

Using Multiple Views for Visual Exploration of Ontologies

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***Abstract.** In this paper, we present a multiple views approach for exploring relationships between ontology classes and their instances. We employ thumbnails, 2D and 2.5D hyperbolic trees, which capture the hierarchical feature of parts of the ontology, while preserving the different categories of relationships between classes. In 2.5D visualization, the ontology is displayed as a tree on a plane, representing only the hierarchical relationships between concepts, and the user can explore other connections by creating projections of nodes (concepts) in another plane and linking them according to the relationships to be analysed. We report the comparison of our tool to Ontograf and propose a visualization method for the representation of instances of ontology classes.*

1. Introduction

Ontologies are used for sharing among people or software agents the common understanding of the information structure in a certain domain. As such, ontologies define concepts and ensure interoperability between systems. Gruber (1996) states that an ontology is a formal and explicit specification of a conceptualization. The conceptualization refers to the way people think, and the explicit specification relates concepts and relationships, which must be supplied in accordance with specific and well-defined terms.

However, due to the specificities of the concepts expressed in ontologies, the analysis of individual relationships is complex. Thus, the ontology visual representation and the quality of the provided interaction must be efficient. It is not simple to create a visualization that will display effectively all this information and, at the same time, allows the user to perform easily various operations on the ontology (Katifori et al., 2007). The challenge is to define the best way to represent relationships between categorized concepts, mainly because each concept can have a number of related relationships as well as attributes.

Visualization systems should consider two main issues: the mapping of information to 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. 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 on the display, and the understanding involves cognitive processes. An image can be

ambiguous or vacuous due to lack of relevant information or by excess of irrelevant information.

This work presents a visualization tool for exploring classes, instances and relationships in ontologies. In our previous works, we investigated ontology creation and visualization (Silva et al., 2009a, 2009b); performed requirements analyses and proposed a visualization tool based on interviews with experts who work with conceptual modeling and ontologies in two specific domains (Silva and Freitas, 2011a); and proposed a multiple views ontology visualization tool that aims at systematizing and transmitting knowledge more efficiently (Silva and Freitas, 2011b). In this paper we also report the comparison of our tool with Ontograf, which is also used for modeling and visualization of ontologies. The text is organized as follows. Section 2 briefly reviews related work. Section 3 summarizes our previous work and presents our new proposal. Finally, conclusions and future work are drawn in Section 4.

2. Related Works

Different alternatives for visualization and interaction with ontologies have been proposed (Katifori et al., 2007). In their work, Katifori et al. discuss 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 reviewed.

The OntoSphere tool (Bosca et al., 2005) uses two techniques - 3D visualization and focus+context – for providing overview and details according to user needs. Baehrecke et al. (2004) and Babaria (2004) proposed the use of treemaps to visualize data from GO (Gene Ontologies Consortium) database. In a treemap, color, size and grouping are used for facilitating user interaction and information extraction. Fluit et al. (2005) present the cluster map technique as a simple and intuitive method for visualizing complex ontologies.

Mostly, researchers use Protégé (Noy et al., 2000) 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 et al. (2008) present a comparative study of four visualization techniques available in past versions of Protégé: Class Browser, Jambalaya (discontinued), TGVizTab (discontinued) and OntoViz (discontinued). The information retrieval features provided by these tools were evaluated.

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. One can combine information visualization techniques, as in the work by Schevers et al. (2006), 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).

Erdmann et al. (2008) presents the NeOn Toolkit, an open-source multi-platform environment, which provides comprehensive support for the ontology engineering life-

cycle. The toolkit is based on the Eclipse platform, and provides an extensive set of plug-ins (currently 45 plug-ins are available) covering a variety of ontology engineering activities. Catenazzi et al. (2009) present a study about tools for ontologies visualization and propose the OWLeasyViz tool. This tool combines textual and graphical representations for displaying class hierarchies, relationships and data properties. Interaction techniques such as zooming, filtering and search are available. Lanzenberger et al. (2010) discuss the visualization of ontology alignment as well as solutions for dealing with the inherent complexity of large ontologies. The presented techniques are also compared.

