Visual Browsing and Editing of Topic Map-Based Learning Repositories

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Abstract. Topic Maps For e-Learning (TM4L) is an environment for building, maintaining, and using standards-based, ontology-aware e-learning repositories. This paper discusses the intuitive, visual interface of the system in the context of TM4L evolution. The focus is on our work on extending TM4L with visual editing functionality. The integration of the editing and visualization supports authoring by providing browsing and editing "in one view."

Keywords: Topic maps, visualization, editing ontology-based collections.

1 Introduction

The success of e-learning ultimately depends on the availability of efficient authoring tools that support authors and learners in creating and browsing online learning materials, and availability of tools with intuitive interfaces and uniformity in their appearance and operation. Using knowledge standards, such as Topic Maps [2], it is possible to incorporate learning content in semantically rich data models.

Topic Maps (TM) are among the most promising Semantic Web technologies for organizing and navigating through large information pools. They can provide a "bridge" between the domains of knowledge representation and information management [17] and serve as the skeleton of ontology-aware applications, such as digital learning repositories. Despite some successes, however, the lack of convenient tools that allow authors to directly enter, modify, index, and query resources in ontology-aware digital repositories remains a major obstacle to their deployment. Among the main reasons for this bottleneck is that resource authors typically lack ontology engineering skills to build them, and ontology engineers lack domain expertise to do authors' work. Tools can help, and many have been built already. However, most of these tools are targeted toward users assuming some experience in structuring and classifying resources based on specific representation models.

A key feature and challenge in today's ontology-aware applications, including Topic Map-based applications, are Graphical User Interfaces (GUI) [4]. It is largely

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recognized that visualization in the form of a graph can help the user comprehend and analyze information easier. This is particularly important when representing ontological structures, which can be very complicated. Ontology visualization is an active area of research and there are a number of graphical interfaces already available. For example, the ontology editor Protégé [16] alone employs three visualization tools: TGVizTab [1], Jamballaya [20], and OntoViz [26]. In the area of Topic Maps, the available visualization tools include Ontopia's Vizigator [28], TMNav [27], ThinkGraph [30], the LIP6' visualization tool [14], etc. Visual interfaces typically provide integrated management of browsing and search in support of users' needs for information exploration. Information visualization normally requires the support of metadata in order to enable intuitive presentation and navigation, as in the case of ontology-based visualization where the interaction is directed by the ontology. Some interfaces provide editing functionality as well, e.g. IsaViz, OntoViz and ThinkGraph.

Topic Maps For e-Learning (TM4L) is an environment for building, maintaining, and using standards-based, ontology-aware e-learning repositories [7]. It targets two groups of users: authors, with a limited or no background of ontologies, and learners, seeking information support in their learning tasks. The goal in its design was to enable users to create, update, browse, and query topic-centered learning repositories without having prior experience with topic maps. The original embodiment of this idea was the TM4L Editor. Later on TM4L was extended with a new functionality aimed at supporting graphical navigation through the learning collection and offering a visual alternative to the available tree structure browsing. The main reason for extending the Editor to allow the use of graphs for interacting with users was the appealing features of graphical notations, especially as an informal graphical front end. They have been found particularly functional in educational settings [3, 5]. Similarly, they have been found intuitive to the ontology engineers, see for example [10, 23].

In this context, the next goal was to exploit the visualization feature in terms of editing Topic Maps-based learning content. The motivation for this was driven by our opinion that automatic topic map construction is not yet an alternative to the manual educational topic map design. Automatic TM acquisition is an expensive operation and more importantly – one with limited reliability. Even if initially accurate and complete, topic maps may need modifications and adaptations at later stages reflecting ontology evolution. This suggests the use of a balanced cooperative modeling and construction approach. Therefore, our goal was focused on employing visualization to provide intuitive editing functionality facilitating TM authoring as much as possible. At present TM4L is an environment for building Topic Map-based e-learning repositories that supports three interactive tasks: editing, browsing and querying. With this multifunctional environment we want to test our insights about how to enable instructors, with limited knowledge of information technology, to populate and maintain ontology-based e-learning repositories relatively easily.

