Contexts as Abstraction of Grouping

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Abstract

This paper presents a framework of *context-centered* digital course libraries founded on the Topic Maps paradigm and used for developing an authoring environment for building such libraries. We explore the idea of using contexts to support more efficient information search. The notion of context is perceived as abstraction of grouping of domain concepts and resources based on the existing semantic relationships between them. The suggested framework implies a layered information structure of the library content consisting of three layers, each capturing a different aspect of the information space - conceptual, resource-related, and contextual. The proposed model of context is used for context representation in the TM4L environment, which enables the creation, maintenance, and use of ontology-aware courseware based on Topic Maps.

1 Introduction

Information search is an old and hard problem in computing. With the growth of the web it is becoming harder. Finding relevant and valid information that meets learners' needs is yet harder. If for example a learner is interested in information related to a Prolog implementation of best-first search, a simple Google search using "best-first", "search", and "Prolog" as keywords results in over 5,190 hits. Moreover, a large part of the references provided in the first few pages assume advanced knowledge of Prolog. Searching information relevant to the "Java threads" topic results in an even worse result – the unmanageable amount of more than 2,240,000 references. Finding good quality web resources poses a major problem for users who have not developed efficient search strategies. People often use the principle of least effort in their information seeking. Following this pattern students frequently use easy accessible, rather than higher quality but less accessible information. In the case of learners searching information to complete a learning task, there is another difficulty - their uncertainty about what kind of resources they need. Learners are also often unaware of the complete context of the task in hand. In such cases they need support in getting oriented in the conceptual structure of the domain of the problem, which will help them in retrieving, evaluating, comprehending, and memorizing information. An even more valuable support should include means for locating online material customized to the individual users by taking into account their interests, level of competency in the considered domain, learning styles, etc.

Why finding needed information on the Web is hard? Regardless of the quality of stored information, it is useless unless it can be indexed and efficiently searched. Conventional search engines can help in identifying entities of interest but they fail in determining the underlying concepts or the relationships between these entities. The main problem with the web and current technology is that it is impossible to semantically relate and compare resources. For example, current search engines are not able to interpret and react adequately to requests such as: *Find another document with more technical details than the current page.* They are not capable to refer to the current page and use its characteristics to guide the search based on transitive dependencies. There is no general-purpose search engine that can answer questions such as: *Find the latest article on the topic (of the current page),* or *Show me a paper that is more detailed than this one*, or *Show me a tutorial that is less formal than this one.*

There is a large amount of high quality learning resources on the web already and they should be made more accessible to users. In this paper we explore the idea of using contexts to support more efficient information search. We propose to define contexts as abstraction of clusters of domain concepts and resources based on the existing relationships between them. This is related to our previous work on contexts as well as on the development of a framework of concept-based digital course libraries [3], [2]. The framework is based on using the new Semantic Web technology Topic Maps [10], [13]. The paper is organized as follows. We first outline our general framework, more details of which can be found in [3]. Then we discuss the use of Topic maps for its implementation. Next we propose our approach for incorporating contexts in this framework. Finally, we discuss the proposed contexts' implementation and use in the TM4L environment.

2 Framework of Concept-based Digital Course Libraries

We have developed a framework of concept-based digital course libraries based on using conceptual structures representing subject domain ontologies for classification of the library content. The classification involves linking learning objects (content) to relevant ontology terms (concepts), i.e. using the ontological structure to *index* the library content. The use of subject ontologies that provide shared agreement on the concepts meaning also allows for ontology-based merging of digital repositories. The main components of the architecture are the information repository, information authoring module, and information retrieval module.

2.1 Library Repository

We propose a layered structure of the library repository consisting of three layers capturing different aspects of the information space (see Fig. 1):

- *Semantic layer*, containing a conceptual model of the knowledge domain in terms of *key concepts* and *relationships* among them.
- *Resource layer*, containing a collection of diverse information resources associated with the specific knowledge domain.
- *Context layer*, containing specifications of different views (contexts) on the library resources depending on a particular goal, type of users, etc., by associating components from the other two layers.

Semantic Layer. The introduction of a separate semantic layer that represents the domain ontological conceptualization allows using it from one side as a subject knowledge *directory* that enables natural and intuitive concept-based content browsing, and from another as a *resource* item relevant to learners' goals. The latter allows for exploration of the ontological structure of the subject domain independently of the information resources, which can help learners to improve their overall understanding of the domain.

