REQUIREMENTS FOR INTERACTIVE ONTOLOGY VISUALIZATION

Using Hypertree +2.5D Visualization for Exploring Relationships between Concepts

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Abstract: Ontologies are used for sharing among people or software agents the common understanding of the information structure in a certain domain. Usually, ontologies are represented as static 2D graphs where the relationships are displayed as edges, which often overlap and cause cognitive overload. Three-dimensional representations can also lead to confusion due to occlusion. Moreover, as the ontology grows, incorporating new concepts (and their relationships) increases the visualization complexity either in 2D or in 3D. In this paper, we present a study about the requirements of visualization and interaction with ontologies. In order to do that, we interviewed with four experts on ontology creation and use. From the results, we propose the design of a 2.5D visualization tool for exploring relationships between ontology concepts.

1 INTRODUCTION

There is a gradual increase of information available and efficient methods for information retrieval are necessary in order to allow interoperability and cooperation between several databases. Data semantics is the more traditional approach for data integration because it focuses on the relationship between data. As such, ontologies define concepts and ensure interoperability between systems. In his work, Sowa (2005) points out that ontology is the study of the categories of things that exist or may exist in some domain, i.e., it is a catalogue of the types of things that are assumed to exist in a domain of interest *D* from the perspective of a person who uses a language *L* for the purpose of talking about *D*.

According to Gruber (1996), ontology is a formal and explicit specification of a conceptualization. Noy and McGuiness (2001) discuss that ontologies allow sharing the common understanding of the structure of information among people or software agents. Ontologies separate domain knowledge from the operational knowledge, make domain assumptions explicit and enable reuse.

However, due to the specificities of the concepts expressed in ontologies, the analysis of individual relationships is complex. Thus, interactive ontology visualizations need to be efficient and allow rapid comprehension of concepts and relationships. Katifori (2007) confirms that it is not simple to create a visualization that displays effectively all the information, and, at the same time, allows the user to perform easily various operations on the ontology. Then, the challenge is to define the best way to represent relationships between categorized concepts mainly because each concept can have a number of related attributes.

This work presents requirements analysis for visualization and interaction in tools aiming at creating, manipulating and exploring ontologies. We conducted interviews with users who work with ontologies and conceptual modelling. From these results, we present an initial design of a 2.5D ontology visualization method that aims at systematizing and transmitting knowledge more efficiently. The text is organized as follows. Section 2 discusses related work. Section 3 presents the user interviews and points out requirements for ontology visualization tools. Section 4 presents our proposal for ontology visualization. Results are discussed and final comments are drawn in Section 5.

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2 RELATED WORKS

Different authors propose alternatives for visualization and interaction with ontologies.

Katifori (2007) discusses different techniques that could be adapted for ontology representation, such as indented lists, trees and graphs, zooming, space subdivision (treemaps, information slices), focus+context and landscapes. Besides that, tools for ontology visualization and interaction are discussed. Fluit et al. (2005) present the cluster map technique as a simple and intuitive method for complex ontologies visualization.

The OntoSphere tool (Bosca et al., 2005) uses two techniques - 3D and focus+context – for providing overview and details according to user needs. Baehrecke (2004) and Babaria (2004) are proposing the use of treemaps to visualize GO (Gene Ontologies Consortium). In a treemap, colour, size and grouping are used in order to facilitate user interaction and information extraction.

Protégé (Noy et al., 2000) is the common software used for the creation and visualization of ontologies. Protégé's main visualization for the ontology hierarchy is a tree view (Class Browser). However, different visualization techniques have been proposed: Katifori (2008) presents a comparative study of four visualization techniques available in past versions of Protégé: *Class Browser*, Jambalaya (discontinued), TGVizTab (discontinued) and OntoViz. The information retrieval provided by these tools was also evaluated.

Lanzenberger (2009) discusses the importance of ontology visualization based on graphs, as well as tools for mapping and alignment of ontologies, and views, which employ different structures of graphs for ontologies visualization. These techniques are compared in order to point out their advantages and disadvantages.

Catenazzi et al. (2009) presents a study about tools for ontologies visualization and proposes the OWLeasyViz tool. It combines textual and graphical representations for displaying the class hierarchy, relationships and data properties. Interaction techniques such as zooming, filtering and search are available. Kriglstein and Wallner (2010) present Knoocks, a visualization tool focused on the interconnections within the ontology and the instances. This tool employs the overview + details approach.

The works by Samper et al. (2008) and Amaral (2008) address semantics aspects. Amaral (2008) proposes a semantics-based framework for visualizing descriptions of concepts in OWL. The framework aims at allowing users to obtain deep insights about the meaning of such descriptions, thereby preventing design errors or misconceptions. Icons and symbols are used in diagrams to characterize classes that represent concepts descriptions. One can combine information visualization techniques, as in the work by Schevers et al. (2008), where the user interacts with the ontology in the Protégé tool. Classes representing spatial information (like polygons, points, etc.) are presented in a second graphical interface that is used to mimic the functionality of a GIS (Geographic Information System).