In this paper, we describe TM4L's visualization and editing functionality. This functionality is separated architecturally into two distinct interfaces. The first one is oriented towards hierarchical structures and exploits the semantics carried by *superclass-subclass*, *whole-part*, and *instance-of* relations to make the representation of the domain more intuitive. This aspect is covered in Sections 3 and 4. The second interface addresses more general structures and is intended to provide a combined picture that is particularly useful when dealing with domains that include both hierarchical and non-hierarchical structures. This aspect is covered in Section 5.

2 Interface: Design Goals and Strategies

Information seeking in an e-learning context is a complex activity that originates from a learner's task-related information needs and involves interaction strategies such as searching and browsing information sources. Our approaches to address the challenges inherent in the interaction with and visualization of TM-based e-learning repositories are in line with the techniques used for visualizing semantic net-based information [12].

Exploit syntactic and semantic knowledge to improve the visualization. Two main sources of information can be used to generate effective visualizations for TMs:

- Syntactic knowledge based on the topological properties of the TM.
- Semantic knowledge based on the meaning of the topics and relationships between them captured by the TM.

Provide methods for abstracting and filtering the information space. Reducing the size of the information space is the key to dealing with scaling problems in visualization and can also make the structure of the learning collection more apparent. This reduction can be achieved by developing multi-level filtering and abstraction techniques to hide nodes and relations. Our approach to filtering is based on abstraction criteria that exploit the task context combined with information semantics.

Provide flexible scoping methods. All user interactions defined on TM structures (e.g., editing, searching, navigating) require a specified region (scope) of operation. A region consists of a subset of topics and links drawn from the overall topic map. For example, we can use the notion of a region to identify a set of related topics constituting a "neighborhood". The user's ability to define a region (scope) that is natural and efficient for the task at hand is essential to effective interaction.

Provide a notion of "semantic distance". The concept of "semantic distance" between two topics is critical to developing user-centered navigation and abstraction techniques.

The TM4L interface was designed with the above considerations in mind and according to two basic principles. The first one was that users' interaction with learning content should be easy and intuitive. The second was that both browsing and searching should be supported. These principles were embedded in the following goals:

1. Offer an insightful overview of the learning collection structure.
2. Provide primary information at the earliest point.
3. Support rapid decision making about information relevancy based on multiple views.
4. Support exploratory browsing to develop intuition.
5. Offer contextual support during searching and querying to allow users to correctly express their information needs.
6. Support multiple perspectives and allow their comparison or the retrieval of additional information at a glance.

7. Offer possibilities for constraining the amount of displayed information (e.g. to selected topics of interest).

From a Semantic Web perspective, ontology-based information seeking is a promising approach for enhancing existing interfaces with features that enable learners to improve exploratory search styles and better express their information needs. This involves interacting with concepts and relations embodied in the ontologies that describe the subjects in the area of interest.

3 Two Perspectives on the Interactions

The functionality and visualization strategy of TM4L is defined to support two groups of users: authors and learners. The users from these two groups have different levels of subject knowledge and skills. While the learners have often only a vague understanding of their information needs, the authors, who know the subject domain, are typically aware of what topics they need. Thus authors and learners differentiate in:

- *Navigation and Query formulation:* Which path is more relevant to current information needs? How should one modify the query to find more relevant information?
- *Vocabulary:* Which terms should be used? (While the learners frequently are not familiar with the terminology, authors typically know the jargon of the field.)

The different ways of tackling these questions reflect the gap in terms of knowledge and perception between the authors and the learners. In general, learners need to alternate phases of browsing the TM content with phases of querying it. In the latter they often need to refine their selection criteria according to the obtained results.

In contrast, the authors need efficient support for structuring, organizing, entering, and updating the learning content. These presume functionality of supporting topic maps evolution, which will enable the authors to modify the underlying ontology, instances and resources.

As it is impossible to fulfill all requirements, we adopted a compromised approach to the interface design:

- Allow users who know what they are looking for to quickly and efficiently find it.
- Allow learners who don’t know what they are looking for to do *exploratory searching*.

Searching and browsing in TM4L is integrated so that users can move easily between the two options so they can focus their search.

