Semantic Visualization Cockpit: Adaptable Composition of Semantics-Visualization Techniques for Knowledge-Exploration

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Abstract:

Semantic-Web and ontology-based information processing systems are established technologies and techniques, in more than only research areas and institutions. Different worldwide projects and enterprise companies identified already the added value of semantic technologies and work on different sub-topics for gathering and conveying knowledge. As the process of gathering and structuring semantic information plays a key role in the most developed applications, the process of transferring and adopting knowledge to and by humans is neglected, although the complex structure of knowledge-design opens many research-questions. The following paper describes a new approach for visualizing semantic information as a composition of different adaptable ontology-visualization techniques. We start with a categorized description of existing ontology visualization techniques and show potential gaps. After that the new approach will be described and its added value to existing systems. A case study within the greatest German program for semantic information processing will show the usage of the system in real scenarios.

1 Introduction

Semantic-Web and ontology-based information systems play more and more a key-role in today's information processing systems. Not only research institutions have recognized the added-value of these technologies, there are many enterprise and non-profit institutions using ontologies for structuring, transferring and adopting knowledge. Ontologies have become an established data model for conceptualizing knowledge entities and describing semantic relationships between knowledge entities and domains. They are used to model the concepts of specific domains and are widespread in the areas of the semantic web, digital libraries and multimedia database management [13]. However, ontologies may become very large and complex what makes it difficult for the average user to understand the underlying knowledge space [15]. To alleviate ontology exploration and knowledge acquirement, visualizations are needed, so that users are able to gain the most benefit from this kind of data models.
Different ontology visualization techniques consider different aspects of ontologies or focus on various but specific ontology characteristics, e.g. displaying the hierarchical inheritance structure, multiple inheritance and semantic relations between ontology entities [13]. The visualization of the complex structure of ontologies with concepts, individuals and relations as fundamental basis, tends to result in visualization with reams of graphs, lines and icons. For this reason is the using of a single visualization not adequate for all tasks or all users. It is

necessary to combine different visualization techniques and reduce the complexity of information by splitting in different separated areas of ontology visualization. Further the different tasks and users have diverse requirements. Users e.g. different precognitions and previous knowledge, where one user is overstrained with same visualization another user can be under challenged.

In this paper a new approach of ontology visualization technique by composing different visualization methods in a user-adaptable way will be described. Every user has the ability to choose within a "pool" of visualizations a number of adequate visualization and combine them as knowledge cockpit. Further he is able to choose colors, icons relation-types etc. for a better comprehension of the knowledge domain.

The paper describes different existing visualization techniques using a classification of Knowledge Visualizations for semantically annotated information. By classifying existing visualization methods the adoption of the visualization in different Usage scenarios, e.g. exploratory learning or searching will be discussed. This classification will allow identifying adequate visualization techniques for a given learning scenario.

After that a new approach of a knowledge cockpit by graphical visualization of ontologies will be presented, which allows visualizing the formal description of knowledge as onologies in different way by using a single User Interface. The paper will depict that Knowledge exploration is important for adopting knowledge with information system, whereas graphical representation of the knowledge can help to optimize the learning process and reduce the cognitive overload.

2 Related Work

Nowadays there are many different approaches for visualizing ontologies. In this section we present an overview of different ontology visualization techniques and discuss the advantages and drawbacks. We start with a short technical introduction to the fundamentals of ontologies and their structure and continue with describe a selected set of visualization techniques representing the most common and valuable visualizations.

2.1 Semanic and Ontology: A fundamental description

For ontology visualization the three most important data elements are concepts, individuals and relations. These elements can contain further properties which describe various features and attributes. Concepts of an ontology represent abstract models of entities in the domain of interest [11]. Concepts are defined as terminological statements in the schema, which tends to be more permanent. A concept can inherit properties from other concepts using the *subclass-of* relation. This inheritance structure constitutes an overlapping hierarchy describing the domain of interest as generalized concepts which become more and more specific downwards this hierarchy. Next to this inheritance structure semantic relations are defined in the schema to model contextual references.

