface search tactics. Since information needs can be roughly cognitively represented through a number of high level concepts, ontologies appear to match seamlessly the inception of information seeking processes. In consequence, ontology-based user interface design for search or information seeking represents an open avenue for further research, including both usability issues and also technical issues regarding the interpretation of the queries. The former includes the design of the search interface and its placement in the overall information architecture of the Web application. The latter is a problem of interpretation of user moves as query-construction steps, involving both cognitive hypotheses and also logical representations.

The ontology-based implementation of a number of existing well-known search tactics have been described, along with a concrete design for search that follows a concrete, stepwise refinement approach from more general to more specific concepts, but enabling also the combination of terms related to the ongoing query through any arbitrary relation. Further work should explore other alternative designs, comparing their performance for given seeking styles or user profiles. One interesting class of such alternative designs is that of hybrid approaches that use classical IR algorithms to try to enhance ontology-based navigation, e.g. by explotiting lexical relations to recommend terms, connecting concepts to lexical structures as described in (De Bo, Spyns & Meersman, 2003).

A wide range of open issues remains with regards to ontology based search interfaces, since the most effective metaphors and models have not yet been investigated. Moreover, the role of personalization may significantly affect typical design decisions – a review of some existing work can be found in (Brusilovsky, 2001) –, and existing collaborative filtering algorithms (Sarwar *et al*., 2000) can be used to exploit commonalities, search patterns and collaboration between users (Twidale, Nichols & Paice, 1997). For example, the system may change its collection of features for novice users, and the history of previous queries and processes can be used to inform new ones, for example, changing the collection of entry point to search for a particular user. Collaborative filtering recommendations could be applied, for example, to automatically include terms in a search depending on the commonalities of the history of the current user with other users of the system, just as e-commerce product recommendations are based on preferences of other similar users.

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