

Context as Collection of Alternatives

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ABSTRACT

In this paper we propose a computational framework oriented towards e-learning applications and information seeking tasks. The notion of context is perceived as an abstraction referring to “locality of connections” based on the existing semantic relationships between concepts. Its utilization is demonstrated within a context-aware information support environment - TM4L (based on the Topic Maps paradigm), which includes an authoring tool for building such support. This environment is used as a platform for exploring the idea of applying contexts to support sense-making of the domain concepts that can guide the searcher in his task of finding relevant information. Some practical aspects of the proposed framework are also illustrated by TM4L.

Keywords

Contexts, Topic Maps, e-learning

INTRODUCTION

Well organized and structured knowledge can be used as a source of knowledge exploration if provided with meaningful annotation to guide students to think and explore. Exploratory learning is highly effective, because learners can focus on self-directed learning on the vast information space. Therefore exploratory learning environments offering interactive support for exploring knowledge have a significant potential. The majority of currently available ontology tools are not readily applicable to such tasks because they are primarily concerned with the task of knowledge acquisition rather than providing multiple ways of accessing and exploring knowledge for a wide range of problems. One direction demonstrating potential for improving efficiency in exploratory learning is related to incorporating contextual knowledge exploration and capture. In this paper we study some contextual aspects of information seeking that can improve exploration experiences in e-learning tasks.

The way the concepts are normally interrelated and the evocative aspects that are observable in everyday practice may be used to support our intuition for modeling certain aspect of a domain. For example the concept Turbulence can evoke concepts such as: Airplane, Pilot, Passenger, Air Movement, Safety, Wind Shear Kolmogorov, etc. What do all those concepts have in common? The common is that they are all related somehow to the concept turbulence.

Turbulence is kind of air movement.

Turbulence is wind shear.

Turbulence can shake an airplane.

Pilots deal with turbulence.

Safety can be influenced by turbulence.

Passengers can be injured by turbulence.

The turbulence was studied by Kolmogorov.

In turn concepts such as Airplane, Pilot, Passenger, Air Movement, Safety, Wind Shear, Kolmogorov, etc. may invoke the concept Turbulence. This observation is connected to information seeking, since the information one is after may be attempted to be reached through associated topics. An information seeking task such as “find resources related to turbulence” is typically associated with subjective group of related concepts. If we are unable to recall the term “turbulence”, we may try to reach the target using related concepts. The point is that different individuals may seek resources about turbulence from different contexts and the resulting behavior normally does not follow anticipated patterns. Although we may know that turbulence is related to certain concepts in the domain, sometimes we are not able to articulate the precise relationships. This fact is demonstrated by use of relations with weak semantics such as “turbulence is related to aircrafts” or “turbulence has something to do with air”.

Information seeking is a process of sense-making, a way of finding meaning that fits in with information the user already possesses. To provide information support in a sense-making process we propose a computational model in which commonly related concepts are grouped together and made accessible from each other. With such type of multi-connectivity any concept such as Turbulence will be accessible in multiple ways, namely from the concepts: Airplane, Pilot, Passenger, Air Movement, Safety, Wind Shear, Kolmogorov, etc. Similarly, the concepts grouped around the Airplane can include topics such as: Turbulence, Trip, Transportation, Jet, Pilot, and Altitude. The implication of this hyper-connectivity is on one hand on grouping concepts and on the other hand on localizing the accessibility of a given concept to a limited collection of concepts forming a context. The concepts such as: Trip, Transportation, Jet, Pilot, Altitude can be viewed also as having a secondary level association to turbulence. Thus in the proposed framework concept turbulence is surrounded by contextualizing concepts, layered into primary, secondary etc. levels. The criteria for deciding which concepts and relations to be included in the context description are domain specific.

