A Topic Map-based System for Identifying Relevant Learning Objects

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Abstract: We propose a Topic Map based system to facilitate study at various levels. The objectives of this system are to help the learner recognize the structure of relevant knowledge, and to locate relevant learning objects (LOs) that help in overcoming conceptual difficulties at any given step. This system would use a graphical interface for the learner as a front end with Topic Map technology at the back. A new form of Learning Object Metadata is proposed, to include machine processable description of content, going well beyond keywords. We call such metadata as "Content Metadata in the Topic Map Format" (CMTMF). This metadata will be a Topic Map fragment, each in the form of a triple showing two topics and the association between them. CMTMF queries, again in the form of triples will be matched with the CMTMF contained in potentially relevant LOs identified by a search engine.

1. Introduction

Technological advancement and the knowledge explosion have made a lot of rich, reusable, content available on the World Wide Web (WWW) (Sampson *et al*., 2002; Brusilovsky & Nijhawan, 2002). Content is available in various forms such as videos, animations, virtual labs, and various online course materials freely available on the Web. Examples are MIT's Open Courseware (OCW) (Iiyoshi & Vijay Kumar, 2008) and material made available by National Programme on Technology Enhanced Learning (NPTEL) (Bhattacharya, 2004), digital repositories such as MERLOT and digital libraries (Littlejohn, 2003). Learners should get relevant content in the form they like whenever they need it. Personalized help of this type is very important to promote learning.

The architecture of a system is proposed here to make the resources available for learning in a personalized manner. The system is compared with those reported in related literature to bring out the differences. This paper answers the following questions by describing the proposed system:

a) How can we help learners to recognize the structure of relevant knowledge?
b) How can we identify, locate and fetch the most relevant resources from various repositories, stored locally or globally as per a learner's need on a personalized manner?
c) Can we improve on the recall and precision of search for LOs[2], compared to current state of the art?

2. Background

In this section we offer a brief introduction to the terms which we will be using throughout the paper.

Metadata is descriptive information about some data. Garshol (2004) points out that the term metadata in computer science is generally taken to mean information about a set of data in a particular representation, which typically means "information about objects". One suitable representation for describing metadata of Web resources uses the Resource Description Framework (RDF), a specification designed by World Wide Web Consortium (W3C, http://www.w3.org/TR/2004/REC-rdf-primer-20040210/). RDF has been defined as a language for representing information about resources on the World Wide Web. RDF triples contain subject, predicate and object. A collection of such RDF triples can support interoperability between applications that exchange machine-readable information on the Web. XML is used to represent a variety of structured data including that in the RDF form.

Ontologies define the terms used to describe and represent an area of knowledge. Ontologies are used by people, databases, and applications that need to share domain information (a specific area of knowledge).

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[2] It is a common practice to refer to Web resources identified by a search engine as documents, irrespective of what form they are in - text, audio, video, etc. LOs can be considered to be a subset of such "documents" meeting specified criteria.

Ontologies include computer-usable definitions of concepts in the domain and the relationships among them (W3C, 2004). Those are used in sharing information and in collaboration.

Learning takes place any time and anywhere, in diverse environments such as traditional classrooms, outside the classroom, and while working through educational videos or online courses. This learning benefits significantly from availability of what the IEEE Learning Technology Standards Committee defines as learning objects: any entities, digital or non-digital, which can be used, reused, or referenced during technology-supported learning (IEEE, 1998). Learning Objects (LOs) stored anywhere locally or globally can be made available at any time and at any place to learners provided they have network connectivity. Learning Objects can be used in any learning environment, across disciplines and facilitate the creation and use of online educational content (McGreal, 2004). Learning Objects use a variety of media; therefore, they can be selected to match the learning style of the user. Learning Objects (LOs) are flexible, portable and adaptable and can be used in multiple learning environments and across disciplines. Learning objects are also reusable, accessible and interoperable (Polsani, 2003; Brusilovsky & Nijhawan, 2002). They may be in a number of forms such as text document, a video/audio file, an image/animation, a simulation, or a virtual lab experiment. They can also be in the form of activities, games, or tests.