Resource layer. The resource layer contains *internal* and *external* learning objects. Internal resources are pieces of information about a concept, such as annotations, definitions, characterizations or short descriptions, stored locally in the library. External resources can be any addressable objects referenced by their URI. By using external learning objects from available collections of standardized (LOM [9], Dublin Core) learning objects the need and efforts to create them will be eliminated.

Context Layer. The separation of the semantic layer from the information repository makes it possible to define different semantic structures over the same collection of learning resources or different collections of learning resources connected to the same semantic structure. A context captures a particular view on the learning resources by preserving the relevant semantic relations among them and filtering out the irrelevant. By maintaining a collection of appropriate contexts in the context layer, it is possible to categorize thematically the learning resources, reflecting multiple semantically customized views that correspond to different situations, user goals, communities of learners, etc. Contexts enable users to access the same resources based on navigational strategies in conceptual spaces appropriate to their current needs.

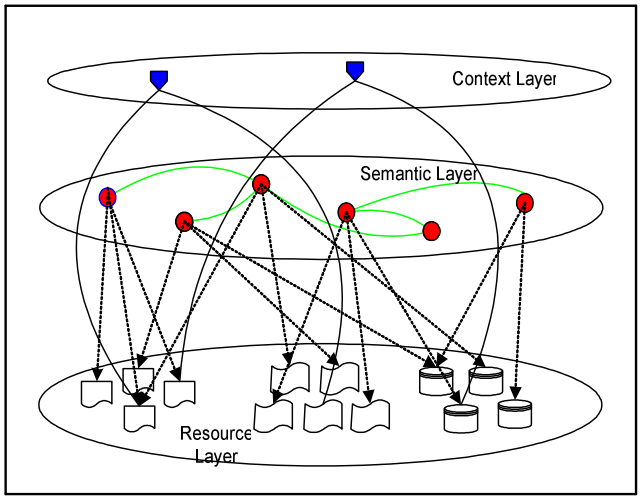

Fig. 1. The layered structure of an information repository.

2.2 Library implementation

We have chosen to implement the proposed general framework of digital course libraries by using the emerging ISO standard Topic Maps [1]. Topic Maps (TM) are appropriate for our goals since they enable users to navigate and access the documents they need in an organized manner, rather than browsing through hyperlinks that are generally unstructured and often misleading.

The main topic maps components are *topics, associations, and occurrences* [10]. The *topics* represent the subjects, i.e. the things, which are in the application domain. They can have zero or more *topic types* and *names* (a base name and possibly variants for use in specific contexts). *An association* represents a relationship between topics. Associations have *types* and define *roles* of the participating topics. *Occurrences* instantiate topics to one or more relevant information resources. The *scope* feature defines the extent of validity of an assertion: the context in which a name or an occurrence is assigned to a given topic, or in which topics are related through associations. An important concept in TM is this of *identity.* Two topics are

the same if both have the same name in the same scope or both refer to the same *subject indicator*. The topics and all their characteristics could be *merged* if this condition holds.

It is clear now that the semantic layer in our framework can be implemented as a collection of associated topics. An important aspect of the topic maps associations is that they can exist despite the absence of occurrences linked to them. Further on, the resource layer can be implemented straightforwardly by defining topic occurrences. The question is how to implement the context layer of the framework in topic maps terms? A quick straightforward answer would be to use the Topic maps *scoping*.

In the TM standard a *scope* is a set of *themes (of validity)*. Themes can be defined and applied to TM objects. The standard allows scoping of topic names, resources, and associations. This is useful for information filtering in Topic Maps Viewers. Obviously a scope can be used to present a context or a perspective however this is a rather static view.