The majority of applications in e-learning assume that context is defined a-priori by the creator and is external to the systems. The importance of representing and using contextual knowledge in an explicit and logical way has been recognized by researchers from different fields and demonstrated by a number of theoretical works and application systems [2, 10, 11]. There is a variety of approaches to exploring the concept of context and the corresponding computational mechanism for representing and utilizing the contextual model. Research on formalizing contexts [10, 12, 14, 19] has been primarily concerned with the locality of knowledge. The most impressive example of large scale contextual application is the Cyc system [13].

In this paper we propose a computational framework for modeling context oriented towards information seeking tasks. In the next section we describe our framework from a formal perspective. The following sections address its applicability to e-learning systems and discuss some implementation aspects of context from the viewpoint of Topic Maps. The last section illustrates the utilization of the framework in the context of TM4L – an e-learning environment for creating and exploring learning resources with information support orientation.

HOW TO CAPTURE CONTEXT

The starting point is our view of context as a model of the world from the viewpoint of connectivity and accessibility. Context is used here as a term associated with relatedness. We consider context as an abstraction referring to “locality of connections” – we do not connect a given topic directly to all known topics but only to a small subset of them. This small subset is what determines the context of relevant topics. By grouping related topics into context, we constrain the immediate accessibility and thus the search space. Therefore, for a known topic t we take context $c(t)$ to be the set of all topics related to t . We distinguish two forms of context – *weak context* $c(t)$ defined by the set of all topics related to t and *strong context* $C(t)$ defined by the set of all relations relating t to other topics.

More precisely, let $Rel(D)$ be the set of all known relations on a domain D .

Definition. For a given topic t *weak context* $c(t)$ is defined as $c(t) = \{x, \dots, y \mid (x, \dots, t, \dots, y) \in Rel(D)\}$, that is context $c(t)$ is defined as the collection of all topics x, \dots, y such that the tuple (x, \dots, t, \dots, y) is a valid relation on D . We call the topic t *center* and the set of all topics $x \in c(t)$, $x \neq t$ – *topical contextualization*.

Definition. For a given topic t *strong context* $C(t)$ is defined as $C(t) = \{(x, \dots, t, \dots, y) \mid (x, \dots, t, \dots, y) \in Rel(D)\}$, that is context $C(t)$ is defined as the collection of all tuples $(x, \dots, t, \dots, y) \in Rel(D)$ containing topic t as one of its components. We call the topic t *center* and the set of all tuples $(x, \dots, t, \dots, y) \in C(t)$ – *relational contextualization*.

These two definitions of context reflect somehow the two viewpoints on this concept known as “to bind together; to

unite closely” and “that which surrounds, and gives meaning to, something else.” [8] Weak contexts model localized views constraining their representation to clusters of related topics, while strong context is a more expressive model for contexts by making explicit the participating relations. Weak contexts can be interpreted as strong contexts formed by using a single relation X *related to* Y , expressing the fact that two concepts are in some way related.

The following are some obvious properties derived from the above definitions. For brevity we omit the dual properties for strong contexts.

- Given $Rel(D)$, a topic t identifies its weak context $c(t)$ and its strong context $C(t)$.
- Each topic x that is a member of a contextualization of $c(t)$ is a center of a weak context $c(x)$ containing t in its contextualization.
- Each context $c(t)$ is characterized by the set of contexts containing t in their contextualization.

From one side, topics x, \dots, y explain or support the process of sense-making of t and from another, they provide indication of possible ways of interconnecting topics. Thus they offer a basis for forming contexts and as a side effect a model for multi-connecting topics.

Relations are devised to organize objects into collections of associated tuples. Context is complementary to relations – organizing the concepts into groups signifying alternative ways of relating to a given concept. If $Rel(D)$ is limited to the Superclass-Subclass relation, then the strong context transforms to areas within a taxonomy tree, while limiting $Rel(D)$ to Whole-Part results in areas within a partonomy tree.

