Application of User Profiling on Ontology Module Extraction for Medical portals

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ABSTRACT

One fit all for approach for searching and ranking discovered knowledge on the Internet does not cater for the diverse variety of users and user groups with different preferences, information needs and priorities. This is of a particular case in the National electronic Library of Infection in the UK (NeLI, www.neli.org.uk) accessed by a number of medical professionals with different preferences and medical information needs. We define personal and group profiles, based on user-specified interests, and develop an ontology module extraction service defining the key area of the infection ontology of a particular relevance to each user group. In this paper we discuss how ontology modularisation can improve the NeLI portal by providing customised alert, recommender service and speciality-customised browsing tree structure.

General Terms

Algorithms, Theory. Digital Libraries, Ontologies, Profiling

Keywords

Digital Libraries, Healthcare Ontologies, User Customisation, Personal and Group Profiles, Modularization

1 INTRODUCTION

Despite the fact that healthcare specialists are overwhelmed by the volume of medical information available on the Internet, they often cannot find what they want when and where they need it [1]. The work presented in this paper focuses on using profiles to personalise user access in the National electronic Library in Infection in the UK (NeLI) (formerly known as National electronic Library of Communicable Disease, NeLCD) [2]. NeLI provides a single access point to the best available evidence around all aspects of infection. Portal users range from public members, GPs, nurses, consultants in infection to senior PCT Trusts executives. Currently, the portal does not support any context-aware services nor it takes into consideration user categories. However, NeLI has been gathering user and groups profiles providing contextual information essential for support of customised services. Context and customisation are one the key factors for accurate, effective relevant information access in Internet digital libraries and in general – in the Semantic Web. Allan et al. [3] define contextual retrieval as a general framework combining search technologies and knowledge about a query and so called "user context" into a single framework in order to provide the most appropriate results for users information needs. The context of the user may includes as well as his/her level of expertise, domains of interest, etc.

In addition to information retrieval, the user information context is applied to enhance a wide range of features including semantic browsing and filtering. Sieg et al. [4] believe that the critical elements that make up a user information context include the semantic knowledge about the investigated domain, the short-term information need that might be expressed in a query, and the user profiles that reveal long-term interests. Profile is a record of user specific data that define users interests, his/her level of expertise, and his/her context.

The development of the NeLI portal takes into consideration the emerging Semantic Web where ontologies are one of the essential components [5]. Indeed encoding of human knowledge in ontologies using formal representation languages is one of the crucial tasks essential for enabling the Semantic Web vision. This is particularly the case in the (bio)medical domain where substantial efforts have been made to develop standards, medical terminologies and coding systems (SNOMED, MeSH and UMLS, which integrates more than 100 most relevant vocabulary sources in medicine[1]), therefore, providing knowledge bases for encoding medical evidence. Knowledge resources in the medical domain are often very large (several hundred or thousand of concepts) and this is the case for NeLI. To improve the access to resources managed by the portal it is essential to dynamically reduce the size of the knowledge resource to the most relevant part according to the context and the usage scenario.

This paper address this particular need and focuses on using profiles to personalize user access in the NeLI portal. We starts by giving a brief overview of the NeLI project in section 2, and then focuses on customisation and user profiling in section 3. In section 4 we discuss usefulness of ontology module extraction service and its application on personalisation and customisation is outlines in section 5. Finally, in section 6 we discuss work in progress and implementation issues. We introduce the related work in section 7 before to conclude.

[1] http:// umlsks.nlm.nih.gov/

2 NELI BACKGROUND

The National electronic Library of Infection (www.neli.org.uk) provides a single access point to the best available evidence on all aspects of infection. The family of NeLI projects include the National Resources of Infection Control (NRIC, www.nric.org.uk), Bugs and Drugs on the Web (www.antibioticresistance.org.uk) and other infection-related projects. Funded by the Department of Health in the UK and the Health Protection Agency, NeLI provides the main source of online medical evidence for a wide spectrum of users - clinicians, GPs, public health professionals, environmental health officers, infectious control nurses, general public and others.