There are various Learning Object Repositories (LORs) available on the Web such as Campus Alberta Repository of Learning Objects (CAREO), TeleCampus, and Multimedia Educational Resources for Learning and Online Teaching (MERLOT). Learners can use the content of these LORs for updating and enhancing their knowledge.

LORs store both Learning Objects and their metadata (Neven & Duval, 2002). The metadata maintains links to the associated LO if it is stored elsewhere on the Web (Mohan & Brooks, 2003). Ontologies and metadata are both sharable. IEEE Learning Technology Standards Committee has defined Learning Objects Metadata (LOM) standards (IEEE LOM, 2001). A number of LORs such as ARIADNE, SMETE, Learning Matrix, MERLOT, CAREO, Learn-Alberta, Lydia Inc. contain IEEE LOM profiles. Neven & Duval (2002) have compared these LORs and have raised a few issues arising from different design decisions: use of peer-reviewing, availability of advanced search facility, user commitments in regard to Intellectual Property Rights of the content stored in the LOR, and decisions about the system and network architecture (for instance, peer-to-peer or client-server communication). Some of the solutions the above-mentioned authors have suggested are:

a) Having customized metadata creation facilities for LORs
b) Having a quick browse function to give new users a feel for the content in a repository
c) Having peer-reviewing facility to ensure quality
d) Having an advanced system to create user models (described in the next paragraph) by asking users to fill a form and giving a facility of chat and discussion forums
e) Using a distributed architecture, for instance with one server holding metadata and others holding content for efficient access.

We have taken into consideration some of these suggestions in the architecture presented in Sec 6.

A good learning experience is one in which a learner can acquire new knowledge and master new skills, critic any examined assumptions and beliefs, and engage in an energizing, collaborative search for knowledge and holistic personal development (Eastmond & Ziegahn, 1995). A User Model is: “a knowledge source, which contains explicit information on all aspects of the user that may be relevant to the dialog behaviours of the system” (adapted from Wahlster & Kobsa, 1989, p.6). Use of a model that covers a learner’s knowledge, skills, preferences, performance and needs is the essence of personalization in an e-Learning context (Lalingkar & Ramani, 2009). It leads to more efficient learning. Many researchers have discussed personalization in the systems described by them (Brusilovsky & Henze, 2007; Brusilovsky & Nijhawan, 2002; Dolog & Sintek, 2004; Muntean & Muntean, 2009). Henze & Nejdl (2001) and Sampson *et al*. (2002) have described some techniques of personalization. The need for personalization in the context of study facilitation is discussed in Section 4.

“Topic Maps” is an ISO standard for describing knowledge structures and associating them with information resources (Pepper, 2000). Topic Maps (TMs) are discussed in greater detail in the following section.

3. Topic Maps and their Use

We had earlier explored improving Web search (Lalingkar & Ramani, 2009) for LOs. This work reports the result of an exploration with Topic Map technology for locating explanatory learning resources.

The technology of Topic Maps is covered by a number of papers (Pepper, 2000; ISO 13250; Ontopoly, 2009; Garshol, 2004). The basic concept model of Topic Map is TAO where T stands for Topics, A for Associations and O for Occurrences. An interesting facility provided by Topic Maps is that we can group the Topics under *Topic Types*, Associations under *Association Types* and Occurrences under *Occurrence Types*.

Also, there are *Role Types* which are used in the Topic Map to represent the roles played by different topics in the association.

Topic Types are like classes and sub-classes, while instances are Topics. “Country” can be a *Topic Type* and “India” can be one Topic of that *Topic Type*. “Occurrences” include internal information and external resources pointed to by URLs where the topics of interest are covered. Internal occurrences are the occurrences where the information about the Topic is provided inside the Topic Map. For Example: If there is a Topic named *Shakespeare*, it could have an association named *born on*, and an occurrence *Date of Birth*. The value of the occurrence i.e. *Date of Birth* will be filled-in when the Topic Map is created. This will appear as an internal occurrence for the Topic *Shakespeare*. *External Occurrence Type* examples are: Text Documents, Books, and Videos available over the web. Associations are like predicates or relationships between the topics. For instance, the associations such as *written_by*, *composed_by* associate some “work” with some “Author”. Hence, “work” can be the *Association Type* for these associations. An association has roles associated with it, determined by the directions of the association. For example: the association *written_by* can be between a work and an author *Shakespeare*. The association roles here indicate what was written by, and by whom. The answers to these two questions are *Hamlet* and *Shakespeare*. The *Topic Types* of these topics are *Play* and *Author*. Hence, *Play* and *Author* are *Association Role Types* for this particular association.