The paper by Kriglstein (2009) presents a survey about users' attitudes and expectations regarding ontology visualization, pointing out some requirements.

3 REQUIREMENTS FOR INTERACTIVE VISUALIZATION OF ONTOLOGIES

The main reason for the use of ontologies is to provide efficient information retrieval, identifying non-explicit relationships between data. Thus, information categorization in ontology modelling is very important.

Ontologies tend to grow, incorporating new concepts and relationships, therefore increasing the visualization complexity. Static graphs, commonly used for ontology representation (Figure 1), are not the best alternative for such visualization. Figure 1, for example, presents two visualizations of the concepts of an ontology hierarchy built with Protégé: tree view (Class Browser) and static graph (OWLViz). The static graph may interfere in the user's perception about the universe represented in the ontology because the display of relationships generates overlapping edges. Likewise, tree view shows the hierarchy of concepts but not their relationships. The solution for these problems may be the use of different information visualization techniques.

Information visualization and concepts of human computer interaction can optimize the comprehension of ontologies. The searched information can be placed in focus, distinguishing it from the unnecessary information and facilitating the understanding of correlated data.

Designers of visualization systems should consider two main issues: the mapping of

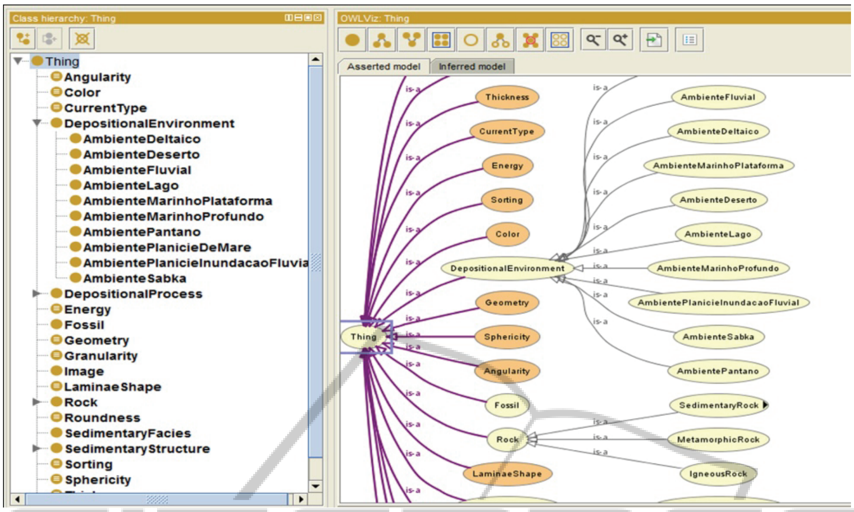

Figure 1: Visualization in Protégé: tree view (left) and static graph (right).

information for a graphical representation in order to facilitate its interpretation by the users, and means to limit the amount of information that users receive, while keeping them "aware" of the total information space and reducing cognitive effort.

As presented in section 2, many studies have addressed the issue of the importance of ontology visualization in creation, manipulation and inference processes. Different visualization methods have been proposed, but there are still many gaps to be filled by efficient methods of visualization and interaction. The study presented in this paper takes into account the results already discussed by other authors, like Katifiori (2007) and Kriglstein (2009), adding new ideas obtained from the users interviews.

3.1 Interviews with Users

This study started with interviews with four users, from the Graduate Program in Computer Science at UFRGS. They work with ontologies daily and can be considered experts in the creation and manipulation of ontologies. From these interviews, we confirmed some requirements pointed out by Kriglstein (2009), and list other necessary requirements for ontology visualization tools.

Three experts are within the Intelligent Database (IDB) group, whose research focus is knowledge engineering, case-based reasoning, document retrieval, information management, and intelligent databases. Another expert belongs to a group studying quality of information on the web and recommendation systems.

Due to the low number of participants, quantitative measurements were not taken, but the qualitative notes are very interesting as indicated by Nielsen (1994). The following questions were posed to the experts:

1) When an ontology is created, which aspects could be improved with visualization?

2) After the ontology was created, which information is searched more often and how this information could be displayed in order to make understanding more efficient?

3) When and why a visualization is better than another?

For question (1), users responded that the main focus is on the elements that define the structure of the ontology. These elements refer to the relations between class and subclasses, between classes, and between the instances of classes. An ideal visualization tool should focus on the ontology kernel (question 3).