On the instance level of the ontology individuals are defined which instantiate concepts and specify inherited properties. The individuals represent real world objects and are the actual data of the modeled domain. Furthermore semantic relations between individuals are specified on the instance level to model a concrete relationship between two individuals. Each relation has a direction, a type and a label. Especially this label is important for the field of ontology visualization, so the user can more easily understand the semantics of that relationship [28].

To ensure a reasonable schema-design ontology-experts work on the process of conceptualizing the domain of interest. But besides the design for reliable reasoning, ontologies are designated to be used as databases for applications domain-experts and common users interact with. To gain the most benefit for the common users an ontology visualization technique must be able to impart the multiple inheritance, the concept hierarchy and the semantic relations between ontology entities [13].

2.2 Existing Ontology Visualization Techniques

Existing ontology visualization for imparting knowledge can be categorized in following techniques: *Intented Lists*, *Node-Link Visualizations*, *Zoomable Visualization*, *Space-Filling Visualization* and *Context*, *Focus and Distortion Visualizations* [13].
Indented Lists are tree-based visualizations that offer a Windows Explorer like tree view of an ontology. Because of their familiarity to the common user, indented lists are easy to use and allow high performance in ontology exploring [13]. They are used in most of the ontology management systems like the Protégé Class Browser [18], OntoRama [7] and Kaon Tree-based visualizations provide a clear view of entity labels and the concept hierarchy. However, this kind of visualization has several drawbacks in the task of ontology visualization. Indented lists are only applicable for representing the hierarchical part of the ontology. Thus the representation of semantic relations and multiple inheritance is not feasible. Furthermore, only a limited part of the ontology can be displayed at once. The top-down layout results in poor space-filling causing the need for scrolling during ontology exploration [20]. For this reason indented lists are not very applicable for imparting the general structure of the ontology.
Node-link visualizations represent the concepts and individuals as nodes and relations as edges. In contrast to indented lists, the representation of multiple inheritance and semantic relations is feasible, by interconnecting a child with edges to all its parents. For this reason this visualization technique is used for many different ontology visualizations, like OntoViz [26], IsaViz [21], OntoTrack [16], OntoSphere [5] and WSMOViz [14]. Node-link visualizations are well suited for imparting an overview of the entire ontology structure. Nevertheless they make inefficient use of screen space [22]. For large datasets this leads to an insufficient presentation of the whole structure of the ontology what results in context-loss and the need for scrolling. Also the visualization of many relations may result in confusing diagrams with overlapping edge labels.
In ***Zoomable Visualizations*** the hierarchy of the ontology is represented by nesting nodes of lower levels inside their parents. Usually the user is able to zoom into child nodes to gather information from items at deeper levels. This visualization technique is used for the visualization plug-in Jambalaya [27] for the Protégé ontology tool, CropCircles [20] and SemaSpace **Fehler! Verweisquelle konnte nicht gefunden werden.**[4]. Zoomable ontology visualizations provide a clear overview of the ontology's hierarchy. The user is able to request details-on-demand for items of interest by zooming into the desired entity which reduces the cognitive load of the user. But on the other hand the context of the selected element is lost and in some cases it is difficult to recognize the parent node of the zoomed entity or to identify its level in the hierarchy. Relations between the ontology elements are usually visualized as directed, labeled links and are displayed by default (Jambalaya) or on-demand (CropCircles). If the ontology contains many relations this type of relation visualization ends in visual clutter and overlapping labels what makes it difficult for the user to acquire the needed information.
Space-filling visualizations are based on the concept of using the whole screen space by subdividing the available space for a node among its children [13]. The best known representative of space-filling visualizations is the Treemap visualization proposed from Shneiderman [25]. It uses a 2D approach of space-filling to represent hierarchies, in which each node is a rectangle and has been applied by Baehrecke et al. for visualizing ontologies [3]. Treemaps are efficient when users are interested in the leaf nodes and provide a good overview if the hierarchy is trivial [13]. If the hierarchy becomes larger and deeper,

significant cognitive effort is needed to understand the hierarchical structure of the visualized information [31], so this type of visualization does not offer an efficient way to impart knowledge from complex ontologies [17]. Another space-filling approach for visualizing ontologies is SeMap, proposed from Nazemi et al. [17]. SeMap allows the incremental exploring of the ontology's hierarchy what reduces the cognitive load of the user. The exploration starts with the root node and the user can expand a single path of entities of interest. The main drawback of both visualizations is that they are only applicable for visualizing the hierarchy of ontologies and are not feasible for an appropriate visualization of semantic relations and multiple inheritance.