Another advantage of TMs is that every topic, association, occurrence and role has a subject identifier (SI) in the form of a Uniform Resource Identifier (URI). If the SI of a topic represents a resource, then it will be a Uniform Resource Locator (URL) (Omnigator, 2008). One can specify the relevant namespace when a particular SI is used i.e. if a common topic name occurs in two or more contexts, the citation of the relevant namespace removes the ambiguity created by the use of a common topic name. For example, *fish* is a member of the *Pisces group of living things* and is also *a food item*. The relevant namespace explicitly associated with topic name *fish* uniquely defines the topic being referred to, ensuring that TMs indicate unambiguously the “word-sense” or denotation of each topic. This facility of unique identification gives us the great power for merging small Topic Maps to make a big Topic Map.

There is also a filtering facility in TM, using which one can filter information like topics, associations, roles, occurrences based on the “scope” associated with them. For instance, Topic Map elements can be assigned the scope “High School Level” to indicate that they are relevant to high school students. One can hide the information that is not required by the learner at that particular moment, thereby selecting a part of a bigger TM for use with a specific user/learner. This has great implications for personalization. Ontologies can also be represented as TMs. Also, with the notion of namespaces one can query information with respect to one particular namespace or combination of namespaces. This is clarified further by a query example given in section 6.

Many researchers have proposed the use of Topic Maps for various educational purposes such as Web-based Education (Dicheva *et al*., 2004); Digital course libraries (Dicheva & Dichev, 2004); creation and browsing of Educational Topic Maps (Dicheva & Dichev, 2006); Subject-Centric Learning (Mihai *et al*., 2009); Brain-Bank Learning: Topic Map based e-Portfolios (Lavik *et al*., 2004). Some researchers have found Topic Maps useful as tools for collaborative construction of knowledge and artefacts (Roth, 1993; Ebner *et al*., 2007). In a book of clinical reasoning, Cahill & Fonteyn (2000) have reported that the use of mind maps improves learners’ understanding. Learners need graphical representation of concepts to understand easily the logical connections between various concepts and for easy navigation among a network of topics.

There is a plug-in from Google named Wonder Wheel which presents the results of any given search in the form of a connected map of the websites. A Google browser developed by a company named Touchgraph (http://www.touchgraph.com/TGGoogleBrowser.html) takes all documents located by Google and presents the results as a graph. One can carry out a search using a set of query terms, or using an URL, and get a graph of websites related to that keyword or URL. Touchgraph uses a graphical interface linking various Web pages located from databases such as Facebook and Amazon. Touchgraph displays can be too complex for a user as they show at least two or three levels of connections between Websites. Wonder Wheel and Touchgraph Google browser are aligned with the Google search engine.

Mihani *et al*. (2009) have described the idea of use of Topic Maps for subject-centric learning, moving away from teacher centric learning which is usually course-centric as well. TM4L (Dicheva & Dichev, 2006) is an environment to create, maintain and use standards-based ontology-aware e-learning repositories. The creators of TM4L discuss reusability of educational resources available on the Web. They mention an efficient context-based search for locating these resources, but do not develop this concept further. Their paper visualizes the creation of TMs and browsing facility of Topic Maps with static URLs identifying relevant Learning Objects on the Web which act as external resources. HyperPhysics is an exploration environment for Physics concepts developed at the Georgia State University (http://hyperphysics.phy-astr.gsu.edu/hbase/HFrame.html). The fact that content and tools are bound to each other limits the value of this system to some extent.

TMs offer navigational facilities, giving all the ontological information. There are tools for graphical displays of Topic Maps, such as Ontopia Vizigator (2008) and the TM4L Viewer.