Recently, Kriglstein and Wallner (2011) presented Knoocks, a visualization tool focused on the interconnections between the ontology, its concepts and instances. This tool employs the overview + details approach, and was evaluated against another tools, although three of these tools are not available anymore in Protégé last versions (TGVizTab, OntoViz and Jambalaya). Also recently, Bach et al. (2011) proposed OntoTrix, a visualization technique designed to enable users to visualize large OWL ontology instance sets. The technique uses both node-link and adjacency matrix representations of graphs to visualize ontology data.

3. Multiple Views Tool

A multiple view system uses two or more distinct views to support the investigation of a single conceptual entity (Baldonado et al., 2000). Multiple views can help users understand complex relationships among different data sets. They are particularly helpful when coupling two or more views showing otherwise hidden relations.

As presented in section 2, many studies have addressed 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 in by efficient methods of visualization and interaction. The solution for these problems may be the simultaneous use of different techniques. In order to pursue an effective visualization tool, our study was divided in three steps:

- Interviews with four experts in creation and manipulation of ontologies to identify the requirements for an ontology visualization tool (Silva and Freitas, 2011a);
- Proposition and evaluation of a 2D and 2.5D hyperbolic tree visualization for exploring relationships between classes of ontologies (Silva and Freitas, 2011b);
- Proposition of a multiple views approach combining thumbnails and tree view visualization for exploring instances of classes in ontologies.

These three steps are described in details in the following sections.

3.1. Requirements Investigation

The study started with interviews with four people, all experts in the creation and manipulation of ontologies. The following questions were posed to the experts:

1. *Which aspects could be improved with visualization when an ontology is created?*

2. *Which information is searched more often after the ontology was created, and how this information could be displayed in order to make understanding more efficient?*
3. *Why (and when) is a visualization better than another?*

From the results of the interviews, we reached the following requirements for an ontology visualization tool:

- Provide overview of the ontology hierarchy, with the possibility of detailing some parts.
- Avoid presenting the different aspects of a specific ontology (classes, description, relationships, instances) together in a unique visualization.
- Optimize the results from ontology validation generated by inference processes.
- Explore the use of visual attributes such as color, 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.

These requirements were considered the starting point to propose our tool described below. There was also a last requirement – “Allow printing the entire ontology in paper sizes commonly used, such as A4”, which was considered less important for the visualization design.

3.2. 2D and 2.5D Tree Visualization and Evaluation: Hierarchy and Relationships

We propose a visualization method that fits the requirements pointed out by users as well as the tasks listed by Katifori et al. (2007). In this step, we have chosen to focus on visualizing the hierarchy of the ontology and the relationships between concepts employing multiple views. For the hierarchy, we employ a 2D hyperbolic tree, a focus+context technique, which reduces the cognitive overload and the user disorientation that might happen during the interaction with the nodes, tree expansion and contraction, especially in ontologies with many concepts (Figure 1a).

However, besides the class hierarchy (relationship "is a"), users of ontologies need to analyze the other relationships in an integrated way. Thus, we use a second view to display a third dimension showing one or more relationships (object properties) selected by the user. To display them, we take the plane where the tree is displayed, and perform a 90° rotation around the X-axis (Figure 1b). 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, without interfering with the display of the hierarchical relationship.

Figure 1c shows the proposed 2.5D scheme applied to an ontology hierarchy/graph.