4 Editing and Browsing Support

Visualizing and navigating ontology-based content is a challenging problem faced in many knowledge domains and applications. In particular, visualization is used in tools that support the development of ontologies, such as ontology editors (i.e. Protégé [30], IsaViz [18], WebOnto [9]). The intended users of these tools are ontology engineers that need to get an insight in the complexity of the ontology. Therefore, these tools employ schema visualization techniques that primarily focus on the structure of the ontology, i.e. its concepts and their relationships.

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, and with very few logical relations between the classes. Light-weight ontologies are a valid choice in many cases because 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, occurrences, and associations. In contrast to other domains in e-learning, instance information along with the resources is often as important (if not more important) as the structure of the ontology that is used to describe them. Therefore, in contrast to the general ontology editors, the TM4L editing facilities enable users to capture the ontology schema, as well as visualize instances, their properties, such as the resources associated with them, and their related topics.

Interfaces that provide multiple views are able to offer users different perspectives on a selected entity. Following this model, the TM4L Editor provides Topic centered, Relation centered and Themes guided views (see Fig. 1).

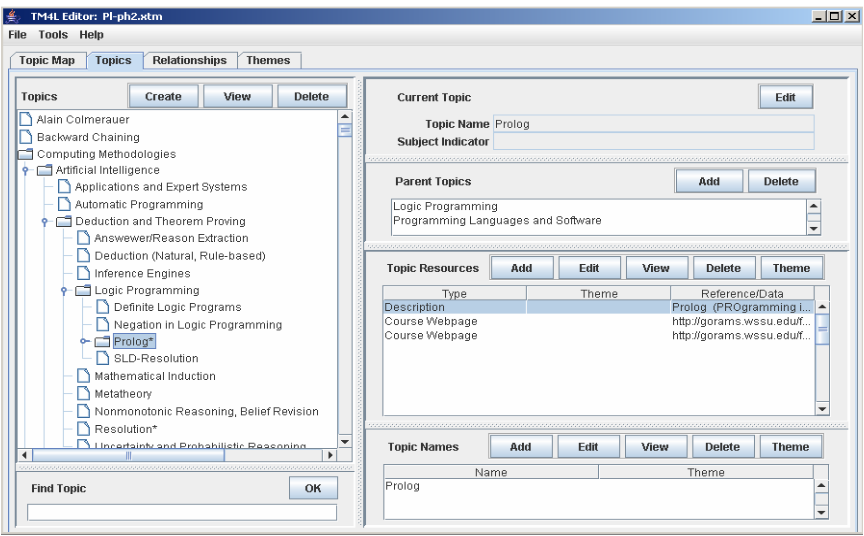

Fig. 1. TM4L Editor: a topic-centered view

In Topic Maps, associations define relations among an arbitrary number of topics. As a primary relation for classifying learning content we have selected the *whole-part* relationship known also as *partonomy*. Like a taxonomy, a partonomy is a hierarchy, but based on the *part-of* relation rather than on a *class-subclass* relation. The reason for picking out partonomy is its important explanatory role in an e-learning context [6]. 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 one technique shown to reduce cognitive load and improve learning is a *whole-part* presentation method [22]. For example, Mayer and Chandler's study [15] 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*, also known as *is-a* relation, allows organizing objects in the domain with similar properties 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 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. Therefore, in addition to the primary *whole-part* relationship, TM4L contains four other predefined relationship types, including the classic *class-subclass* and *class-instance* extended with *similar-to* and *related-to* relations [6]. By offering this minimal set of five predefined relation types we support TM4L authors that experience difficulties in articulating and naming relationships.

The TM4L Editor interface is a typical tree rendering, with the left pane showing the tree and the right pane showing the properties (facets) of each selected node. The nodes of the tree are topics and the edges denote either the default binary *part-of* relation or a relation chosen by the user (*superclass-subclass* or *class-instance*). The hierarchical tree allows browsing the topic partonomy at different levels of detail. The topic attributes, resources, topic parents and relations are displayed in separate panels.