The main source of medical evidence are books, journals, and Internet-based sources. These include: Health Protection Agency (http://www.hpa.org.uk), Cochrane database (www.cochrane.co.uk), NHS Centre for Reviews and Dissemination, Effective Health Care Bulletins, British National Formulary, CDC, BMJ, WHO, DH and others. However, the quality and reliability of provided information significantly vary. For example, studies of Mulrow [6], Oxman and Guyatt [7] have revealed how unreliable some editorials and review articles can be if they are not prepared systematically. In particular, although readers rely on journal review articles and editorials, the scientific evidence of these is inherently unreliable and biased towards a positive and optimistic view of the effectiveness of intervention.

The key value-added feature distinguishing NeLI from other medical sites is the aim to provide quality-appraised evidence-based knowledge and clearly identifying the level of evidence of the study.

Resources in the library are indexed using a NeLI ontology that has been created form a pruned sub-tree of the MeSH[2] (Medical Subject Headings) vocabulary and a custom classification for the infection control and public health.

The development of the NeLI domain ontology has been conducted in a close collaboration with infection experts in the UK. The ontology will be used as the background knowledge for the portal as there is no standard ontology meeting our specific need. For example, there are number of initiatives developing taxonomies for public health domain but neither of them has been widely adopted. There is no working ontology of healthcare organisations and medical service providers, nor agreed standards in health care (coding standards, data representation standards and common legal and ethical recommendations). Also, there is no common internationally accepted clinical coding scheme – currently, several coding systems are being used by different organisations: MeSH, CTLV3/SNOMED and ICD10. This is not only a UK but an international issue.

3 PROFILING NELI USERS

In this section, we will look into the spectrum of NeLI users and discuss how they could be categorised in terms of profiles.

NeLI users come from different professional backgrounds and specialties (microbiologists, clinicians, GPs, nurses, Environment Health Officers, public health consultants, etc.) which determine their medical interests, information needs and type of questions they are asking on the portal. In addition to their professions, they practise in a particular speciality and might have particular interests in treatment or investigation of a particular disease or a group of diseases. In addition to their personal profiles that are difficult to obtain from users, semi-automated definition of group profiles serves the purpose.

3.1 Personal User Profiles

Based on personal profiles, inserted by NeLI users, we have understanding of their professional backgrounds and personal interested. Users provide this information to us when signing up for the project. However, it is increasingly difficult to encourage more users to register their profiles. Therefore, we use the personal profiles as a base for semi-automated development of group profiles.

A NeLI user profile is a tuple N defined as N={name, surname, email, project, society, p,s,e,o} where

- name, surname, email are personal details
- project € {NeLI, NRIC, GRACE}, projects from the NeLI family
- society includes the professional society of the expert
- p € P, s € P u O, and e,o € O where O is the set of NeLI ontology terms and P is the list of NeLI recognised professions.

The list P of NeLI recognised professions include: clinical scientists, nurse, consultant, environmental health officer, general practitioner, lecturer, microbiologist, etc.

The following table is an example of a user profile:

name	Jo
surname	Blog
Email address	jo@yahoo,co.,uk
Society/Affiliation	BIS
Which project	NeLI
Profession	microbiologist
Speciality	virology
Expertise Area	antimicrobial resistance
Other Area of Interest	HIV

This profiling allows the user with the most time to customise their alerts to their individual preferences, choosing exactly which topics they want to receive alerts on, rather than the standard profession or specialty options. And enhance this by the option of other most common area of interest.

3.2 Speciality Group User Profiles

As NeLI serves several groups of healthcare professionals with particular information needs, there is a need for variations in the document search and ranking to meet the specific needs of each group. Based on personal profiles, each profession profile is described by the key information needs derived from the speciality and expertise area.

The profession group profile is defined as a tuple N={p,s,e,o} where p € P, s € P u O, and e,o € O where O is the set of NeLI ontology terms and P is the list of NeLI recognised professions.

Example is the table below.