Independently of the standard we propose using topic map associations to represent *context as grouping*. Topic map associations can be interpreted as statements relating topics. For instance, in the case of educational applications, it is possible to express the statement that a given concept is represented using a particular teaching method (e.g. *tutorial, definition, example*, etc.) in the form: topic X *is represented by* tutorial Y. Similarly, associations such as SWI-Prolog *is instance of* Prolog, Prolog *is based on* Resolution, Computation *is part of* Prolog, Prolog *is related to* Horn-Clause Logic, Prolog *uses* Backtracking, make the topic Prolog pertinent to the related topics. Obviously, association types combined with role types enable meaningful grouping of topics, which we call *context.*

Formally context can be defined as a collection of statements that are true in a model. In less formal perspective, context can be interpreted as the things, which surround, and give meaning to something else. The statement "Snow is white" is meaningful if we talk about New Year in Alaska, but has no meaning in terms of CPU scheduling. We can view contexts as a means of grouping facts relevant to a particular situation. Grouping and classification of objects is a human invention to simplify communication. For our purpose we take a restricted model of this view of context, namely, as a grouping of topics based on their relations to a given topic. Translated in topic maps terminology a context is a collection of associations related to a common topic selected to represent and name the context. Technically, this is a nested topic map drawn around a topic chosen to name the context.

We outline our view on context representation in topic maps in more details in the following section.

3 Using Context in Topics Maps

The notion of context includes two aspects that are addressed in the research on modeling contexts. Some authors [8], [11] interpret context as a set of facts describing a particular situation from a specific point of view. Another approach taken for example by [7] is based on the intuition that reasoning is always "local", i.e. it involves only a small subset of what an agent actually knows; this subset is what determines the context of reasoning. However there is no standard way to specify contexts of assertions. Topic maps can be used to model both aspects. The contextual support for organizing (and locating) learning content described above can be interpreted as modeling viewpoints.

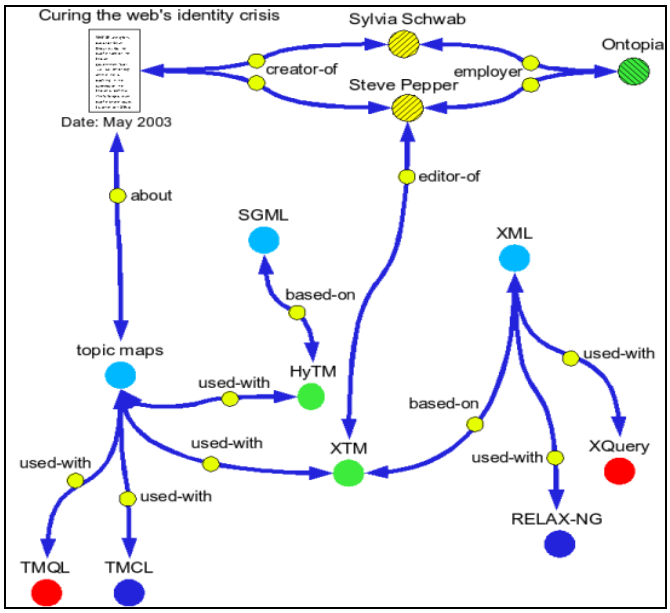

Fig. 2. An excerpt from the Ontopia Topic Map.

The topic maps framework provides support for modeling of context which matches our intuition, namely, that the context is an abstraction of *grouping related information*. Consider the topic *XTM* in the example in Fig. 2 borrowed from Garshol [6]. The objects (facts) that we would consider relevant to this topic are the statements "*XTM is based on XML*", "*XTM is used with Topic Maps*" and "*Steve Paper is editor of XTM*". This collection of facts expresses a clustering of statements. The sticking point of the clustering is the topic "*XTM*". Intuitively these statements make the topics *XML*, *Topic Maps* and *Steve Paper* relevant to *XTM*. The statement that *Steve Paper* is employed by *Ontopia* is less relevant in terms of the current topic (*XTM*) and the fact that "*Puccini is born in Lucca*" would typically be considered as irrelevant. Thus in TM terms we can define context as a grouping of a set of topics clustered around a given topic and therefore

considered relevant to that topic. To make the model more coherent it should account for boundaries that separate one context from another.

Most works related to formalizing context are centered around the so called "box model", where "Each box has its own laws and draws a sort of boundary between what is *in* and what is *out*" [7], [8], [11]. The problem with this approach is that we have to predefine all potentially needed "boxes" in order to use them. The world is too unpredictable to foresee the complete set of contexts that might be needed. Rather than preparing a set of static boxes we suggest to use a TM model that allows shifting boundaries of the context dynamically based on the current topic. We propose to interpret context as a collection of topics surrounding a given topic (denoting the context) and intended to localize the search and the inference within an area of *relevant* topics. The proposed interpretation allows us to introduce a measure of relevancy.