Because of the tree-centered representation, a multiple inheritance is approximated with the help of "cloned" subtrees, appearing in the list of descendants of every parent. Nodes with more than one parent in the *whole-part* hierarchy are indicated. The learning units organized by the *whole-part* relation not always form trees in the formal sense. TM4L handles the case where these relationships are discontinuous, which implies that it is able to visualize forests as well as trees.

For facilitating the access and selection of topics during the editing, expand-and-contract style selection for the topic class hierarchy is provided. To provide a context of the interactions whenever an element of the visualization is selected, it is highlighted. Besides adding new topic types and relation types to the ontology schema, it is possible to add new instances to topics, new relations, and new resources, as well as to modify or delete their attributes at any time, without instances becoming invalid.

5 Graphical Editing and Exploration

The original TM4L Editor enables authors to create TM-based learning content and repositories, by adding topics, relations, resources and scopes (themes). In a typical scenario, after the collection is created, the author can realize (during a browsing session) that certain modifications are necessary. Then the author updates the learning repository structure by using the general editing functionality of the Editor.

One of the recommendations of the TM4L users was for a global view of the repository structure along with "visual editing" functionality. This prompted us to combine the TM4L graphical viewer with an editor so as to offer the author a graphical view of the collection with the possibility of performing some basic editing operations (such as adding, moving, and deleting) on it. As the typical TM4L users are instructors or students, who typically do not have experience with constructing topic maps, we extended the original environment with a graphical editor (called TM4L-GEV), based on a graph representation. It was supposed to complement both the TM4L Viewer and the original TM4L Editor with editing functionality.

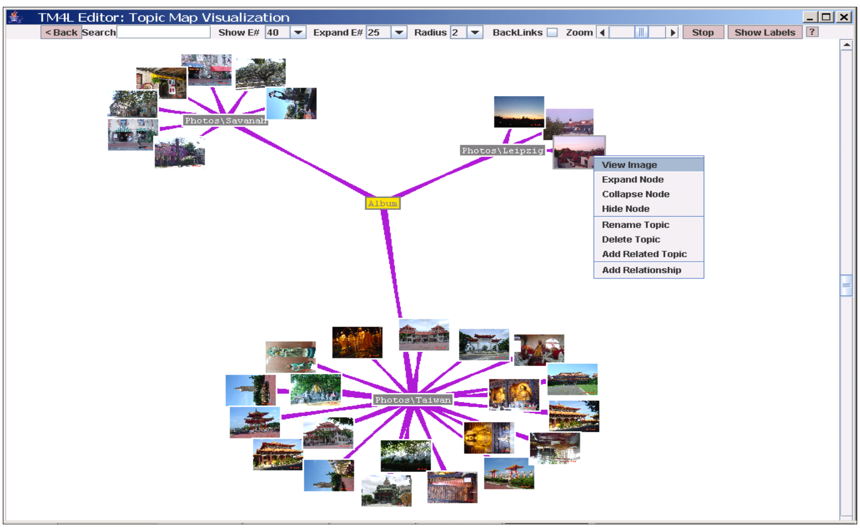

Fig. 2. The TM4L–GEV menu

Currently, the Graphical Editor allows modifications of the TM structure and related properties, such as topic and relationship type names, but not of the resource content. In this section we describe our approach concerning the graphical extension of the TM4L environment.

TM4L-GEV is a GUI for creating and modifying (educational) topic maps. It is a visualizing and editing tool for topic maps, which aims to reconcile topic maps with the semantic network philosophy by providing a set of graphic idioms that cover TM constructs. The graph visualization interface is based on the "TouchGraph" technology [31], an open source graph layout system, which we connected to TM4L and extended to meet its GUI requirements. We studied different tools for visualizing conceptual structures and chose TouchGraph because of its expressive, clear, and intuitive visualization. In addition, it offers a number of advantageous features for visualizing networks, such as high level of interactivity, fast rendering, locality control, pan and zoom capability, etc. These characteristics have been shown to be vital for visualizing large information networks. TouchGraph applies a spring-layout technique, where nodes repel each other while edges attract them, which results in placing semantically similar nodes closer to each other.