[2] www.nlm.nih.gov/mesh/2002/index.html

Profession	nurse
Speciality	Infection Control
Expertise Area	TB
Other Area of Interest	Hand washing

Currently, we are looking into a dynamic weblog-based generation of the profiles. This is discussed in section 6.1.
These profiles allow a group customisation to certain keywords and alerts. The speciality profiles allow three level customisation of knowledge specific to and typical of a particular profession, specialty and main expertise area and other area of interest.
Users in a group may have different interests, but also sufficiently similar interests for the development of group default preferences. These preferences are currently predefined but will evolve over time as more use of the site provides greater feedback for analysis.
The need for a combination of professional, speciality and topic comes from different questions asked by different users. For example, all users search for TB (tuberculosis) but the information they actually need varies: a clinician will ask about latest TB guidelines, an infection control nurse about isolating patients with TB, public health office is more concerned about high-risk TB populations and outreach to them, while a GP might need to check the latest diagnosis and treatment recommendations for TB.
The table below demonstrates the different needs users or user groups might have. Based on the user group (profession), different information is to be provided. The case scenario is based around TB. Following table illustrates the typical user groups and their targets for further information.

User group	**Ontology**	**Targets**	**Question**
GPs	Galen	BNF Back to NeLI treatment pages	Coughing blood and lost weight – could this be TB?
clinicians	MESH	PubMed Clinical Evidence BNF	Diagnosing TB from an X ray? Mantoux text understanding
microbiologists	MESH GO	PH Observatories Web sites ?	Is bug X resistant to antibiotics X? How do I isolate bug Y?
public	Galen?	Wikipedia HPA Public leaflets NHS DO	Why the BCS vaccination was dropped? Where can I catch TB?
Anyone with a suspicion	Galen/MESH	Contacts DB	Who shall I inform?
Head masters at schools	Galen	Wikipedia	Shall I get all kids vaccinated when I have a one case study?

The defined profiles are used customizing large ontologies for information access.

4 EXTRACTING ONTOLOGY MODULE

It is increasingly difficult to manage a very large ontology, such as the NeLI ontology, as scalability is causing some serious performance problems. From the user perspective, it is also increasingly difficult to navigate due to human cognitive limits. As the ontologies in Semantic Web are getting larges, it is becoming more important to work with a relevant subset or module of the original ontology according to the current needs or user context. The notion of modularization is well understood and accepted in the area of the Software Engineering. The aim of ontology modularization is to reduce the size of the ontology being currently in use to keep only the part(s) relevant to a given context. Ones extracted, an ontology module can be used as it is or perhaps extended by new entities according to the need in time of usage. One of the main characteristic of an ontology module is its 'self- containment'. An ontology module is self-contained if all the concepts defined in the module are defined in terms of other concepts in the module, and do not reference any concept outside the module [8]. Thus the module obtained given a set of input entities is constituted by the minimal set of axioms that are required to understood, process, evolve and reuse these entities [9].
To provide a better and easy access to the NeLI portal and allow personalization, we are implementing an algorithm for ontology module extraction based on user profiles described in section 3.

5 PERSONALISATION

In this section, we present some scenarios where extracting ontology module can help user customization.

5.1 Browsing Tree Customisation

A recent survey on the NeLI portal logs shows that users prefer the browsing modality to others information access modalities [10]. We use pruned NeLI ontological tree as a controlled vocabulary for user search input. The pruning was performed to reduce the number of the keywords and reflect the needs of the communicable disease domain. Therefore, looking at the MESH-derived part of the NeLI ontology, sub-trees B "Organism", C "Diseases" and parts of the sub-tree D "Chemicals and Drugs" were originally selected; the number of levels included was chosen according to the frequency of each particular term. Typically, the pruning process included terms up to the 3rd or 4th MESH tree level. Figure 1 need to sort out numbering illustrates a small sample of the pruned sub-tree C'.

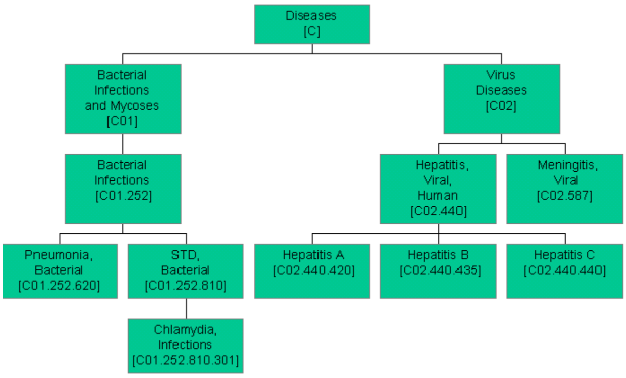

Figure 1: Example of Pruning the MeSH ontological tree

Users can also input free text for search themselves, however, as these typically vulnerable for spelling mistakes, language differences, etc, therefore, the preferred way for search data entry is navigating the controlled vocabulary based on NeLI ontology [10].