3.1 Topic centered contexts

The starting point is our view of context as a collection of topics that surround, and give meaning to some other topics. The interpretation of what are the surrounding topics is relative. At one point a topic can be a part of the surrounding collection and in another point it might be viewed as surrounded by some other topics giving meaning to it. The relationships are at the heart of semantics, lending meaning to concepts and to resources linked to them.

We begin with the basic assumptions underlying the proposed contextual framework.

- Each context is a collection of topics related to a certain topic of the TM that plays a role of a *focus or center* of the context.
- The central topic is unique and can be used to name the context.
- All semantically related topics identify regions formed by the topics directly or indirectly related to the center of the context.
- The relevance of a topic to the current context is reverse proportional to its distance to the focus of the context.

According to the last assumption the topics of the collection forming a context have no equal status with respect to that context. Their role in the context depends on somewhat spatial properties – the distance to the central topic. The following definitions try to capture the above aspects of the context in more formal terms.

Immediate Propositional Context. An immediate propositional context $c_R(t)$ of topic t is the collection of all associations (statements) $A{:}R_1(t),R_2(t_2),..,R_n(t_n)$ such that the topic t is a role player in that relationship.

$c_R(t) = \{A{:}R_1(t),R_2(t_2),..,R_m(t_m) \mid m \in I,\ t$ is a role in a relationship of type $A\}$.

Immediate Topical Context. An immediate topical context (or simply immediate context) $c(t) = \{t_i \mid A.R_i(t_i),\ A \in c_R(t)\}$ of the topic t is the collection of all topics t_i playing a role in the associations $A \in c_R(t)$, that is, the collection of all t_i coordinates of the m-tuples defining the immediate propositional context of the topic t.

Thus the immediate context of topic t is determined by the set of the associations $A_1, A_2,\ldots, A_n$ in which the topic t plays a role (sticking point) and is characterized by the collection of all topics playing a role in A_k, $k = 1, 2, ..,n$.

Context (recursive definition):

1. The immediate contexts of topic t belongs to the context $C(t)$ of topic t.
2. A topic t_1 belongs to the context $C(t)$ of the topic t if there exists topic $x \in C(t)$ and t_1 is an the intermediate context of x, i.e. $t_1 \in c(x)$.

Informally,

Context of topic(t) = All topics directly or indirectly related to t.

Definition. Topic t_1 is related to t_2 if there exists a sequence of associations $A_1, A_2,\ldots,A_n$ such that each pair A_i, A_{i+1} has at least one common role player and t_1 is a role player in A_1 and t_2 is a role player in A_n. The sequence of associations $A_1, A_2, \ldots,A_n$ is called relating sequence of t_1 and t_2 and n is its length.

Definition. The *level of relevancy* of topic t_1 to the central topic t (and thus to the context $C(t)$) is reverse proportional to the length n of the minimal relating sequence $A_1, A_2, \ldots, A_n$ of t_1 and t.

Notice that according to the above definition the level of relevance of a topic t_i to a context $C(t)$ is characterized by the level of relevance to its central topic.

The context $C(t)$ depends on the topic t and is called *current context* when t is the current topic (e.g. the topic being currently visited or observed). Changing the topic t results in changing the context $C(t)$ and thus changing the region of interest.

We can use the following metaphor to illustrate our perception of context: we can view the context like a moving spotlight that throws a strong light on the central topic and to its immediately related topics but only a dim light on the topics that are indirectly related to the central one (where the dimness is proportional to the levels of indirection). Shifting the spotlight changes the set of topics under strong light.

Among the valuable features of this context model is that it provides a mechanism to refer to the *current context*, and use it to identify an area of interest within the TM. This implies that searching for relevant information can be localized into a specified area of interest.

3.2 Relational contexts

Grouping of related objects is a natural way for humans to simplify and comprehend reality. Grouping of related objects can be found in such diverse fields as biology, physics, learning, statistics, economics, psychology, pattern recognition and engineering. We can group places, events, actions, spatial events, social events, and many other types of entities, both concrete and abstract, over an enormous range. In e-learning context learning content can be grouped based on taxonomic or partitive relationships. It can be grouped based on students' knowledge levels, rates of progress, interests, or instructional goals. A grouping can be used to differentiate units that are functionally related. (e.g. program - programming language, programming language - compiler, compiler - parser, parser - lexical analyzer etc.). From these observations we can formulate a context as a *relational grouping of topics*.