Note that defining context involves second order properties. For example, in terms of Prolog the following goal $?-rel(X, Y)$.

will find all instances defining $rel(X, Y)$, while given a topic t and a set of relations Rel_D finding the corresponding context implies second order properties such as:

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?-member(F, Rel_D),
    (T = .. [F, X, t]; T = .. [F, t, X]), T.
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This indicates that in general the task of determining the context of a given topic t is computationally costly. One reason for this computational complexity is that the present computational world is with relational orientation where relations are first class citizens, while context is not. To account for context we need complementary topic centered structure.

CONTEXT-BASED EXPLORATION

The above contextual framework is equally applicable to e-learning tasks. In general e-learning tends to be textbook-centred. However the organization of the teaching material should not be limited to the online equivalent of printed table of contents and back-of-the-book indexes. Despite its widespread use, the back-of-the-book index is weak in

identification of relationships between subjects. In many cases we need a richer access structure to the units contained in a collection. Because the intent of a student or an author cannot be foreseen in advance by the creator of the collection, it should be designed to allow multiple access and navigational modes, so that it can accommodate a wide variety of uses. For example, the source of an individual's needs for information about Prolog Lists may originate from a number of topics such as Data Structures, Logic Programming, List Processing, Recursion, Prolog, Symbolic Computation, etc. Displaying related topics, in addition to enhancing orientation capabilities, can help topics such as Prolog Lists to make more sense to the searcher. The context-oriented approach suggests that the topic Prolog Lists is placed under the Prolog Data Structures class and linked to List Processing, Recursive Programming and Terms, thus allowing for multiple ways of accessing it. Based on a taxonomic classification only, a learner will be left to locate the desired resources by navigating through topics such as Data Types and Prolog Data Structures. However, in order to maximize the access to Prolog Lists by non Symbolic or Logic Programming initiated learners this topic should be accessible from a larger set of programming concepts such as Data Types, Lists, Recursive Programming, Lisp Lists and Difference Lists.

It is unlikely that in learners' mental maps concepts are associated in any standard way that can result in a predictable behavior. Therefore, e-learning technology needs methodology and tools for organizing the learning content according to semantic categories and relations that aid learners in navigation. It must facilitate accessing the learning resources depending on the observed connectivity between topics. Consider the Prolog Lists example from this perspective:

- Prolog List is *subclass of* List.
- Prolog List is *instance of* Terms.
- Prolog List is *part of* Prolog Data Structures.
- List Processing is *part of* Prolog Lists.
- Difference List is *instance of* Prolog List.
- Prolog Lists are *related to* Recursive Programming.
- Prolog Lists are *similar to* Lisp Lists.

Because the student/author experience and intention cannot be foreseen in advance by the creator of the collection, it should be designed to allow various access points to Prolog Lists (signifying typical contexts) resulting in navigational modes that can accommodate variety of browsing strategies. Even without naming the relations the graph on the Fig. 1 provides a sufficient weak context of the concept Prolog Lists.

From the viewpoint of our definitions of context, the topic Prolog Lists determines a weak context defined through the collection of related topics:

{Terms, Prolog Data Structures, Recursive Programming, List Processing, Difference Lists, Lists, Lisp Lists}. The secondary weak context includes topics: *{Data Structures,*

Programming Techniques, Prolog, Lisp, Trees, Sets}. Also Prolog Lists determines a strong context (see Fig. 2) defined through the relations *{ Prolog List is subclass of List, Prolog List is instance of Terms, Prolog List is part of Prolog Data Structures, Difference List is instance of Prolog List, Prolog Lists are related to Recursive Programming and Prolog Lists are similar to Lisp Lists}*.

Various forms of multi-connectivity are already in use in many hypertext and hypermedia applications. However, this trend has to be further extended with technologies/tools that support more precise connections among semantically related topics, as well as connections:

- Among alternative views on the same topic.
- Among progressively finer grain size of the same information.
- Among different kinds of topic media/formats/representations.
- Among alternative versions/views of the same information.