During the process of ontology development, users want to visualize different aspects of specific demands that arise in a certain stage of development. Thus, display features could have privileged access at certain points, for example, checking the range of an object property. However, the development of ontologies is still a traditional activity, with no defined workflow and directly influenced by the domain.

Another important aspect related to question (1) is the visualization of the ontology validation generated by inference processes. Displaying errors can (should) be improved, with the indication of correction.

In relation to question (2), we must consider that ontologies can encapsulate a large amount of information (hundreds of thousands of classes and relationships, for example). Moreover, this large volume of information can be segmented into several distinct types (classes, attributes with different values, relationships between types and properties). Usually, users do not want to see these types simultaneously, due to the cognitive overload it would arise.

For example, clicking on an X-class, relations with classes Y and Z are displayed. These classes could be highlighted, while other parts of the ontology could loose focus. The highlight could be obtained through visual attributes such as colour, transparency, shapes and positioning. This feature would be very useful to get an idea of organizing a mereology (part-to-whole relationship, part-to-part relationship). Clicking on a main class could be easy to identify the classes that represent the parts.

The relationships properties (transitivity, reflexivity, symmetry, if it is functional or not) are an important structural component, because they have impact onto the inference that can be performed with the ontology. Likewise, the attributes of each class (data properties) should be considered in the visualization.

Regarding question (3), the main problems of current tools for ontologies visualization are common to any tool for graph visualization: problems of scale versus amount of information that needs to be presented. An alternative would be to use different visualization techniques.

According to Gurr (1999), visual representations can be constructed in order to express the properties of a concept. The use of tooltip texts can help in the encoding of the displayed information, because they contain high loads of information and are presented selectively as the user explores the visualization of the ontology.

Finally, a simple but important suggestion from the users was that views of ontologies fit on an A4 format, with sufficient level of detail. It would also be interesting to have a tool that allows adding and removing elements of the visualization in a quick and simplified mode.

3.2 Requirements

From such results, we can list the following requirements for ontology visualization:

- Provide overview of hierarchy ontology, with the possibility of detailing some parts;
- Avoid presenting the different aspects of an ontology (classes, description, object properties, data properties, individuals) together in a unique visualization;
- Optimize the results from the ontology validation;
- Explore the use of visual attributes such as colour, transparency, and shapes;
- Provide display filters based on different techniques of focus+context and/or overview+detail, zoom, pan and rotation of the image;
- Allow rapid and simple inclusion of visual elements in the visualization, as well as their removal;
- Allow printing the entire ontology in paper sizes commonly used, such as A4.

Considering these aspects, in the next section, we present the initial idea of our method to assist the user in the visualization of ontology hierarchy and relationships.

4 PROPOSED VISUALIZATION

When we analyze an image, we activate our perceptual mechanisms to identify patterns and perform segmentation of elements. The user must perceive the information presented in the display, and the understanding involves cognitive processes. An image can be ambiguous due to lack of relevant information or by excess of irrelevant information.

Graphs are the most intuitive form of visualizing the relationships between concepts of ontologies by their both hierarchical and relational characteristics. However, relationships are displayed in expanded nodes and the overlapping edges can be a problem for the efficiency of information display. An interactive graph or tree solves part of the problem, allowing the user to highlight the information in focus through selection, but the overlapping edges are still a problem. In this sense, Katifiori (2007) list tasks related to ontologies and visualizations as shown in Table 1.

We studied the hypothesis of representing ontologies in a 3D space, allowing the user to navigate through in-depth visual representations, rotating, expanding and selecting the desired items. However, such views require the user immersion and depth perception is crucial.

Considering these aspects, we propose a visualization method that fits the requirements pointed out by users as well as the tasks listed in

Table 1. In the first part of this study, we have chosen to focus on visualizing the hierarchy of the ontology and the relationships between concepts. As an approach to that, the hyperbolic tree is an overview+detail method, which reduces the cognitive overload and the user disorientation that might happen during the interaction with the nodes, expanding and contracting them, especially in ontologies with many concepts.

However, besides the class hierarchy (relationship "is one"), users of ontologies need to analyse, in an integrated way, the other ontology relationships. Thus, we actually have a graph along with the tree, but end up with the problem of occlusion of information by the overlapping edges. This problem can be solved with the use of a third dimension to display one or more relationships (object properties) selected by the user. To view them, we take the plane where the tree is displayed and perform a 90° rotation around the X-axis (see Figure 2a). The rotated plane, positioned in 3D as an XZ-plane, displays the hyperbolic tree, and selected relationships are represented as curved lines in space, connecting the related concepts (Figure 2b), without interfering with the display of the hierarchical relation.

Table 1: Tasks related to ontologies and information visualization techniques (adapted from Katifiori, 2007).