Relational context. A relational context $v(A)$ from the viewpoint of the association A is the collection of m-tuples $(t_1,t_2,..,t_m)$ playing a role in an association A:

$v(A) = \{(t_1,t_2,..,t_m) \mid t_i\ ,\ (i = 1,\ldots m,\ m \in I),$ are roles in a relationship $A{:}R_1(t),R_2(t_2),..,R_m(t_m)$ of type $A\}$.

The above definition of context was motivated by some practical considerations such as Topic Map authoring in e – learning settings. Typically the TM author is applying some construction techniques to build a topic map (set of abstract topics). The fundamental construction techniques are *partitioning* of topics (top-down reasoning in a part-whole context); *aggregation* of topics (bottom-up reasoning in a part-whole context), *specialization* of topics (top-down reasoning in a class-subclass and class-instance context), correlation of topics (horizontal reasoning in a relevancy context). As a result, the conceptual knowledge about the *domain to be learned* is structured based on a *taxonomical* and a *compositional hierarchy* (using *class-subclass* and *part-whole* relationships) coupled with horizontal *related-to* relationships. To assist TM authors we had to provide functionality supporting different views such as the *taxonomical (class-subclass hierarchy)*, *class-instance hierarchy* and the *compositional hierarchy* of concepts of the learning content. These views are essentially relational viewpoints/contexts of the topic map displaying related topics based on the particular properties of the relations, e.g. transitivity.

3.3 Contexts, viewpoints, ontologies

When learning material does not appear in isolation, *structure* is needed to encompass a set of learning objects in an instructional unit. For example, a particular unit could belong to one of the general granularity levels *Component, Lesson, Module, Course* and *Program*. These levels are interconnected with *part-of* relations in order to build a complete instructional unit comprising these levels. Thereby, a *Component* is a part of a *Lesson*; a *Lesson* is a part of a *Module*; a *Module* is a part of a *Course* and a *Course* is a part of a *Program.* The *part-of (part-whole)* relation is included in the Dublin Core standard named as *IsPartOf*. The intended use is to relate smaller resources to larger resources or collections that already exist in the collection (e.g. in the library).

The XTM standard does not include *part-whole* relations (as it does for the class-instance and class-subclass relations), but it does support sufficient expressive power to capture most of what one may want to represent about part-whole relations. The standard considers such relations application-specific and therefore does not recommend hard-coding them. Instead the Topic Map standard provides a general construct for defining relations. Therefore for relations such as part-whole the user needs to introduce a dedicated association type. Properties such as transitivity are also defined on application level.

Besides the traditional structuring every unit of the learning content can be related with another unit by multiple kinds of relations, such as a *class-subclass* relationship capturing learning domains taxonomic trees, a *prerequisite* relation capturing learning dependency graphs or a *related-to* relation representing correlation.

The ontologies currently used for structuring e-learning content are typically light-weight. Light-weight ontologies are typified by the fact that they are predominantly taxonomies, with very few cross-taxonomical links. Light-weight ontologies are valid choice in many cases as they are easier to understand, easier to build and easier to get consensus upon. Topic maps are seen as lightweight ontologies because they are able to model knowledge in terms of topics, their classes, instances, occurrences, and associations.

The instruction involves two types of knowledge, the subject (discipline) to be learned coupled with instructional knowledge. From the viewpoint of the category of individuals involved in the learning process there are students and instructors. As a result we distinguish two domains: the domain of the *discipline* to be learned and the *instructional* domain, and also two categories of individuals: learners and instructors. This might be viewed as a high level grouping specifying high level contexts. These four contexts identify in turn four types of ontologies:

1. A *domain ontology*, with object classes from the discipline to be learned.
2. An *instructional ontology*, with topics and relations from the domain of pedagogy.
3. Author's ontology capturing the viewpoint of the instructor.
4. Learner's ontology capturing the viewpoint of the learner.