5.2 Recommender

Based on the extracted ontology relevant to specific profession, the NeLI portal will allow recommending the most accessed document by infection control nurses, for example.
Also, semantic relationships will allow highlighting other documents of interests for users with the same group profile who visited a certain document - e.g. TB and HIV relation might be used this way.
Evaluating the weblogs to investigate whether users are following the recommenders will further enhance the profile definitions and work in a self-tuning manner.

5.3 Search Recommender List

The NeLI portal provides an auto-completion service which suggests to users keywords to be used during the search process.
When typing a search term, a query is sent to the NeLI server using Asynchronous JavaScript and XML (AJAX). A list of ontology's terms are sent back to the user and displayed in a combo box (figure 2). Instead of providing the same list to different users (e.g., nurses or clinicians) having different needs, user profile is take into account when querying the server and returning the result.

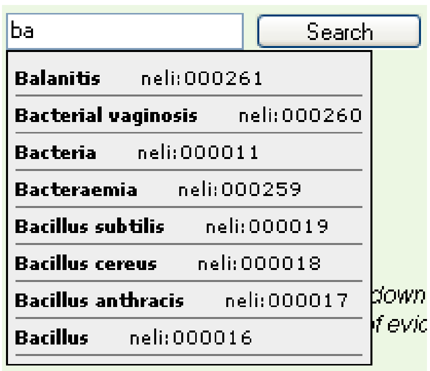

Figure 2: Recommended Keywords List

5.4 Search Customisation

One application of personalisation is in providing a 'richer' search functionality to users. For example, in addition to defining keywords for a query and their combination by logical operators, users can customize the search by restricting the resultant set to *certain criteria*, as indicated by the Dublic Core fields elements from The Dublin Core Metadata initiative (http://www.purl.org/DC) defining all resources in NeLI. For example, we can perform a search for all documents regarding meningitis and children and display only Randomised Control Trials, or Case Studies. There are two aspects to search on the WWW; firstly there is the algorithm to identify a set of documents that match a particular search query and secondly there is the algorithm for ranking the documents in a certain order of importance. Personalisation can be applied to the ranking aspect of the search function and we can use profiling information as an added dimension in the ranking of documents [11].

5.5 Alerts

In addition to customising the search, as the typical strategy, alerts can highlight the most important papers for each profile and be emailed to users as soon as relevant documents are inserted.

Proactive personalisation is where agent technologies can play an important part. Information within the database needs to be presented in as efficient a manner as possible, so that access to key information is not overlooked by end users. Anticipation of what the user is looking for or may be interested in would enable a more productive information retrieval session. A pilot study was performed on the National electronic Library for Infection in order to examine these patterns [12]; automated analysis would add further information on a continuous basis.

Alerts can include new documents, new reviewer's assessments, conferences, deadlines etc, and the agent can try to fulfil the user's needs by matching the alert frequency with the selection of preferred intervals (i.e. daily alerts, weekly alerts, monthly digests, etc).

Again, any combination of the speciality profiles and personal profiles will be applicable:
Group Alerts:
1. Alerts specific to profession (GPs, nurses, microbiologists, etc.)
2. Alerts specific to specialty (e.g. Infection Control)
Personal Alerts:
3. Alerts specific to individual choices of topics

5.6 Dynamic Knowledge Provision for Semantic Browsing

This issue is motivated by the development of the SeaLife project [13]. The main goal of the project is to develop a grid browser for the life sciences, which will link the web to the current emerging e-science infrastructure. Particularly SeaLife will help users to browse semantically the Web by highlighting the semantic data contained in the Web page which is being visited and providing a dynamic access to Web servers and Web/Grid services related to the Web content retrieved. The system is built using the

Conceptual Open Hypermedia Service (COHSE) system [14] developed at University of Manchester. COHSE automatically adds hyperlinks on web pages by recognizing terms contained in background knowledge, based on uploaded ontology. For any term highlighted on a page, resources are provided for broader, narrower and related terms obtained from the underlying vocabulary. COHSE works with only one background knowledge in the same time even if sometimes in order to better describe the knowledge contained in a web page the combination of several relevant knowledge sources is necessary. Moreover, the use of very large knowledge source can affect the performance of the system. Thus, in this case, selecting the relevant part of the knowledge source according to the user profiles may enhance the performance of the system and can enhance the appropriateness of the provided dynamic services.