This should be coupled with meaningful annotation of the connections. Multi-connections should not be limited to taxonomy and classification. Instead the tools should support variety of meaningful ways of grouping of topics. Having multiple ways of accessing the same information would help us to cope with learner's and author's variants.

IMPLEMENTATION ASPECTS

The framework for modeling context is based on the Topic Map (TM) paradigm [1, 9, 16, 17], which provides a simple data formalism for talking about topics, their properties, inter-relationships, and categories. TM are a powerful subject centric model that may be used to create multi-dimensional indices and interfaces to resources and digitally-encoded data. They allow one to build lists of concepts important to a collection or to a particular area of research and link those concepts to electronic resources [18]. Such properties make Topic Maps appropriate for exploring learning resources. In addition they allow learning content to be linked to and/or merged with other resources by TM applications. In practice, this means that learning resources can be distributed across the web in a decentralized way, but still be meaningfully composed and integrated by applications, often in novel and unanticipated ways.

The TM model encourages hyper-connectivity - multiple ways of accessing *the same information*, with the support of the associations. Using associations we can provide multiple access points to different topical dimensions, enabling users to select options reflecting their search contexts.

One of the advantages of using ontology-based e-learning systems is the ability of having multiple interpretations of the same entity. In particular, by employing the Topic Maps model, concepts in a learning collection can be associated with more than one topic present in the structure. In addition Topic Maps offer use of topics with roles to repre-

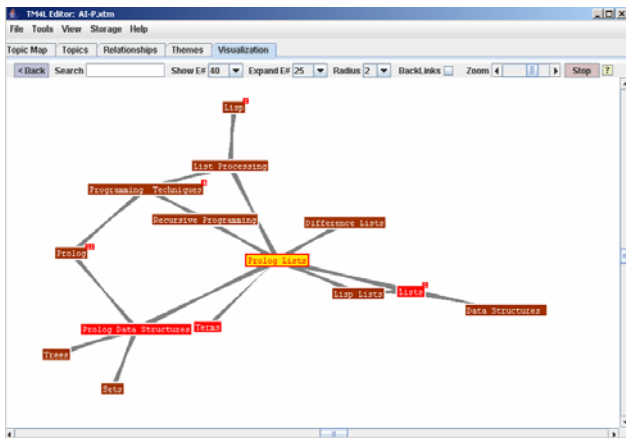


Figure 3. Topic “Prolog Lists” in the center of its two-layer context.

The point was that by enabling users to create an initial “sketch” of a Topic Map, we could facilitate the process of expressing the users’ current context. The focus in this approach is on Topic Maps *sketching* that reveals the topological relationships among the topics.

Further on, for a given topic t *strong context* is rendered as a graph structure that displays all associations in which topic t is one of the role players (see Fig. 4).

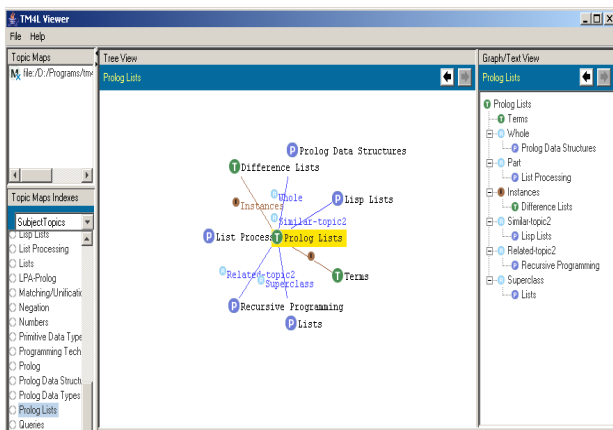


Figure 4. Topic “Prolog Lists” in the center of its immediate strong context.

When using different classifications, access to multiple views becomes critical, because it allows inspection of the learning content in different contexts. Some views for example can be global structures of learning content; others can be local overviews. Multiple classifications can also be used to represent multiple abstractions of the same learning content. TM4L facilitates editing, maintenance, sharing and reuse of learning content in a visual environment with multiple views. These views do not simply equate to different screens but are different ways of interacting with and exploring the conceptual structure of the learning content.