The distinction of the above viewpoints is essential during the design of an e-learning environment. This distinction was one of the guiding principals when we decided to predefine some relations in TM4L. For example,

taxonomy is vital for the conceptualization of the discipline in categories, on different levels of abstraction. In TM4L class-subclass was included as predefined relation to support generalization/specialization classification.

An organized collection of learning content embodies topics related in different ways. Intuitive interface should support abstract grouping of learning resources such as grouping by unit-structure, goals, learning style, learning paths etc. In such cases a representation in conventional hierarchical structures only is typically insufficient. We needed a model for expressing a grouping of topics based on generic relations. The derived goal was a minimal set of generic relations which covers the needs of the intended applications. The advantage of such an approach is that generic relations subsume particular instances that might be impossible to articulate in specific terms.

In Topic Maps, associations define relations between an arbitrary number of topics. As a primary relation for classifying learning content we have selected the *whole-part* relationship known also as *partonomy* (see Fig. 3) Like a taxonomy, a partonomy is a hierarchy, but based on the *part-of* relation rather than on a *kind-of* relation. The reason for picking out partonomy is its important explanatory role in e-learning context [17]. Explaining what a learning unit is about, often involves describing its parts and how are they composed. For example, we may choose to structure learning material on Programming Languages in terms of its components i.e. Syntax, Semantics and Pragmatics. However, the learning units describing the syntax, semantics and pragmatics are part of the Programming Languages unit and not subclasses of it. By emphasizing the compositional structure, the partonomy is closer to the approach normally used for representing learning content. Recent research in education also indicates that the whole-part presentation method is a technique shown to reduce cognitive load and improve learning [17]. For example, Mayer and Chandler's study [16] suggests that studying initially a part (piece by piece) rather than a whole presentation allows the learner to progressively build a coherent mental model of the material without experiencing cognitive overload.

In many application areas the natural model of the domain requires the ability to express knowledge about the *class-subclass* relation. The class-subclass known also as a *is-a* relation allows us to organize objects with similar properties in the domain into classes. The class-subclass relation has received a lot of attention and is well-understood. However the interaction between whole-part and class-subclass relations has not been studied in any detail. Despite their different purposes knowledge base, database, object-oriented and e-learning communities heavily rely on conceptual models which have a lot in common. Inter-relationships such as *is-a*, *part-of*, *similar-to*, etc. are used to define and constrain the interactions of concepts within these models.

Applications that provide multiple views are able to offer users different perspectives on a selected entity. Therefore, in addition to the primary *whole-part* relationship our TM tool contains four other predefined relationship types, including the classic "class-subclass" (see Fig. 4) and "class-instance" extended with "similar to" and "related to" relations. By offering this minimal set of five relation types we support TM authors that experience difficulties in articulating and naming relationships.

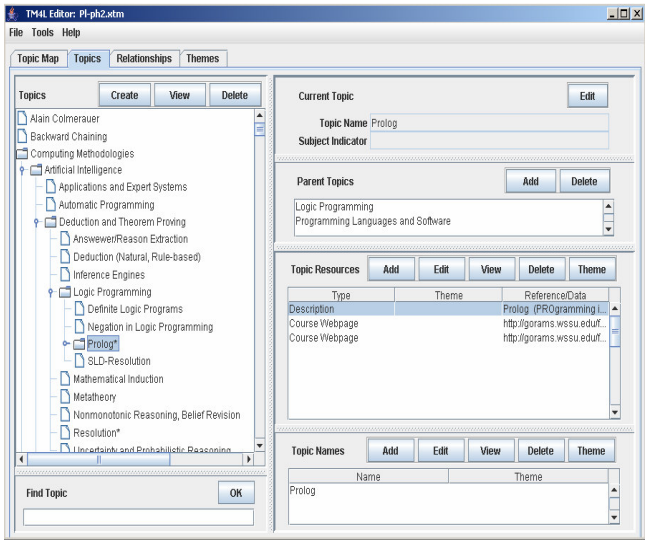

Figure 3 A part-whole view on AI and Prolog.

The proposed set of relations provides also a strategy for organizing the information. It supports a shared way of grouping topics by standardizing the used set of relations. The strategy is based on specifying the set of topics in the domain and the relationships between them in terms of the proposed minimal set. The process of creating the complete contextual structure is incremental; the global TM is a result of growing and interrelating the local structures of immediate contexts.