Context, Focus and Distortion Visualizations are based on the concept of distorting the view of a visualized graph. The user is able to select a node of interest in order to focus and enlarge it. The focused node is usually centered and other nodes are placed around the focused node reduced in size. This technique is used in ontology visualizations like TGVizTab [1] and OntoRama [7]. Both representatives are based on graph visualizations and thus they are able to represent multiple inheritance and relations between the entities of the ontology. The advantage of context, focus and distortion visualizations is that an entity of interest is visualized without losing its context. The drawback of this visualization technique is that the position of nodes alters when the user selects a new node and thus it is complicated for the user to keep track of the visualized ontology structure and to understand the complete inheritance structure.

3 Composition of Ontology-Visualizations to Explore and Adopt Knowledge

3.1 Knowledge Exploration using Semantic Data Structures

Ontology is a formal, machine readable description of knowledge, whereas today's learning processes are not formal anymore. A common scenario of gathering and adopting knowledge on web could be the usage of Wikipedia. The user starts searching for a specific topic and finds an article on Wikipedia. The most users read the main description and scroll down to the different headlines of interest. But the process of knowledge exploration has just begun now. The users find in the searched article hyperlinks to other topics and want to know more. As we made a small evaluation with students, who had to answer a very simple question using Wikipedia, we could observe nearly all students read articles related to the main one and spend more time with the related articles, a typical behavior of exploring knowledge.

Semantically annotated knowledge has more associations between the knowledge entities and is further explicit and entitled. The users have the possibility to navigate through the relations of the knowledge assets and learn while interacting. The knowledge exploration can be more structured using the meaningful relations between the learning objects of interest, and so improve the process of knowledge acquisition.

3.2 Composition of Visualization Techniques

Knowledge exploration is an important process for adopting knowledge with information system, whereas graphical representation of the knowledge can help to optimize the learning process and reduce the cognitive overload. As we described in our related work section, different ontology visualization techniques try to solve the problem and offer an adequate way to visualize ontology in different ways for different tasks and users. But further we shopwed that the visualizations have drawbacks or disadvantages in usage or interaction. To provide an added value for learning with graphical systems, the visualization should be usable without an additional learning expense. The main criteria of a visualization should be the reduction of the

usage complexity and hence also the learning expense. How is it possible to reduce the complexity of a system without loosing main functionalities or main information?
A knowledge visualization cockpit breaks the complexity of a single visualization down into several visualizations. Each of the cockpit visualizations is easy in its way of interaction and knowledge acquisition. And with the orchestration of the visualizations the complex information can be visualized without complex visualizations. In the following section this visualization cockpit will be introduced, beginning with a description of some ontology visualization techniques, which will be further composed to a knowledge cockpit. First of all it is necessary to describe the functionalities and how they complement each other:

SEMAP
SeMap is a combination of the Shneiderman's Treemap and Treeview [17]. The Semantic Map (SeMap) uses the two graphical metaphors, Treemap and Treeview, to combine the surpluses for a special case: the usage of semantic annotated data and the implicit impartation of knowledge.
The following shows a screenshot of seMap:

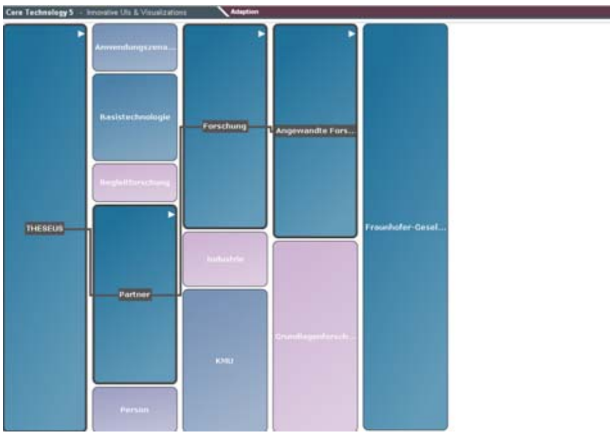

Figure 1: Screenshot of SeMap

Graphical primitives like color, order and size are used to communicate relevant information in a way the user can fast and proper percept it. Color indicates user specific relevance whereas the order and size are determined by a combination of user- and data-based relevance. Order arranges the most relevant element next to the selected element of the last row, as the arrangement of the blue elements in figure 1 indicate.
SeMap is an ontology visualization that only visualizes the concepts and their hierarchy. It is possible to navigate through the set of concepts, where different graphical primitives indicate the relevance of the concept. The navigation is very fast, the information is highly reduced for an abstracted perception.