When learning material does not appear in isolation, a *structure* is needed to encompass a set of learning objects in an educational unit. For example, a particular unit could

belong to one of the sections *Prolog Lists*, *Prolog Data Structures*, or *Prolog*. These sections are interconnected with *whole-part* relations in order to build an educational unit comprising these sections. Thereby, *Prolog Lists* is a part of *Prolog Data Structures*; *Prolog Data Structures* is a part of *Prolog*. The *part-of* (*whole-part*) relation is included in the Dublin Core [7] standard named as *IsPartOf*. The intended use is to relate smaller resources to the larger resources or collections that already exist in the collection.

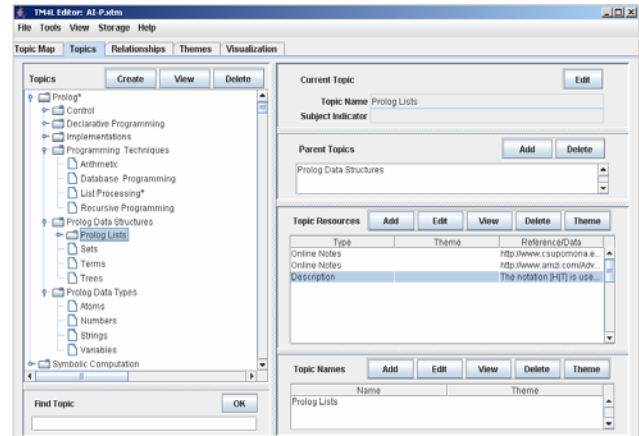


Figure 5. Compositional view of the topic “Prolog Lists” in the context of its wholes and parts.

Since editing is made by the user via interface we offer a number of alternative interfaces that may be accessed within the same editing session. Interfaces that provide multiple views offer users different perspectives on learning units. The user chooses the type of interaction according to their decision, situation and personal preference. TM4L incorporates three views: partonomy, taxonomy and typing views. *Whole-part* relations play an important role in the topology of e-learning [3]. We support *whole-part* to enable users to express the inherent composite structure of the learning content. For example, Fig. 5 depicts an editing session based on the partonomy view. Instances of a particular class along with the resources attached to it play a key role in e-learning, while *super-class-subclass* relationship capturing learning domains taxonomy trees. With this enhancement we intend to provide alternative insights into the learning content structure. Notice that partonomy, taxonomy and typing views can be interpreted as a strong context where the set of relations on a domain D is restricted to *whole-part*, *super-class-subclass* and *class-instance* correspondingly.

In addition to the three primary relationships TM4L contains two other predefined relationship types, including *similar-to* and *related-to* relations [3]. By offering this minimal set of five relation types we support TM4L authors that experience difficulties in articulating and naming relationships. In this aspect the *related to* relation, which carries weak semantics by enabling us to express the fact that two concepts are in some way related is in-

tended for expressing unknown relationships. Another aspect playing role in the selection of the predefined relation set is to reduce the subjective factor. Consensus assumes minimum subjectivity. Relations such as *whole-part* and *superclass-subclass* have logical foundation in contrast to relations with subjective flavor such as *based-on* and *depend-on*.

CONCLUSION

Context is a very important factor in many e-learning applications. Even though the research on understanding and using context has been intensified in the last decade the progress is still in its early stages. In this paper we propose a computational framework oriented towards e-learning applications and information seeking tasks. The framework is based on the definition of context as a collection of topics related to a specific topic called center of the context. The defined weak and strong contexts are used as a base for information browsing in TM4L. Our future plans include applying them in online information search.

The approach presented in this paper is still limited in number of ways. As there are several ways to define a context, a particular context may be represented by more than one valid relational structure. This raises the issue of how to *represent* and *integrate* such multiple contexts in coherent contextual structures.

ACKNOWLEDGMENTS

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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