5.7 Semantic Annotation of NeLI Resources

In order to support a user-customisable search, resources need to be precisely described. Semantic annotation is the process of attaching to a resource one or several semantic entities.
Resources managed under the NeLI portals are both characterized by the NeLI ontology and Dublin Core which defines a list of fields characterizing an electronic document for cataloguing and search purposes. The semantic annotation process if performed manually is a difficult time consuming task specifically when the annotation specialist have to deal with a very large knowledge source (several thousand of entities). The ontology extraction process helps reducing the knowledge source to be used during the annotation task. Infection control resources would be tagged on NeLI by the relevant bacteria, disease and population. However, in NRIC (an infection control specific portal) the same document would be tagged by bacteria, disease, mode of transmission, healthcare setting where it is to be controlled etc.

6 WORK IN PROGRESS

In this section we discuss related areas of our work in progress and implementation issues. Our current work is based on set of static users profiles which may present some drawbacks. We are developing a Dynamic Profiling using server weblogs.

6.1 Dynamic Profiling

Web server logs (henceforth referred to as "logs") are collected by the web server. They are used for historic as well as real time analysis. The aim is to use real time analysis of the logs for carrying out group profiling. User session identification in the logs is based on either user IP address and a set session time or logged user information. The information stored within the Lotus Domino logs includes the standard fields such as IP address, username (if logged in), pages visited, etc. Historic log analysis provides useful information about the site such as the most commonly accessed pages, common search terms etc. Automated agent analysis of the logs can provide ongoing dynamic evaluation of the use of the site.

Dynamic profiling is based on using a sliding window snapshot of the logs. The sliding window enables the system to 'reset' itself, thus mitigating the effects of incorrect profile identification whilst maintaining the level of correct identification.

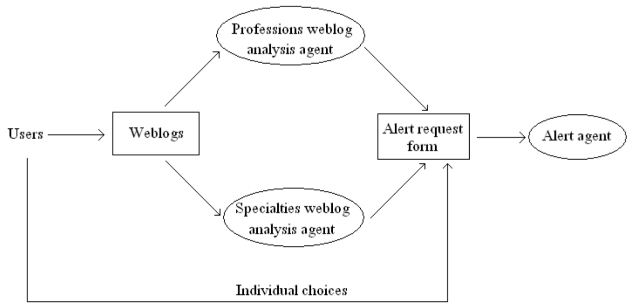

Figure 3. The Agent-based Personalization alerts process.

Having recorded the profession and specialty of each registered user as they first register to use the extended features of the site.

A Professions log analysis agent runs on a scheduled basis e.g. daily, to analyse the logs for users who have browsed the site whilst logged in. This agent ranks the topics viewed for each profession in the last 4 weeks, writing this information to a hidden field within the Alert Request Form. A second agent, the Specialties log analysis agent, runs in the same way to rank the topics viewed for each specialty in the last 4 weeks, and writes this to another hidden field within the Alert Request Form.

The Alert Request Form is used by users to specify what information they would like to receive in regularly mailed alerts. They can choose to accept the default setting of topics which are in both their profession and specialty rankings, topics in their profession rankings only, those in their specialty rankings only, or they can make an individualised choice from a complete list of all the MESH-based topics on the site. A mailing agent will then run on a scheduled basis to email the personalised alerts to all those who have filled out the alert request form. This method is illustrated in Figure 3.

The data obtained by the agents through this profession / specialty log filtering can be examined further to also be useful for recommending information whilst the user is browsing the site. If, for example, a user is looking at a topic on the site whilst logged in, then the page will also show suggestions of other potentially interesting resources within the most popular topics of that professional group. Extra functionality can be added by the implementation of an underlying ontology to be a part of this recommendation, e.g. if a clinician is looking at information on TB, they will also be presented with a link to documents on HIV if an ontological relation between the two has been specified within the system. Thus dynamic profiling opens up avenues for providing customised navigation to users.