Task	Description	VI Techniques
Overview	Gain an overview of the entire collection.	Trees and graphs, 3D landscapes, *treemaps (space filling)*
Zoom	Zoom in on items of interest.	Indented lists, trees and graphs, 3D landscapes
Details-on-demand	Select an item or group and get details when needed.	Trees and graphs, 3D landscapes,
Filter	Filter out uninteresting items.	Indented lists, trees and graphs
Relate	View relationships among items.	Indented lists, trees and graphs, zooming, 3D landscapes
History	Keep a history of actions to support undo, replay and progressive refinement.	-

In addition to rotations around the X-axis, rotations around the axes Y and Z, zoom and pan are also allowed, providing full 3D navigation. These interactions are performed with a control, common in tools for visualization of georeferenced data and following usability heuristics "consistency and standards", Thus, this control becomes more intuitive for the user in order to facilitate the setting with the tool.

Figure 2b shows the proposed 2.5D scheme applied to an ontology hierarchy/graph. We explored colour and thickness of edges and line contours in nodes. The user remains "aware" of the ontology hierarchy and visualizes one or more relationships in a separate spatial dimension.

Our 2.5D visualization was presented to the four users after they were interviewed. Informally they approved the new possibilities for displaying and interacting with the ontologies represented in that way.

Also as a preliminary validation, we invited a fifth specialist, belonging to a group that studies quality of information on the web and recommendation systems. She was asked to perform a new analysis based on three questions: (1) The initial layout is clear? (2) It is possible to clearly separate the hierarchy concepts of the relationships between theses? (3) The technique is useful for the exploration of ontology aspects? Three possibilities of answers were defined: Yes; Partially; No. The user explored the visualization in many ways, marking the option “Yes” for all questions.

For sure, we need to perform further studies to find alternatives to display tooltips related to nodes, attributes, instances and semantic concepts. Icons, symbols and transparency are being studied in addition to other information visualization techniques.

5 FINAL COMMENTS

Information visualization techniques amplify cognition and reduce exploration time of a data set, allowing the recognition of patterns and facilitating inferences about different concepts. We have designed a visual and interactive way to explore ontologies, improving the process of insight from such data.

In this work, we also discussed requirements for visualization and interaction with ontologies in order support our approach to help users to perform more easily and efficiently the different operations on the ontology. Considering these aspects, we have proposed a 2.5D visualization of ontologies that combine aspects of both 2D and 3D views and take into account the aspects pointed out by the expert users. The main idea is to provide a representation that is intuitive and allows efficient analysis of the

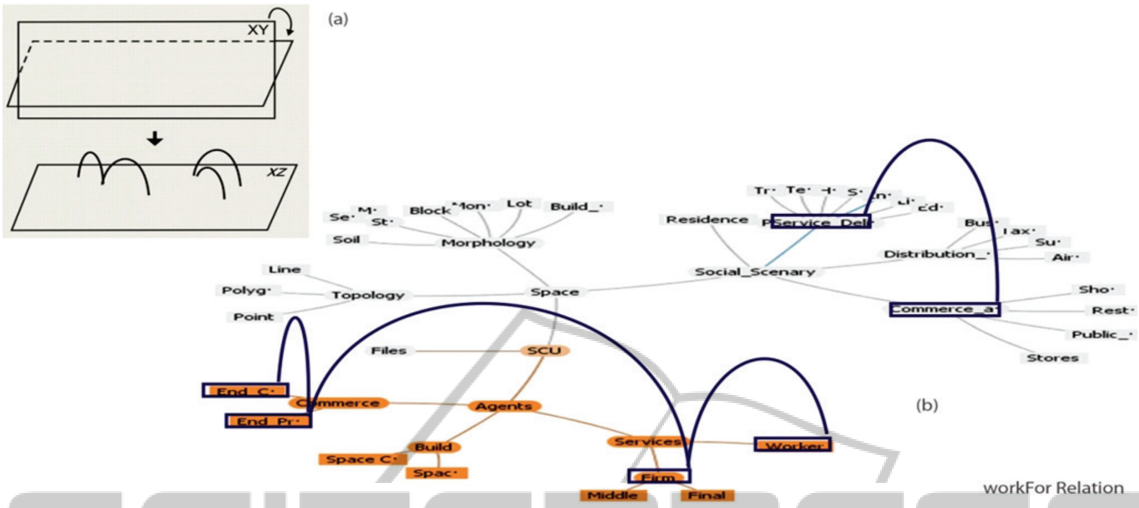

Figure 2: (a) Rotation of the plane with ontology hierarchy and relationships; (b) 2.5D ontology visualization.

concepts displayed in the ontology visualization.

This study represents an initial step in the development of an ontology visualization tool. Future work involves the investigation of alternative display of properties and instances of an ontology in addition to other requirements listed in Section 3.

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