The current version of Omnigator (2008) provides external resources in the form of URLs that need to be put into the TM by the Topic Map developer. One can use these static external URLs - by clicking on any one of them, one can access the relevant document or LO directly. The limitation with this is that the external occurrences are not dynamically located – for instance, they do not take into account the new material that becomes available on the Web after the Topic Map is finalized.

We visualize the use of Topic Map technology with a graphical interface as the front-end and Topic Maps as the back end. In this design, the nodes displayed are topics and the arcs are associations; all such elements have unique SIs. We can use scope markers as well other information such as that provided by the user model to select the set of topics to be displayed. The exploratory path of the knowledge space around a concept selected by the learner can be considered to generate a query. This information can be used for the automated construction of a search query by the system for fetching relevant resources. A system to offer help to the learner in locating relevant resources is discussed in the following section.

4. A Study Facilitation System (SFS)

Very often the learner needs to go beyond the textbook or class notes to achieve adequate understanding of the lessons. To meet this need, learners are increasingly turning to LOs available on the Web. However, learners seeking LOs from the Web face many problems (Lalingkar & Ramani, 2009):

- Difficulties in constructing suitable queries to accurately locate relevant LOs - they often lack the knowledge and skills to carry out effective search.
- The Web search often distracts learners by directing them to unsuitable or irrelevant documents.
- Sometimes search engines locate URLs with no direct access to the content required; considerable manual navigation from the landing page to the relevant content is necessary in such cases.
- Some documents found may not match the academic level of a learner.
- The material found through Web search might not match the learning style of that particular learner (Dicheva & Dichev, 2006).

Getting personalized help during study is important for learning, as different learners are at different levels of understanding and have different preferences for the type of material they use – text, images, videos etc. (Brusilovsky & Henze, 2007; Muntean & Mutean, 2009; Parvez & Blank, 2007; Felder & Spurlin, 2005). A solution to these problems would be to create a SFS that offers personalized help to the learner.

Access to Web-resources, especially learning objects, for use as supplementary material can be vastly facilitated by user models describing an individual in terms of parameters such as name, age, grade of study, languages known, level of academic achievement and preferences for types of learning material. Parts of such models can be created at the time of user registration, when the learner fills up a relevant form. Thus basic information such as those mentioned above can be acquired and used for personalized retrieval of LOs. Subsequent to registration, learners will login for each learning session, thereby identifying themselves. Learners can be asked to rate the viewed LOs. The system can update the learner's profile after each use, taking the ratings as input to a process that infers user preferences. It could use the information from the user's profile, such as topics studied, to fetch appropriate LOs at a given stage of learning. One can also use an ontology (in Topic Map format) of concepts required to be learnt, for the purpose of personalization. Here one can distinguish between concepts learnt and not learnt on the basis of evidence from tests etc.

The next issue that needs addressing how a SFS can cope with a growing Web in which LOs can be added after the SFS is created. This is dealt with in the next section.

5. Enriching Topic Maps

As mentioned earlier, TMs allow the use of URLs as "external occurrences". This enables one to link a topic to any resource on the Web. The trouble with is that a static URL limits one to the use of resources which the TM creator is aware of. This can be rectified to some extent by using a search string as the external occurrence - for instance, http://www.google.co.in/search?hl=en&q=hydrogenation+of+fats. However, this is not fully satisfactory, because the query words used may be ambiguous. The creator of the TM needs to have expertise to foresee and minimize such problems.

It is well-known that searches using traditional search strings do not offer a high degree of precision and recall. Hence, we propose here an alternative using structured queries to search for LOs with matching metadata. We argue that metadata should provide detailed content descriptions for each Learning Object. Current LOM standards provide for indexing LOs at the keyword level. If key-words provide a facility comparable to an index at the end of a book, content descriptions need to be at the level of a detailed table of contents in machine processable form. This can be done by using triples, each of them involving two concepts and an association that links them. One can exploit the notion of reification in Topic Maps to include topics that are not mere terms but are predicative expressions, for use in the metadata. The analogy involving the index and table of contents of a book is useful here. Indexes deal with terms, in most cases single words. The table of contents on the other hand, usually deals with predicative expressions.