GEV provides a graph representation for TM constructs (topics are represented as nodes and relations as edges) and offers capabilities for navigating and editing topic maps. It is a browsing and editing "in-one-view" tool. The simplest editing feature consists of direct editing of the topic name of a selected node. In a similar fashion the author can edit a relation type name. The more complex editing functionality of TM4L-GEV includes:

Create New Topic. This operation consists of creating a new topic in the topic map. This does not link the new topic/node to any other nodes of the displayed graph.

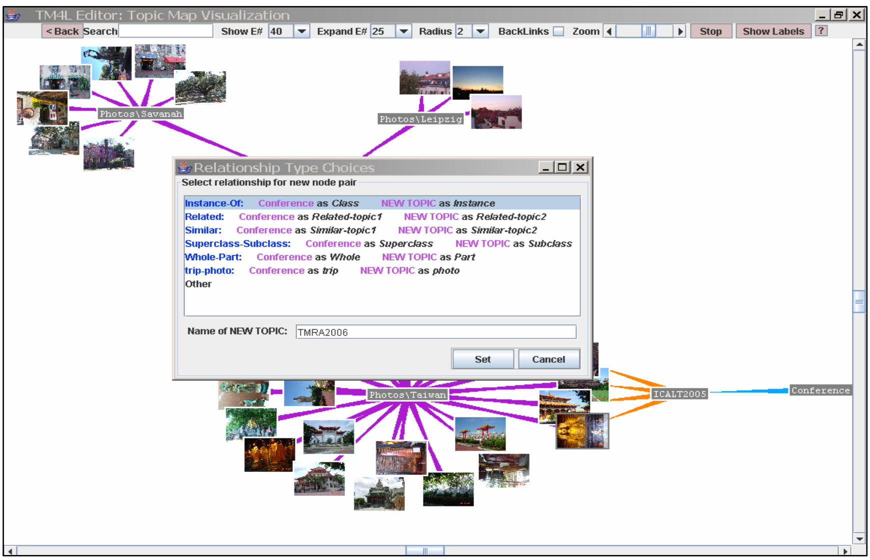

Fig. 3. Creating a new topic and linking it to a selected topic

Add Related Topic. This operation consists of creating a new topic and linking it to the currently selected topic. The user is prompted to select a relation by which to link the two topics.

Delete Topic. This operation consists of deleting an existing topic along with all its resources and associations (linking the deleted topic to some other topics) in the current topic map.

Add relationship of an existing type. The system first asks the user to select a type for the new binary relationship from a list of predefined and user-defined relationship types. Considering the currently selected topic as the player of the first role of the newly created relationship of the selected type, it asks then the user to select a topic to play the second role in the relationship.

Add relationship of a new type. This operation consists of creating a new relationship type in the topic map, followed by performing the "Add relationship of an existing type" operation.

Delete Relationship. This operation consists of disconnecting related topics.

These operations can be selected from a menu, which is activated by right-clicking on a certain graph element. If a user right-clicks on a topic (a node), s/he will see a menu of the options: Rename Topic, Delete Topic, Add Related Topic, and Add Relationship. If a user right-clicks on an edge, s/he will see a menu with the following option: Delete Relationship, and if a user right-clicks on an empty space, s/he will see the following option: Create New Unlinked Topic. Additionally, to enable the display of different perspectives on learning resources matching the learners' level and interests, TM4L-GEV implements theme *filters* that can simplify the display by hiding topics and relationships that have no meaning to certain users.

6 Related Work

The availability of tools for building and prototyping TM applications can considerably improve the reception of Topic Maps and Semantic Web technologies in general. The early examples of visualizations of Web resources include the Hyperbolic Tree [13] for navigation of large trees and The Brain (http://www.thebrain.com) for navigating graphs. A more recent example is Hypergraph [25], a Java application that provides a hyperbolic layout in 2D that allows interactive repositioning of nodes to provide more magnification to regions of interest. Normally these visualizations focus on syntactic structures such as link structures. The current generation of tools represents a new step in this direction in that the emphasis is on interfaces for manipulating information. For example, systems such as Haystack [11] are emerging that concentrate on the concepts important to the users of the information: documents, messages, properties, annotations, etc.