4 Using Context in TM4L

In the last decade, a number of tools for ontology construction have emerged [18]. Although some currently available ontology editors such as Protégé-2000 (http://protege.stanford.edu/) have plug-ins allowing export to Topic Maps, they do not support essential TM features, which are of significant importance for e-learning applications. The TM4L (Topic Maps For E-learning) environment [6, 7, 8] presented in this paper is intended to complement existing Topic Map editors and visualization tools. It combines two main applications, TM4L Editor and TM4L Viewer. The modeling language of TM4L is based on Topic Maps standard [9]. Two groups of users are targeted by the TM4L design: (i) authors with limited background of ontologies; (ii) learners seeking information support to complete their course tasks. TM4L is currently available as a standalone application. It can be downloaded from: http://www.wssu.edu/iis/nsdl/download.html. The

proposed model of context forms the contextual framework of TM4L which enables the creation, maintenance, and use of ontology-aware courseware.

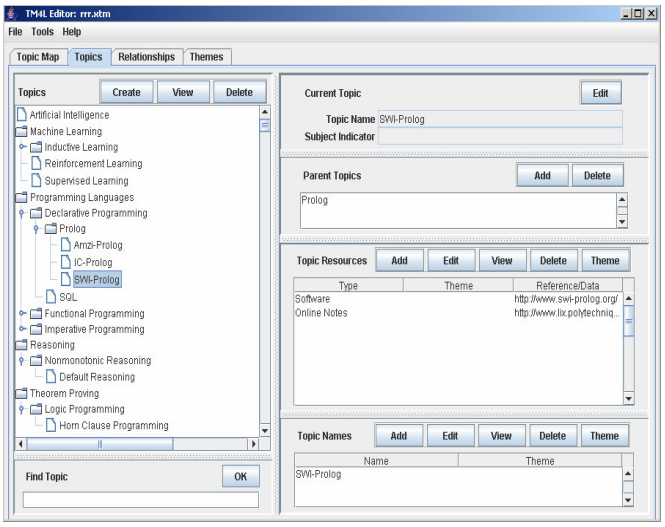

Figure 4 A class-subclass view on AI and Prolog.

There are other software tools employing Topic Maps that can be used to incorporate content into semantically rich data models. One group of tools consists of general Topic Map editors such as the Ontopia Knowledge Suite (http://www.ontopia.net/) - a set of tools for building, maintaining, and using TM-based applications [3] or *Atop* (http://sourceforge.net/projects/atop) - a Topic Map editor written in Java as a NetBeans module using TM4J. With these editors Topic Maps can be interactively built and stored as .XTM (Xml Topic Maps) documents, or in databases. The general TM editors however do not support specific ontological needs such as managing 'whole-part' hierarchy and other types of transitive relations. Besides, they do not support domain specific vocabularies. Instead they tend to use Topic Map-related concepts such as associations, roles, occurrences etc. in their representation. Applications in specific domains such as e-learning require interfaces that supports the particular e-learning objectives coupled with ontology support for classification, navigation and exploration of classes, instances, relations and resources.

As an alternative to conventional authoring systems, TM4L is aimed at facilitating the integration of already existing learning resources on the web. The driving factors and design challenges regarding TM4L interface lie in the following questions: What does the representation mean to learners and authors? Does the representation enable easy detection of the classes of concepts and their relationships? Does it reveal the vocabulary of the domain? Is it immediately apparent which items belong to one or multiple classes, which classes overlap and which don't?

Interfaces that provide multiple contexts are able to offer users different perspectives on a selected entity or on a group of entities. TM4L supports multiple perspectives as the editor and viewer interfaces are context driven. The TM4L Editor provides *Topic centered*, *Relation centered* and *Themes* guided contexts. With TM4L Viewer a topic map can be viewed from six different perspectives: *Subject Topics*, *Relationships*, *Topic Types*, *Relationship Types*, *Resource Types* and *Themes*. In addition, the relational context enables exploration of the e-learning collection in terms of a part-whole tree and a taxonomy tree (see Fig. 3 and Fig 4). Any transitive relation can be mapped to a tree view visualizing particular relational context.