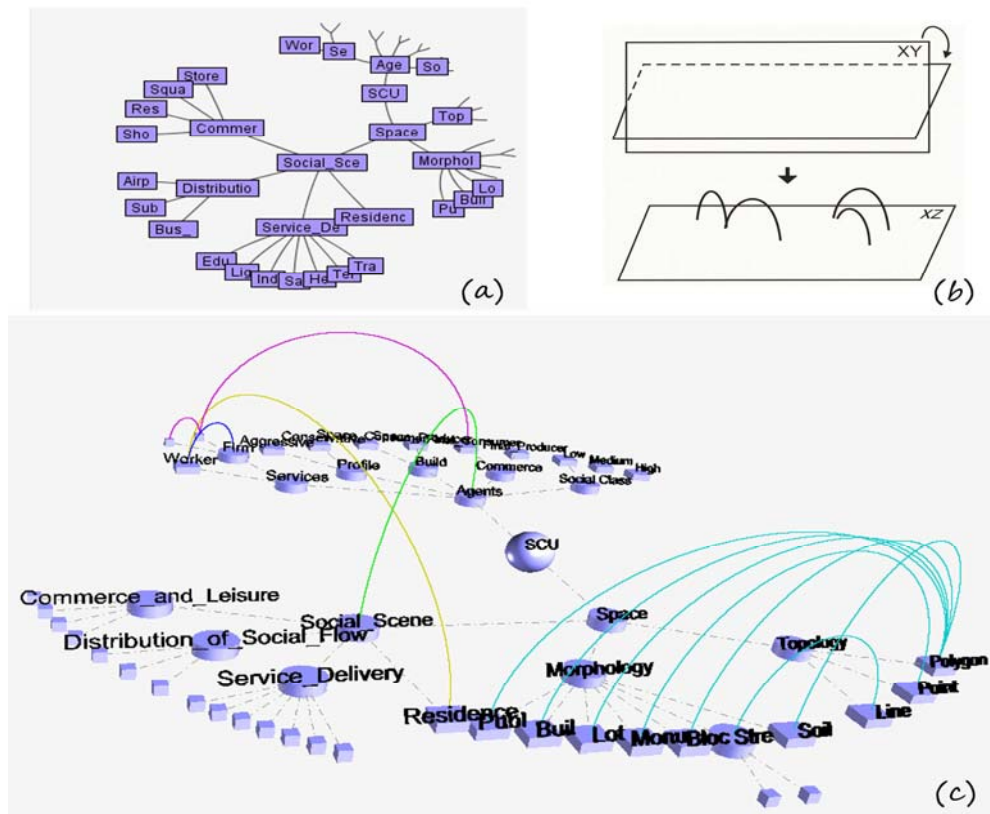


Figure 1. Ontology visualization. (a) 2D hierarchy visualization; (b) 2.5D visualization scheme; (c) Hierarchy and relationships in 2.5D

The main aspects of our technique regarding visualization and interaction are:

- Nodes are displayed with different geometric forms according to their type (root, subtree and leaf).
- Edges of hierarchy are displayed with solid lines and edges of relationships are displayed with dashed curves, the colors being related to the different relationships.
- In 2D hyperbolic tree view, the user can choose which nodes will be in focus on the image, hiding the other ones.
- Both 2D and 2.5D views can be displayed together, side by side, so the user remains "aware" of the ontology hierarchy and visualizes one or more relationships in a separate spatial dimension.
- The user can choose to display one or more relationships at the same time or hide them.
- In 3D space, the user can choose which levels of the tree view or hide, reducing the cognitive overload.
- 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.
- The background color can be changed.
- Tooltips are displayed over nodes and edges as additional information.

Such usability features aimed at reducing the cognitive effort of the user in analyzing the image and, at the same time, add functionality to the tool.

In order to evaluate our 2.5D visualization method, we have chosen to compare it with Ontograf (Falconer, 2010), a 2D tool for visualizing hierarchy and relationships of ontologies, which is available in the current version (4.1) of Protégé.

Ontograf presents seven visualization possibilities: alphabetical grid, radial and spring graphs, and four implementations of tree visualization: vertical, horizontal, directed vertical and directed horizontal. Figures 2a and 2b show two Ontograf visualization examples.