6.2 Implementation issues

NeLI is hosted on a Lotus Domino web server using the proprietary database and JavaScript and Lotus Script as the scripting languages. Detailed information about accesses to the server are collected daily and stored in the web server logs. Using the latter logs, we are building an Automatic Profiling Engine which will provide an API that will be used for other modules such as the Recommender. Before the logs can be used for such analysis, they have to be processed in order to eliminate unwanted or unimportant accesses from the records. For example, we have to remove all accesses from web crawlers. However, automatic identification of web crawlers is not a trivial task. Such cleaning of the logs is essential in order to avoid misleading the profiling engine. The primary use of web crawlers is to index the WWW on behalf of search engines. Often these are well known and publicise their intent openly such that their respective accesses can be identified and discarded from the logs. However, we also have lots of web crawlers that "behave badly"! Typically, these are spammers harvesting email addresses or obscure search engines. And automatic identification of this class of web crawlers is very challenging; often they try to hide their presence by mimicking "human browsing behaviour". As part of our work on customisation we are currently building an automatic crawler detection tool. Once processed and cleaned, the logs are sent to the Automatic Profiling Engine (APE). APE analyses the logs and builds up the profiles. APE can run in two modes: an interactive mode where profiles are built and updated continuously or a historic mode where profiles are built offline. APE provides an API that applications or modules such as the Recommender can use to query the profiles.

Finally, from the ontology point of view, the first version of the NeLI knowledge has been formalised in the OBO format using the OBO-Edit. Due to the limitation we had in the definition of new semantic relationships between entities for the NeLI knowledge (OBO provides a set of predefined relationships), we have started migrating the NeLI knowledge to the SKOS format[3].

7 RELATED WORK

User profiling is a well-established domain in user modelling with a wide applicability on recommender systems, information retrieval and alerting. Profiling for recommending research papers based on ontologies was investigated by Middleton [15]. Dynamic profiling applied to information retrieval on the web has been widely applied [16]. However, a very common application of profiles is the vision of customised content relevant to the particular profile [17].

From ontology construction point of view recently, [18] published an attempt to develop a multilingual ontology using the OWL language specialised in infectious disease outbreak surveillance.

The problem of extracting ontology modules has been recently addressed in [19,20, 21, 22]. Two different main approaches are reported for the ontologies modularization: ontology partitioning [19][20] and ontology extraction [21][22]. The first approach relies on splitting up a large ontology into several modules such that each module is an ontology and the union of all modules is semantically equivalent to the original ontology. The second approach relies on the reduction of an ontology to the subpart that covers a particular sub-vocabulary [22][23][21]. In this approach, usually elements to be included in the module are recursively extracted by traversing relations in the original ontology starting by the input sub-vocabulary.

Search customisation using web server logs has been demonstrated by [11]. They used web server logs to customise the search results for searches carried locally on a website. They complemented the PageRank algorithm with data collected from the logs and have shown that such customisation improves the performance of the PageRank algorithm. They did not use any semantic data. On the other hand, we use semantic as well as quantitative data in the logs in order to customise the search.

8 CONCLUSION

NeLI is a single-access online portal to the best available evidence and knowledge on infection. There are a variety of user groups accessing the portal and one for all approach to search, ranking, alerts, browsing no longer works.

In this paper we have described the personal and speciality based profiles determining what information might be users interested in order to better customise the service. Linking profiles to ontology module extraction defining the best subset of the knowledge relevant to the particular user group was investigated and several applications were outlined.

Dynamic profile generation based on web logs to improve the understanding of user needs is currently being explored. These three key components applied on NeLI will allow customised semantic service meeting the needs of infection professionals in the UK and abroad.

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10 REFERENCES

[1] J.A. Muir Gray, S de Lustignan. National electronic Library for Health (NeLH). BMJ, 319, 1476-1479, (1999).

[2] P. Kostkova, J. Mani-Saada, J. R. Weinberg. "Do you read the literature properly, and if you do how can others benefit from it?". PHLS Annual Scientific Conference 2002, Warwick, UK, (2002).

[3] J. Allan et al.(2003) Challenges in Information Retrieval and Language Modelling : Report of a workshop held at the centre for intelligent information retrieval, University of Massachusetts Amherst, September 2002. ACM SIGIR Forum, 37(1):31-47.