Detailed metadata will use many more bytes of data than standard LOMs, but the size of metadata poses no problem to the user if the metadata does not clutter up the displays, and are used only by computer applications.

Reasoning with the information provided by the metadata is often necessary to benefit from it. The use of Topic Maps technology supports a degree of deduction using “rules” to implement reasoning. Some lines of reasoning are:

Y = External Occurrence For (topicX) => Y = External Occurrence For (supertype_of X)
Y = External Occurrence For (topicX) => Y = External Occurrence For (subtype_of X)
Y = External Occurrence For (topicX) => Y = External Occurrence For (instance_of X)
Y = External Occurrence For (topicX) => Y = External Occurrence For (synonym_of X)

If a conceptual framework and adequate tools are made available to create and utilize such metadata, the Web 2.0 kind of effort that creates open educational resources as public goods can also create such metadata. Universities and other educational institutions would be early players in this effort.

For this purpose, we propose the use of what we call “Content Metadata in the Topic Map Format” (CMTMF). CMTMF associated with LOs will enable the fetching of appropriate resources from the LORs with a high degree of precision and recall. While creators of educational resources would be the most likely creators of associated CMTMF, there is room for specialized groups that create CMTMF for popular educational resources already on the web. Contributors can submit such CMTMF to selected LORs and to specialized search engines which are equipped to handle CMTMF. We name such search engines “Topic Map Based Search Engines” (TMBSE). In addition to CMTMF submitted to them, these search engines would harvest CMTMF from sites which carry them to describe their resources. Hyperlinks included in the CMTMF would point to the relevant educational resources they describe.

The effort required for the creation of an ecosystem for CMTMF is not to be under-estimated. There would have to be ontologies created and shared by communities in different domains. Their creation would involve significant coordination. Open source tools like Omnigator can be used for the creation of Topic Map ontologies and CMTMF annotating resources. However, we can visualize large-scale use of these tools to begin soon, setting the stage for the growth of CMTMF collections. The structured description in the form of a set of triples can be thought of a set of labelled sub-graphs describing a desired document. Thus CMTMF can be represented as Topic Map fragments.

Topic Map Remote Access Protocol (TMRAP, http://www.ontopia.net/topicmaps/tmrap.html), a web service interface included in Ontopia (http://code.google.com/ontopia/) can be used to retrieve desired topic map fragments or the entire topic map from remote topic map servers. This would be valuable because the user then create triples using a suitable interface to search for relevant LOs. We have to visualize that LOs and related CMTMF would be distributed over various LORs accessible over the Internet. Naito (2009) describes TMRAP as consisting of various methods such as get-topic, get-topic-page, get-tolog, add-fragment and delete-topic for interoperability among topic maps. TMRAP can use plain HTTP or SOAP. Tolog is a query language which is used for querying any information within the topic map.

Java code can be written (to be integrated with Omnigator) for the system to create a CMTMF query automatically selecting elements from a Topic Map on the basis of the navigation path the learner uses to arrive at a particular display when she invokes help from the Study Facilitation System (SFS). An example of a query created on the basis of the user’s navigation path is presented in Section 6. The SFS would use the TMRAP interface to interact with remote topic map servers to locate LOs. We visualize CMTMF queries to be in the tolog query language so that SFS can use TMRAP and TMBSEs to map these queries onto LOs carrying CMTMF that match the query.

We propose a distributed architecture to facilitate scaling up; this is presented in the next section. Issues related to scalability have been discussed by Naito (2009) for the use of Topic Maps based Web Services.

6. Proposed Architecture and Structure

The learner can ask the SFS for information related to one or more concepts, while reading a book, taking some e-learning course, or doing an assignment. The SFS can respond to this by accessing resources in LORs distributed over the Web. The system (see Fig 1) has four major parts:

- A Graphical User Interface which is accessed by using an Internet browser. The module implementing this interface along with the personalization module will run on a server on which the user has an account. For instance, this server could be a SFS in the user’s school. An ontology server in which TMs defining the base-corpus[1] are stored can also be run on the same hardware as the one that runs the SFS.