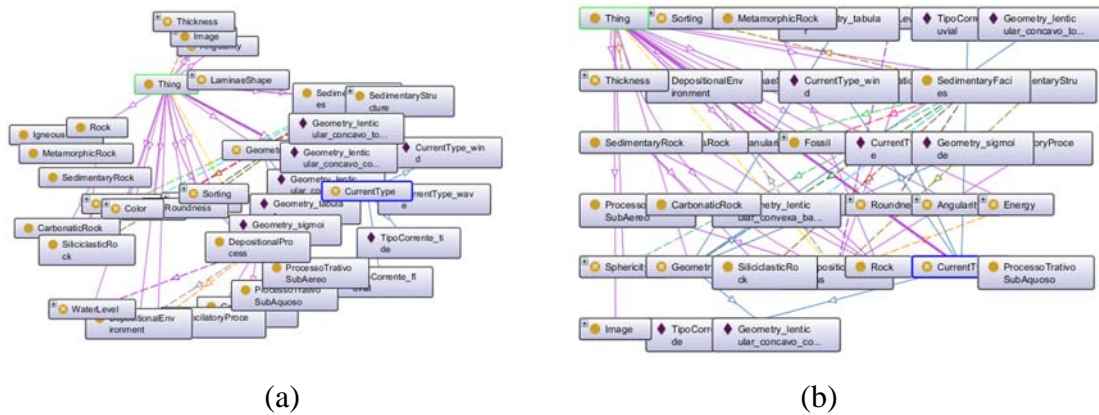


Figure 2. Ontograf views (a) Radial; (b) Alphabetical grid

The four experts interviewed in the first phase of our study (as described in Section 3.1) were invited again to perform evaluations of our 2.5D visualization and Ontograf. Moreover, we invited two other experts in ontology specification to participate, so we had a sample of 6 people.

For the evaluations we used two ontologies as case study: a large ontology related to Stratigraphy concepts, and a smaller one, representing cities' urban performance. Before the participants started with the tasks, we shortly introduced them to the important functionalities of the tools, and they explored them in many ways using a training ontology. After the participants had finished their training, we started the evaluation process.

The tools were presented in different order for the participants. For each tool, they were asked to perform an analysis based on four questions that were defined in order to obtain the requirements listed in Section 3. The questions are listed below:

1. *Is the initial layout clear?*
2. *Is it possible to clearly separate the concepts' hierarchy from the other relationships between these concepts?*
3. *Does the possibility of rotating the ontology representation improve the analysis of relationships?*
4. *Do the pruning and expansion of the ontology levels enhance the understanding of hierarchical relationships?*

Three possibilities of answers were defined: Yes, Partially and No. Figure 3 summarizes the users' answers for these questions.