SEMASPACE
SemaSpace is a visualization of knowledge spaces, modeled as ontologies (concepts, instances, relationships etc.), supporting different aspects, e.g. thematic, co-occurrences, spatial, clusters, or configurable domain-specific representations. It provides different knowledge domains (ontology concepts) visualized as circles containing the instantiation of the knowledge domain as smaller circle. The semantic visualization tool SemaSpace offers a sophisticated way to explore knowledge spaces. It offers concepts and related knowledge items to them as factual knowledge and interrelation between knowledge spaces. Awareness knowledge is acquired, when the user explores knowledge spaces and makes decisions to follow different branches or chooses alternative branches in the semantic visualization. The interactive navigation of SemaVis allows users to explore knowledge spaces, to filter different

aspects, to follow different branches, or return to the starting point. Users can also reorganize the semantic visualization of knowledge spaces to put the important or relative knowledge spaces in the focus just like working on the desktop. It means that users have a very active role in exploring knowledge spaces, which leads to gain active experience about knowledge spaces instead of just passive learning. [4]
The following figure shows a screenshot of the SemaSpace visualization:

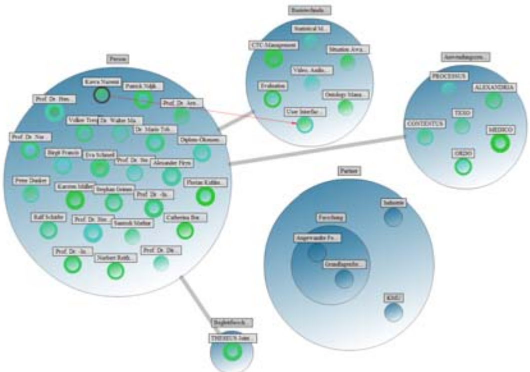

Figure 2: SemaSpace

The SemaSpace visualization contains the most information about a set of concepts within an ontology. It visualizes concepts, relations between individuals and the individuals themselves. The user has a full information overview of the given ontology, but the information could be very complex for some users or if many entities should be visualized.

SEMAGRAPH
The SemaGraph Visualization is a very simple visualization that provides different graphical algorithms for visualizing individuals and their relations. The user is able to navigate through a set of individuals with the first grade relations.
The following figure shows a screenshot of various SemaGraph implementations:

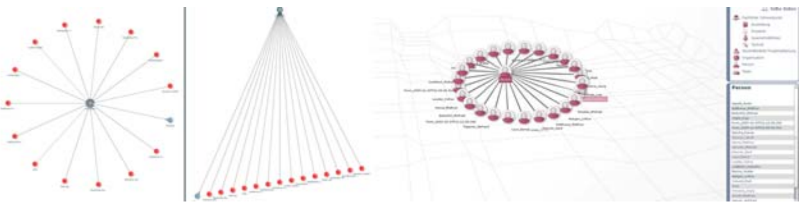

Figure 3: SemaGraph Derivations

The SemaGraph visualization provides an adequate navigation through all individuals of a concept and offers a very simple to use user interface. The information details are reduced on individuals and their first grade relations.
All the described visualizations have their own advantages and disadvantages. SemaSpace visualizes all information, but is too complex to understand and to use, SemaGraph and SeMap are very easy to use, but do not offer all the required information. It is necessary to provide a visualization that covers all aspects and is adaptable enough to create a personalized user interface.