- A set of Topic Map Based Search Engines accessible over the Internet; these TMBSE's contain CMTMF, each covering a large number of Learning Objects hosted all over the Web. The TMBSE's harvest CMTMF information and also receive submitted CMTMF information and keep them as one or more large Topic Maps. The external occurrences in these Topic Maps point to different LOs.
- A set of ontology servers accessible over the Internet, defining a set of namespaces. These will serve users all over the Internet, including creators of LOs, to work within relevant standards while creating CMTMF for their works. The SFS which the learner uses will also query relevant ontology servers and present choices using a drop down menu enabling the user to specify the desired namespaces during search for LOs.
- A set of LORs that house LOs along with their associated CMTMF. This metadata can be actively submitted to the TMBSEs, or harvested by them without the active submission by the LOs.

The SFS will act as an intermediary between the learner and resources, including ontology servers, TMBSE's and LORs distributed over the Web.

When a student needs any help, she can type a term[2] in the dialogue box of the SFS accessible from that browser. The SFS will ask a student to indicate the correct word sense if the term has different meanings. This is done by the SFS consulting relevant Ontology Servers, local and global, to identify different namespaces in which term occurs. The SFS presents a drop-down menu indicating different name spaces in which the term occurs, and the student chooses one. Once a student selects the namespace, the system will display a map related to words typed in by her, deriving it from the base-corpus TM by filtering it to suit the profile of that particular student. The learner can navigate through the displayed map, by clicking on the next focus of attention, thereby getting a revised display centred on that topic along with topics associated with it.

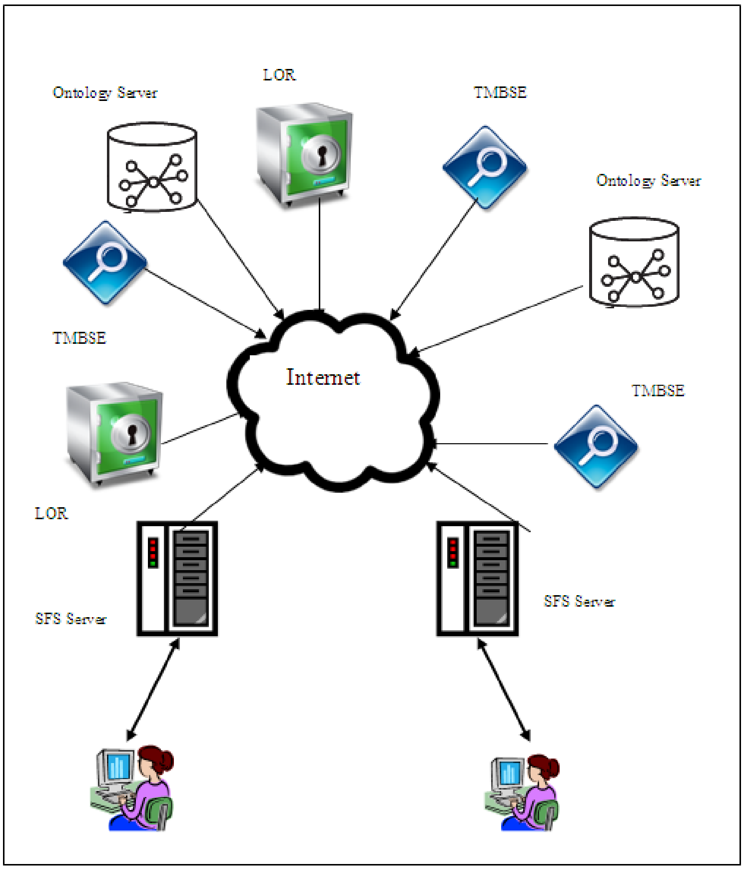

Figure 1. Overall architecture and structure of the system

[1] The term "base-corpus" refers to what the student is known to have used as primary learning material such as a textbook studied in the previous grade and can be presumed to provide an indication of her vocabulary and knowledge.

[2] By term we mean either a word or a phrase

One can see the name of the association (and the roles of both the topics) displayed on the connector between two topics. In the example illustrated by Figures 2 to 5, the student starts by typing “mixture” as a term. This is disambiguated and the relevant map fragment is displayed. Then the student navigates through the following sequence of concepts:

Methods of Separation of Mixture
Distillation
Water Distillation
Animation.