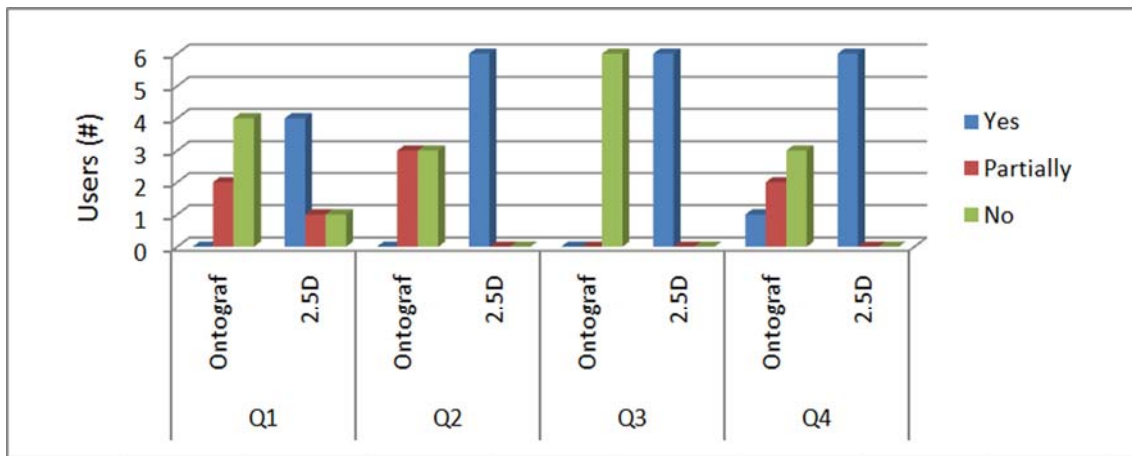


Figure 3. Evaluation results: Q1. Is the initial layout clear? Q2. Is it possible to clearly separate the concepts' hierarchy from the other relationships between these concepts? Q3. Does the possibility of rotating the ontology representation improve the analysis of relationships? Q4. Do the pruning and expansion of the ontology levels enhance the understanding of hierarchical relationships?

Regarding question (1), the majority of users (67%) responded that the initial 2.5D layout is clearer when compared with Ontograf. Among the reasons for that, users pointed out the large amount of information displayed at the same time (nodes overlap) in the image of Ontograf. This is a problem of scale versus amount of information, and causes user disorientation. In our 2.5D method, this problem is solved due to the nature of the hyperbolic tree.

In relation to question (2), users were divided (50%) between “Partially” and “No” answers for Ontograf, because nodes and edges overlap. Usually, users do not want to see relationships simultaneously, due to the cognitive overload that would arise. Thus, the possibility of analyzing the “is a” (hierarchy) and other relationships in different dimensions helps the user to understand the ontology. Another problem reported for Ontograf is that the user needs to change the positions of nodes in order to reveal the relationships occluded by them.

An important positive aspect noticed by users in both tools is the presence of tooltips when the mouse is over the nodes or relationships. 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.

Users also approved different colors for different types of relationships. Colors are mainly a resource for information categorization, and graphical elements like shapes and location of elements in the space help the user in mapping the concepts (Ware, 2008), and these features are present in our 2.5D method.

Regarding question (3), this functionality is not present in Ontograf, and the users considered it an important interaction mode. In our 2.5D method, rotations around the three axes (X, Y and Z) are possible, and complemented by zoom and pan. Thus, users have more freedom to interact with the visualization, and are able to reset to the

original layout at any moment. One of the users reported that when interacting with the 2.5D view, he did not feel claustrophobia, which is common in other tools, including Ontograf.

Finally, in relation to question (4), while 100% of users answered “Yes”, for the 2.5D view, for Ontograf, most users (83%) answered “Partially” and “No”. This result is due to the feature of Ontograf related to the repositioning of nodes when it is pruned or expanded, this fact causing disorientation on users. On the other hand, the 2.5D allows pruning and expansion in two ways: through the hyperbolic tree functionality of repositioning nodes, and through hiding/showing levels of the hierarchy.

These results indicate that the use of 2.5D visualization might be a solution to common problems presented by 2D and 3D ontology visualization tools, mainly cognitive overload and user disorientation.

3.3. Thumbnails and Treeview Visualization: Instances

Ontologies provide the explicit formalization and specification of the classes and their corresponding relationships (Gruber, 1996). Ontologies can have associated specific instances for the corresponding classes, which represent an essential part of any knowledge base, and are often orders of magnitude more numerous than the concept definitions. Thus, besides the class hierarchy and relationships, the visualization of instances of classes in ontologies is another important aspect.

The traditional way of displaying instances of classes in ontologies is through lists of items or indented lists (Figures 4a and 4b). We do not consider these the best modes of visualizing instances of classes because a lot of instances displayed together can generate cognitive overload. Bach et al. (2011) present OntoTrix (Figure 4c), which employed a hybrid visualization introduced as NodeTrix (Henry et al., 2007) in order to visualize the structure of ontologies. However, NodeTrix representations are less familiar to users than graphs and trees, making ontologies analysis more difficult and are likely to increase user’s cognitive load.