Aiming at reducing the information overload, we have chosen at each navigation step in the TM4L Viewer to display only the topics of *immediate topical context* along with the topics immediately related to them (see Fig 5). In addition, we have chosen not to show the resources associated with the displayed topics in the Graph view, since the visualization becomes too crowded and unclear. Thus the Graph view represents only 'ontology' objects - topics, relationships, roles but not resources. The resources linked to topics can be examined using the Tree or Text views (see the rightmost pane of Fig. 5).

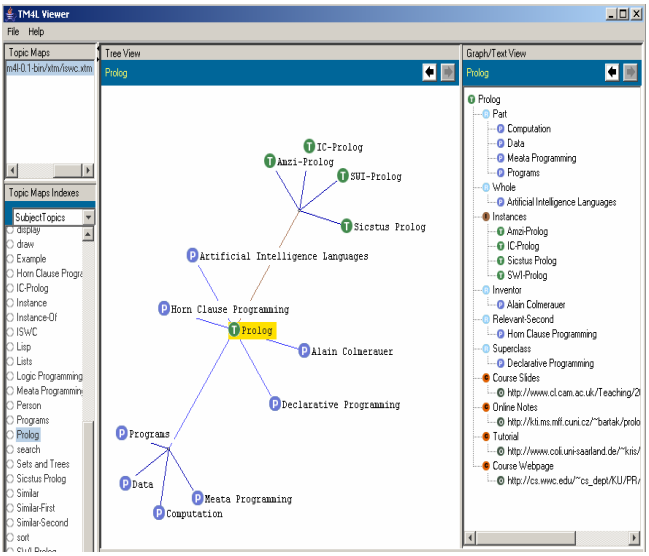

Figure 5. Screenshot from TM4L Viewer with Prolog as a current topic, shown *as a* Declarative Programming Language, *part-of* AI languages, *based on* the Horn Clause Logic and *invented by* Alain Colmerauer. The topics Computation, Data, Programs and Meta Programming are *part of* Prolog while Amzi-Prolog, IC-Prolog, Sicstus-Prolog and SWI-Prolog are *instances of* Prolog.

In addition *Context/theme* filters can be applied to the content shown in the viewer. Every topic characteristic may have a scope, which is specified explicitly, as a set of *themes*. A theme is a topic that is used to limit the validity of a set of topics and relations. The objects that are **not** valid in the specified theme are filtered out. One common use of scopes is to provide localized names for topics.

Name scoping can be used among others for multi-language support. For example, in order to represent the term "Computer science" when browsing a Computer science Topic Map either in English ("Computer science") or in Bulgarian ("Информатика"), the name of the Computer Science topic should be scoped with the themes "English" and "Bulgarian".

5 Conclusion

Efficient information retrieval requires information filtering and search adaptation to the user's current needs, interests, knowledge level, etc. The notion of context is relevant to this issue. In this paper we propose an approach to context modeling in Topic Maps-based educational applications. It is based on the standard Topic Maps support for associations and defines the context as an abstraction of *grouping related information.* The degree of membership of the topics to the context depends on their level of relevancy to the specified topic. This context model provides also a mechanism for referring to the *current context*, and using it to identify a current area of interest within the Topic Map. The second perspective on context is as grouping of *topics that are related to each other in some way*. The notion of context is useful for localizing navigation and search for relevant information within the intended area.

The proposed model of context is utilized in the design of TM4L, an e-learning environment aimed at supporting the development of efficiently searchable, reusable, and interchangeable discipline-specific repositories of learning objects on the web. Providing adequate support for learners to efficiently search for useful web resources is crucial in self-directed learning and presently a problem of high priority in e-learning. We believe that the discussed here approach to context modeling and its implementation in TM4L will contribute to the advancement in that direction by supporting efficient, context-based navigation of educational Topic Maps.

Many different directions for enhancing the TM4L interface are possible. As there are a number of ways to build up the *whole-part* structure of specific learning content, a particular learning unit may be represented by more than one valid partonomic hierarchies. This raises the issue of how to *represent* and *integrate* such multiple hierarchies. In addition to the usual *whole-part* relation, any transitive relation can be used to represent a tree view of the Topic Map.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. DUE-0333069 "NSDL: Towards Reusable and Shareable Courseware: Topic Maps-Based Digital Libraries" and under Grant No. DUE-0442702 "CCLI-EMD: Topic Maps-based courseware to Support Undergraduate Computer Science Courses".

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