Figures 2-5 illustrate how the learner gets a series of displays centering on the focus of attention at each stage. There will be two buttons named “Cancel” and “Ok” at each stage of the navigation. When a student has completed traversing the desired path on the map defining her immediate interest, and clicks on “Ok” to confirm the selection, the SFS creates a structured query in tolog format and sends it to TMBSE’s over a TMRAP connection. The TMBSE’s use the CMTMF information they have collected to create a list of relevant URLs; these are sent to the user. By clicking “Cancel” at any stage, the user can go back to the clean dialogue box to make a new beginning.

If the learner has navigated the path shown above and clicks on “Ok”, the query generated would be of the form

```
using o for i"http://psi.ncert.net/"

select $ANIMATION from
o:has_animations($WATER_DISTILLATION: o:application, $ANIMATION: o:medium),
o:has_applications($DISTILLATION: o:instrument, $WATER_DISTILLATION: o:application),
o:has_separation_method($MIXTURE: o:separatee, $DISTILLATION: o:separator)?
```

In the above query ‘o’ stands for the namespace in which the topic map components need to be searched. This format of query is that of tolog.

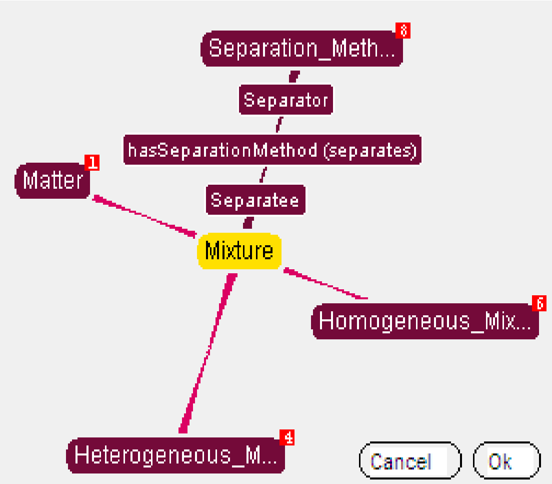

Figure 2. Map of terms related to Mixture

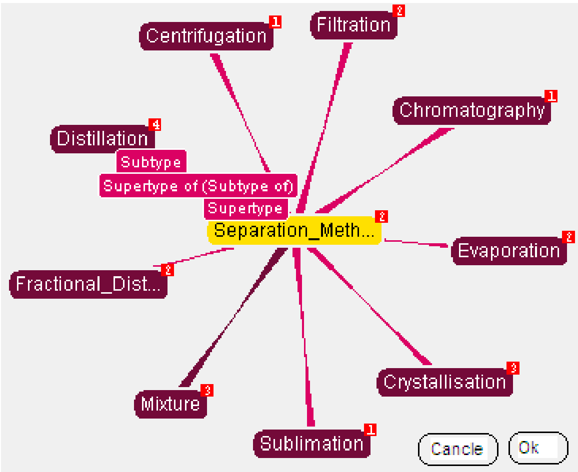

Figure 3. Map with Separation_Methods as a focus

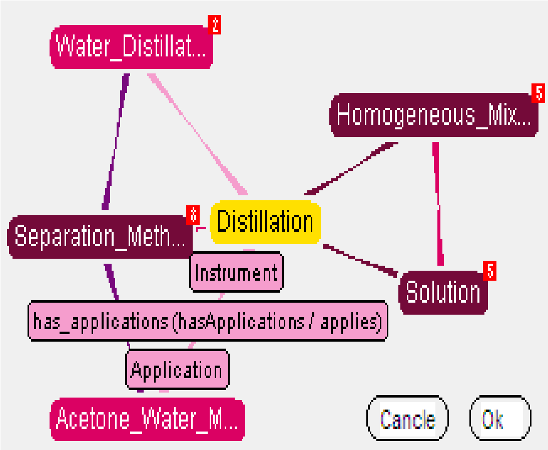

Figure 4. Map with Distillation as a focus

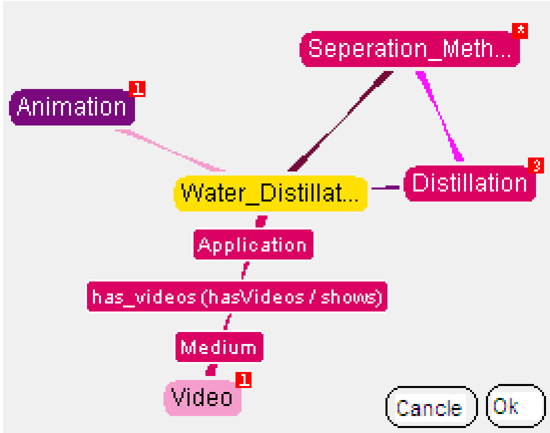

Figure 5. Map with Water_Distillation as a focus

7. Comparison with Related Literature

We offer here comparisons with some systems with similar objectives, such as TM4L, Hyperphysics, BrainBank, Google Touchgraph browser and Wonder Wheel. One important difference between the system described here and the systems such as TM4L (Dicheva & Dichev, 2006) and BrainBank (Lavik, & Nordeng, 2004) is the way external occurrences are located. URLs representing external occurrences in the Topic Maps used in both these systems are static. The system described here gets one or more searches made using tolog queries through TMBSEs.

The difference between SFS and HyperPhysics is that the latter has bound content and mechanism; you cannot use it as a tool to create HyperChemistry, for instance. This is not the case with SFS, which offers only the tools and expects content creators to provide metadata in the specified form.

Mihani *et al*. (2009) visualize use of an automated system to create TMs. In the system described in this paper, the creation of large topic maps is expected to occur through a collaborative Web 2.0 kind of effort. The creator of each document creates a fragment of the TM using a simple tool, describing the content of the LO she has created.

In TM4L, users can create their own Topic Map. In the SFS, contributors create and upload LOs along with relevant CMTMF information. Dicheva & Dichev (2006) have described the use of tolog for searching for relevant information inside a Topic Map. In contrast to this our focus is on finding LOs spread over the Web using CMTMF metadata.