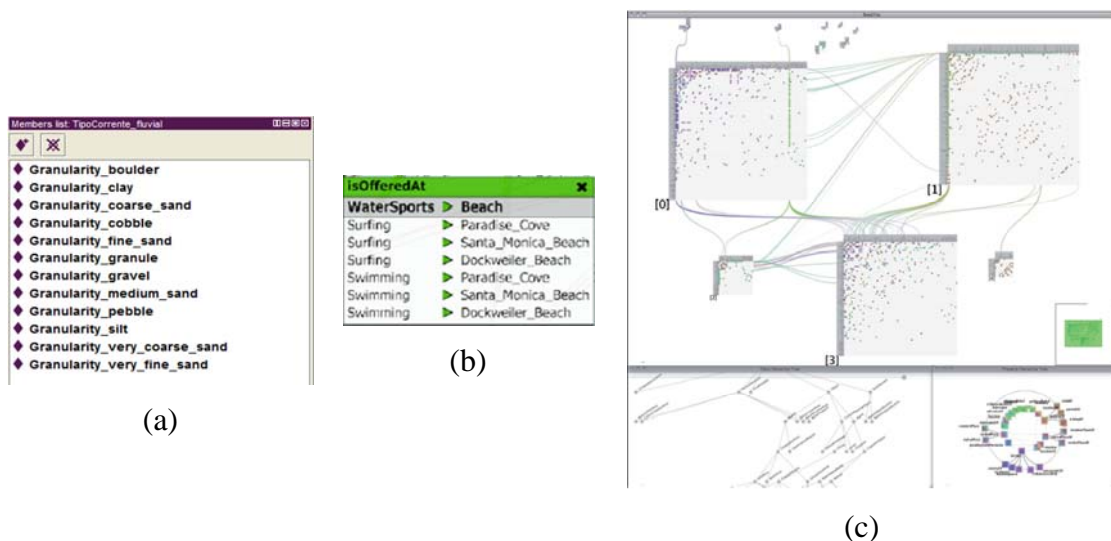


Figure 4. Instances visualization. (a) Protégé (Noy et al., 2000); (b) Knoocks (Kriglstein and Wallner, 2011); (c) OntoTrix (Bach et al., 2011)

Based on the previous interviews with experts and in solutions adopted by other authors, we propose a visualization for showing instances of ontology classes, which employed thumbnails and a schematic treeview, as shown in Figure 5.

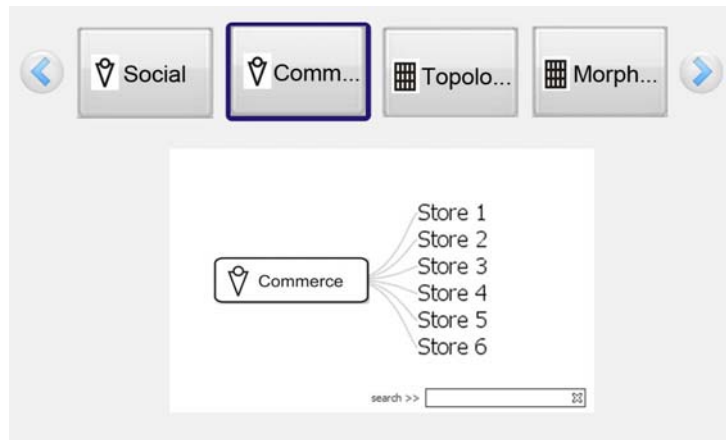


Figure 5. Proposed instances visualization

The classes of the ontology are exhibited as miniatures at the topmost part of the visualization (overview area), and the whole set can be navigated using shifting buttons as in common pictures displays. The detail area shows the selected class in treeview representation at the center of this view. This approach helps users to understand how the entire collection is organized, keeping both views visible for quick interaction. The classes can also be found by a search function of a typed keyword.

We adopted icons with a textual description because this representation gives a better comprehension than icons alone or text alone. The icons are related to two main categories of concepts of the urban ontology used in this example (agents and space) and are based on the work of Murray et al. (1994).