3.3 Adaptable Composition as a Cockpit

The cockpit metaphor is rampant and indicates that different information systems are arranged as a visualization board. The user of a cockpit is always able to see the required information

in a predefined area. The information gathering process is very fast and clear, whereas a common cockpit is not interactive. A common cockpit just visualizes some kind of information and the user is just able to “read” it.
A visualization Cockpit should provide the possibility to navigate through certain visualization and the user is able to see the same information in different windows of a user interface. The research on visualization techniques on ontology showed that the complexity of an ontology is very difficult to be visualized as just one visualization.
The approach that we developed is the orchestration of different low-level and easy-to-use visualization for navigation and interaction with ontologies. The user is able to choose the kind of visualization and combine it with other visualizations. He is further able to create a personalized schema for color, order and size of the different visualization. So that he as an individual is able to understand and follow the complex structure of the ontology.
For this case all the mentioned visualizations was developed with the same functionalities and are sending messages about user events to each other. The user starts with opening a single visualization and can add more visualization to create his own Knowledge Cockpit. Further he is able to personalize and adapt all the graphical presentation elements, like color, complexity, hierarchy etc.
The following figure shows different combinations of Knowledge Cockpits created by users:

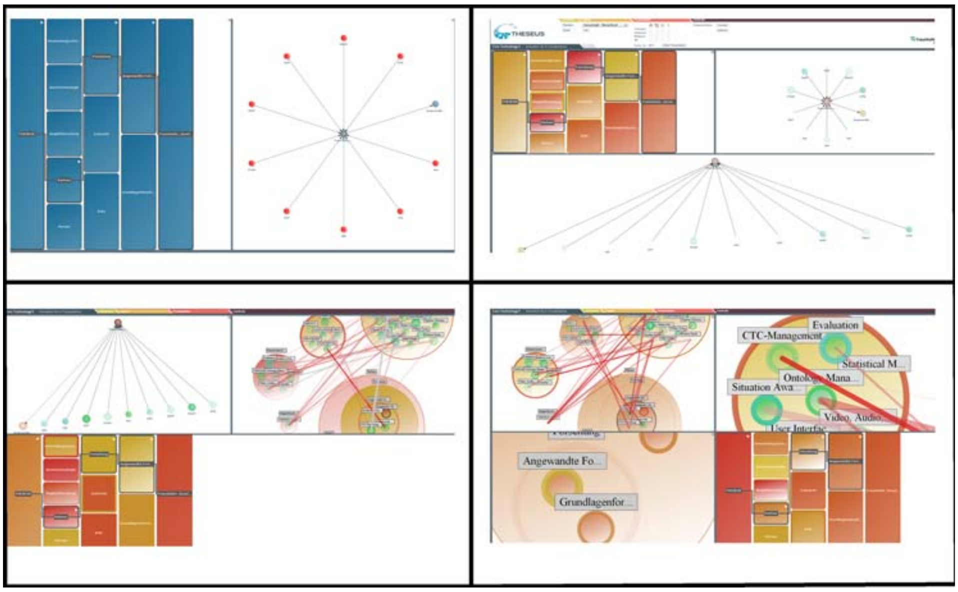

Figure 4: Different Cockpits with the same information

4 Case Study: The THESEUS Program

The described Semantics Visualization Cockpit was developed as a part of the Core-Technology-Cluster (CTC) of the THESEUS Program [29], a 60-month program partially funded by the German Federal Ministry of Economics and Technology. The partners in the THESEUS Program research under the device “New Technologies for the Internet of Services” heterogeneous technologies for gathering and offering semantic information on web. The program itself consists of twelve projects, divided in THESEUS Use Cases and the THESEUS Core-Technology-Clusters. Where the six Core-Technology-Clusters are lead by research institutions and focus on fundamental research areas, the THESEUS Use Cases are lead by enterprise institutions and bridge the gap between fundamental research and industrial dissemination. Different enterprise partners focus on their usage scenario of the different areas of information processing. For example the Siemens Corporation investigates the processing of medical-related information. In this THESEUS Use Case (Medico) different usage

scenarios identify different user groups: There are medical doctors, who use the information of the patient's clinical and medical records to find similar cases and provide the adequate care for them. On the other hand you have the patients themselves, who should be able to understand about their disease and find for example groups or a community with similar ailments.
Another example for a THESEUS Use Case is Contentus, lead by the German National Library. Here you find the same heterogeneity of users. There are domain-experts, who have the required knowledge in a specific scientific domain, e.g. experts for German Literature, but are not experts in using and processing complex ontology-based information-systems. Of Course you find in Contentus the average user too, who just explores knowledge domains and expects a very simple to use visualization and user interface.
The following figure shows the general structure of the THESEUS Program, the six Use Cases and their leading partner:

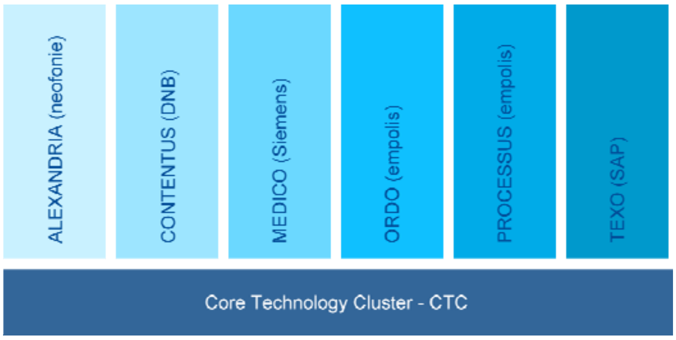

Figure 5: Structure of the THESEUS Program

Beyond the THESEUS Use Cases there are six THESEUS Core-Technology-Clusters (CTCs) investigating different fundamental research questions regarding semantic information processing. The CTC are mainly conducted by research institutes. The CTC for Ontology Management, lead by "Forschungszentrum Informatik", investigates for example managing, reasoning, editing and inferencing ontologies. The CTC Situation Aware Dialog Shell investigates different questions regarding context-aware information processing.
The following figure shows the different Core-Technology-Clusters in the THESEUS Program:

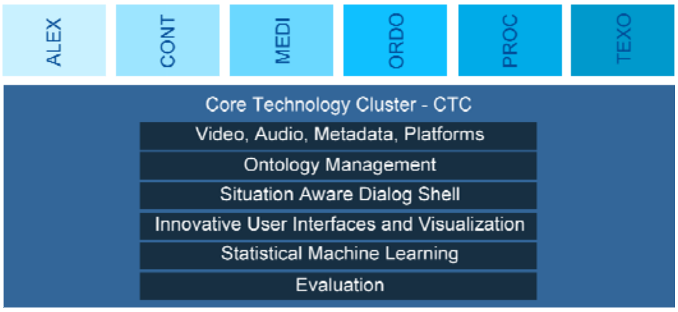

Figure 6: THESEUS Core-Technology-Clusters

The Semantics Visualization Cockpit was developed as a CTC-component of the THESEUS Core-Technology-Cluster Innovative User Interfaces and Visualizations and is used in different THESEUS Use Cases for exploring knowledge domains within the specific scenarios of the Use Cases.
The visualization cockpit was tested in different Use Cases in their specific semantic knowledge domain. The first tests in real scenarios, where the user was able to choose between different visualization at the beginning of his knowledge exploration, pointed out a

higher frequency of usage compared to other provided ontology visualizations, especially for the average user.

5 Conclusion

Nowadays, computer-based learning systems offer huge capabilities to impart and adopt knowledge. Furthermore, different so-called authoring applications give the possibilities to create eLearning content in form of video- and audio-files, rich-text, pictures, animations and structured eLearning courses, which mostly use the international standard SCORM. Complex technologies in combination with high technical possibilities can confuse the creators and frustrate them while working with such systems. Therefore, it is necessary to consider users' precognition and experiences for making the application easy to use. Software with the attribute "intuitive" fulfills users' requirements and offers a working style, not leading to a cognitive overload. The users are able to concentrate on their main task and not in learning to use the application.

In this paper we presented a novel approach of ontology visualization which is based on the sunburst visualization metaphor. We improved this visualization metaphor, which is naturally designed for displaying hierarchical data, to the tasks of displaying multiple inheritance and semantic relations. Thereby the sunburst visualization is capable for displaying ontologies without information loss. To reduce the cognitive overload of the users we integrated incremental ontology exploration, so users are able to focus on entities of interest and to request information on demand. The radial layout of the sunburst visualization offers thereby the expansion of multiple paths and maintains the context while the user navigates through the knowledge space.

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