RDF and OWL-based Applications. The ontology editor Protégé [16, 26] is a Java-based knowledge modeling tool. It incorporates hierarchical visualization plug-ins to aid the construction, editing and visualization of ontologies. These include OntoViz [26], which is based on the AT&T GraphViz visualization libraries for graphical representations of hierarchical data, and TGVizTab [1], which also uses Touchgraph, and provides functionality for searching and saving graphs as image files. SHriMP [19] is a modular component that is combined with Protege to form Jambalaya [20], a tool that provides fish-eye views that make use of a continuous zoom for overviews of large data sets. Encoding of data nodes using color and depth cueing in 3D helps to distinguish more important data.

Tools for editing and visualizing graphs of RDF data are available on most platforms. The most common graphical visualization for RDF is IsaViz [18]. It is a visual environment for browsing and authoring RDF models represented as graphs, using

Jena (http://jena.sourceforge.net/). It features a 2.5D user interface allowing zooming and navigation in the graph. It also supports the creation and editing of graphs by drawing ellipses, boxes and arcs. Triple20 [21] is another ontology manipulation and visualization tool for languages built on top of the Semantic-Web RDF triple model. Growl [24] is a visualizing and editing tool for OWL and DL ontologies and provides graphic representation for all OWL constructs and all common Description Logic expressions as well as advanced methods of navigation within large ontologies.

Topic Map-based Applications. In the field of Topic Map-based applications, one of the first interactive Topic Map visualization tools has been implemented by Le Grand and Sotto [14]. The proposed tool supports sophisticated visual and navigational forms, however the presentation is not easily comprehensible and intuitive. TMNav [27] is a combined text and graphical topic map browser that allows users to easily navigate through the topic maps of interest. It is based on the TM4J topic map library and uses Java Swing, TouchGraph, and HyperGraph.

The Omnigator [29] is Ontopia's generic topic map browser. One of its recent additions is the Vizigator [28], which provides a graphical alternative to the text browsing environment. The Vizigator includes two components: the VizDesktop, used by application designers to control colors, shapes, fonts, and icons, and the VizLet, a Java applet that can be embedded in OKS applications.

ThinkGraph [30] is a 2D drawing application specialized for Concept Maps authoring. It uses only standard XML: SVG (Scalable Vector Graphics, a XML language specialized for 2D drawing) is used for the presentation part (shape and graphical attributes) while XTM is used for the data part.

ENWiC [8] is a framework for visualization of Wikis that offers an alternative to the standard text interface. It represents the structure of the Wiki as a topic map, which is visualized using Touchgraph. The graphical representation helps users to see an overview 'map' of the Wiki, which enables efficient navigation. However the visualization is primarily concerned with navigating Wiki's type of websites rather than general educational topic maps.

TM4L. Where Protege is primarily designed as a general ontology editor, TM4L is primarily a Topic Map-based editor and browser with e-learning orientation. What is central to our work is the provided help to authors for logically grouping the repository items by providing a set of predefined relations equipped with adequate visualization interface. Other tools also similar to our work in that they are based on using TouchGraph are the Ontopia's Vizigator and TGVizTab. However these tools provide only visual navigation of the presented conceptual structure, while TM4L-GEV also supports visual editing. Perhaps the closest in spirit to TM4L-GEV is IsaViz, which is also aimed at combining editing and visualization but based on the RDF technology. The distinguishing feature of TM4L is that it supports synchronization between the two editing interfaces thus allowing the author to switch at any time between them.

7 Conclusion

We continue to see the man-machine collaboration as the most powerful ontology producer. Tools have been built and continue to be built to automate some tasks of ontology extraction. However, manual editing in addition to the automated acquisition process will remain as a fundamental method of knowledge capture in the near future. In this relation, to foster development of Topic Maps-based e-learning applications, authors need adequate editing systems and development environments.

In this article, we presented our work on extending the editing and visualization features of TM4L towards a browsing and editing "in-one-view" authoring environment. The focus is on integrating the visualization and editing support. The intuitive, visual interface is discussed in the context of TM4L evolution.

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