This schematic view is shown along two other views that show the 2D and 2.5D hyperbolic tree visualizations (Figure 6).

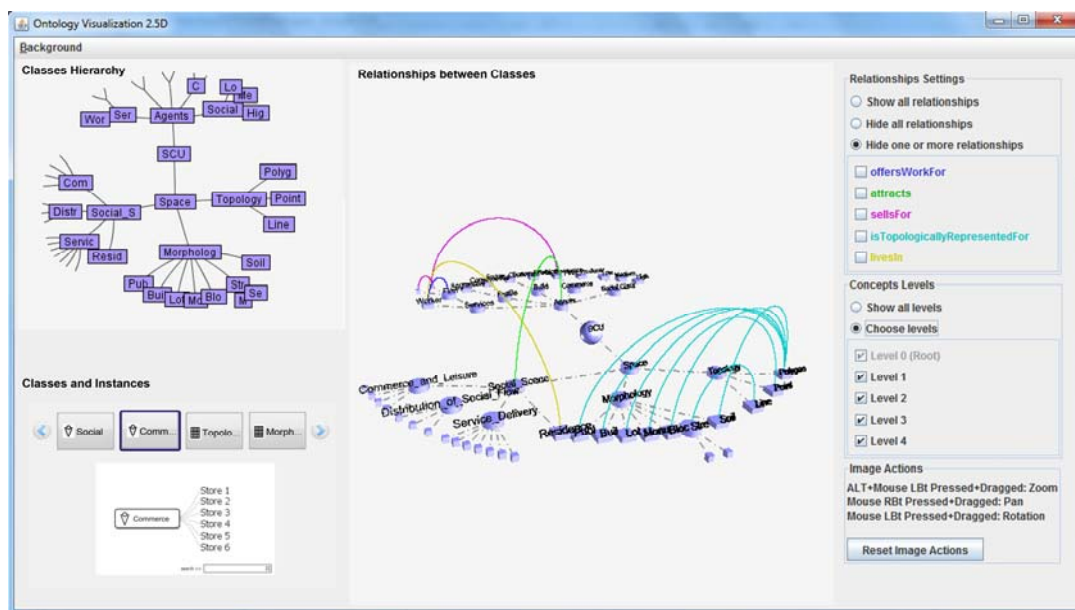


Figure 6. Multiple views in our tool

4. Conclusions

Ontologies tend to grow, incorporating new concepts and relationships, therefore increasing the visualization complexity. Static graphs, commonly used for ontology representation, are not the best alternative for such visualizations. Thus, we need efficient visualization and interaction methods tailored to ontologies. Information visualization techniques amplify cognition and reduce the exploration time of data sets, allowing the recognition of patterns and facilitating inferences about different concepts.

In this work, we have designed a visual and interactive method for exploring ontologies, aiming at improving the insight from such data. For this, we employed multiple views; a common and useful system that offer advantages like improved user performance, discovery of unforeseen relationships, and unification of the workspace.

We started this study with the definition of requirements for visualization and interaction with ontologies in order to support our design decisions for helping users to perform different operations on ontologies more easily and efficiently.

In our 2.5D visualization tool, we combine aspects of both 2D and 3D techniques. During its development we have taken into account the aspects pointed out by expert users. We evaluated the 2.5D visualization proposal by comparing it with the Ontograf tool, available in the version 4.1 of Protégé.

Besides the 2.5D visualization, we explore two other views: hierarchy classes and instances of classes. For the first, we use 2D hyperbolic tree, an intuitive focus+context technique that aims at representing very large trees. On the other hand, instances of classes are displayed as a hybrid view, exploring thumbnails and treeview methods. The main idea is to provide a visual representation that is intuitive and allows efficient analysis of the ontology concepts.

As future work, we intend to perform new evaluation experiments while investigating interactive visualization techniques for displaying data related to inferences.

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