[4] A. Sieg, B. Mobasher, R. Burke, G. Prabu, S. Lytinen. Representing User Information Context with Ontologies, In Proceedings of HCI International 2005 Conference, Las Vegas, Nevada, July 2005.

[5] T. Berners-Lee, J. Hendler, and O. Lassila, "The Semantic Web," Scientific Am., May 2001, pp. 34–43

[6] C.W. Mulrow. The medical review article: state of the science. Ann. Intern. Med., 106, pp 485-8, (1987).

[7]A.D. Oxman, G. H. Guyatt. Guidelines for reading literature reviews. Can. Med. Assoc. Journal, 138, pp 697-703, 1988.

[8] P.Doran. "Ontology Reuse via Ontology Modularisation". In Proceedings of KnowledgeWeb PhD Symposium 2006 (KWEPSY2006) Budva, Montenegro, 17th June 2006.

[9] B. C. Grau, B. Parsia, E. Sirin, and A. Kalyanpur, 'Modularizing owl ontologies', in Proceedings of the KCAP-2005 Workshop on Ontology Management, Banff,
Canada, (2005).

[3] http://www.w3.org/2004/02/skos/

[10] A. Roy, P. Kostkova, E. Carson, M Catchpole. Web-based provision of information on infectious diseases: a systems study, Health Informatics J.
2006 Dec;12(4):274-92.
[11] Q. Cui and A. Dekhtyar On improving local website search using web server traffic logs: a preliminary report, ACM International workshop on Web information and Data management (WIDM'05), Nov 2005, Germany
[12] G. Madle et al. Evaluating the online activity and searching behavior of users of a medical digital library. HDL 2004: Healthcare Digital Libraries Workshop held in conjunction with EDCL2004.
[13] M Schroeder, A Burger, P Kostkova, R Stevens, B Habermann, and R Dieng-Kuntz. From a Service-based eScience Infrastructure to a Semantic Web for the Life Sciences: The Sealife Project. In *Workshop on Network Tools and Applications in Biology, NETTAB 2006*, Sardinia, Italy, 2006
[14] S. Bechhofer, Y. Yesilada and B. Horan. *COHSE: Knowledge-Driven Hyperlinks* the Semantic Web Challenge at the International Semantic Web Conference (ISWC 2006), 2006
[15] S.E Middleton,N.R, Shadbolt, and D. C. De Roure. (2004) Ontological User Profiling in Recommender Systems. ACM Transactions on Information Systems (TOIS) 22(1) pp. 54-88.
[16] C. Danilowicz and A. Indyka-Piasecka. Dynamic User Profiles Based on Boolean Formulas, Lecture Notes in Computer Science, Volume 3029/2004, pages 779-787
[17] A. Wærn, User Involvement in Automatic Filtering: An Experimental Study. In User Modeling and User-Adapted Interaction, Volume 14, Numbers 2-3 / June, 2004
[18] N. Collier, A. Kawazoe, L. Jin, M. Shigematsu, D. Dien, R. Barrero, K. Takeuchi, A. Kawtrakul, A multilingual ontology for infectious disease outbreak surveillance: rationale, design and challenges", Journal of Language Resources and Evaluation, Springer-Elsevier 2007
[19] H. Stuckenschmidt and M. Klein, Structure-Based Partitioning of Large Concept Hierarchies. In Proc. International Semantic Web Conference 2004: 289-303
[20] B. C. Grau, B. Parsia, E. Sirin and A. Kalyanpur, Automatic Partitioning of OWL Ontologies Using E-Connections. In Proceedings of the 2005 International Workshop on Description Logics (DL-2005)
[21] N. F. Noy, M. A. Musen. Specifying Ontology Views by Traversal. Third International Conference on the Semantic Web (ISWC-2004), Hisroshima, Japan, 2004.
[22]] M. d'Aquin, M. Sabou, E., Motta, Modularization: a Key for the Dynamic Selection of Relevant Knowledge Components. Workshop: First International Workshop on Modular Ontologies, International Semantic Web Conference (ISWC'06), Athens, Georgia, USA.
[23] J. Seidenberg, A. L. Rector: Web ontology segmentation: analysis, classification and use. WWW 2006: 13-22