Touchgraph and Wonder Wheel show maps of related websites. The work reported here focuses on relations between topics and not the relations between the websites.

8. Conclusion and Future Work

We have described architecture of a Web-based Study Facilitation System with some examples. The system uses personalization information such as the level of a student, to give her an appropriate map of relevant topics when she enters a search term and selects the correct namespace for it. The map displayed (a graphical view of a part of a TM) to the student helps exploration of the knowledge space around that term. The use of such “knowledge maps” will promote understanding of topics relevant to the user’s situation and the connections between these topics.

We have also introduced an extended form of content metadata named CMTMF using TM concepts to describe the content in LOs. Our claim is that this content metadata in TM form (CMTMF) can provide for very precise identification of relevant educational resources. The system generates tolog queries used in search automatically, based on the navigation path used by a learner to explore the knowledge space around the desired concept.

As future work we also visualize semi-automatic creation of semantic triples (CMTMF) using natural language text processing. Natural language parsers assign Parts of Speech (POS) tags to words in documents with a fair degree of accuracy. An extension of this technique can contribute to the process of creating semantic triplets (CMTMF) for a given document. We cannot expect this to be done with high accuracy or completeness.

However, this mechanism would automate a whole lot of work involved in creating a set of semantic triplets to serve as CMTMF. Human interaction and post-editing can improve the accuracy and completeness of this process.

LOMs can serve as valuable starting point for the creation of CMTMF, as the keywords listed in LOM would cover the major topics in the document. However these keywords may offer only a subset of the topics to be covered by CMTMF. Automatic generation of CMTMF would need to identify and use other terms in addition. We plan to explore how this can be done.

This paper visualizes future work to be carried out in reasonable detail. Creation of the SFS and TMBSE prototypes, creation of CMTMF for a set of documents and experimentation with these constitute the future work visualized. The prototype system can be evaluated against a traditional search engine to measure the precision of search.

The framework described here has implications for the creators of LOs and their potential users. As a future plan we also visualize using the results of tests/examinations that the learner undergoes to update the user model of learners.

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