An approach to visualize ophthalmic ontologies

Christian Henninger, Constantin Rieder, Klaus Peter Scherer
Karlsruhe Institute of Technology
Institute for Applied Computer Science
D-76344, Eggenstein-Leopoldshafen, Germany
<firstname.lastname>@kit.edu

Abstract

In this position paper we introduce an approach of visualizing the ontology describing ophthalmic knowledge. The data consists of semantic information provided by a knowledge based system. This ontology is developed using the Semantic Wiki KnowWE and the visualizations are developed as a plugin. The visualization aims to satisfy the needs of ophthalmological experts and trainees as well as knowledge engineers. The visual exploring assists all users to obtain a general overview of the knowledge and detects specific characteristics. Therefore different approaches of visualizations are shown and evaluated.

1 Introduction

In this paper, we describe the work in a project on visualization of ontologies. This project is part of the "Wissass" Project[1]. The aim of the project is to assist the physicians working in the ophthalmology. In this field, the cataract surgery is the most common procedure. This operation is performed very often. That's why there is very much knowledge available. On the other hand, various cases are known in which a special treatment is required to obtain the bests results possible. In "Wissass", we develop a knowledge-based tool to provide the knowledge to the experts in special cases. Another goal of the system is to help teaching young physicians the knowledge as a tutor system. Based on positive feedback of former projects, for instance [Dieng-Kuntz et al, 2006], we used an ontology to represent the knowledge. In order to do so we based our work on the Semantic Wiki KnowWE. Our aim is to provide a visualization of the knowledge to the user. As a part of the research towards a "knowledge formalization continuum", the "Wisskont" sub-project focuses on fusion of the process of Knowledge Engineering and productive work with the system.

Besides the decision support aspects and the tutoring capabilities, visualization methods can also help during Knowledge Engineering. Visualizing helps the developers to get a quick overview of the knowledge and to spot interesting or even malicious parts of the knowledge base. It also helps the expert to see whether the database is complete. Due to its easy use it helps the user during the Knowledge engineering process to expand the knowledge and alter parts which are out to date. To provide a simple possibility to visualize the knowledge during the productive workflow, the extra use of generic ontology visualization tools is difficult.

Our work is also influenced by the small iterations between the reviews of the involved physician, whose suggestions are tried to be added contemporary. This paper describes the state of implementations and variety of representations we evaluated.

This paper is divided in the following sections:

In section 2 we describe the ontology we developed to describe knowledge in the ophthalmic domain, visualized by the described plugin. In section 3 the different visualization approaches are comparatively discussed. In section 4 we report on the review results of the sessions with ophthalmologist experts. The reviews checked whether the chosen representations are easily understandable by the experts and whether the work and representation are worth the effort. Section 5 discusses related work and gives a brief conclusion.

2 Ontology for cataract surgery

The application will be used essentially by physicians in an ophthalmological domain, especially in the cataract surgery. Like most areas of medical knowledge, the knowledge in this domain is very extensive. The knowledge is represented by concepts connected to other concepts by relations. When we outline all concepts from the knowledge base and their relations between each other the result is a net. The major task for us is to represent the allocated knowledge and accordingly to simplify the information maintenance and retrieval for the end-user by using visualization techniques.

Transferring the knowledge from the predecessor system "Visu-XPS"

At the beginning of the "Wissass" Project, the ophthalmologic knowledge stored in the software developed in the previous project was transferred to the wiki system "KnowWE" shown in figure 1[KnowWE, 2013]. The screenshot presents a concept page from the actual system. The predecessor system "Visu-XPS" was a standalone application developed in Java. It only supported one type on semantic information: *"associated with"*. Therefore, the presentation was limited to a directed graph, which could be simply traversed.

[1] The Wissass project is founded by Zentrales Innovationsprogramm Mittelstand (ZIM) from 2012 - 2014

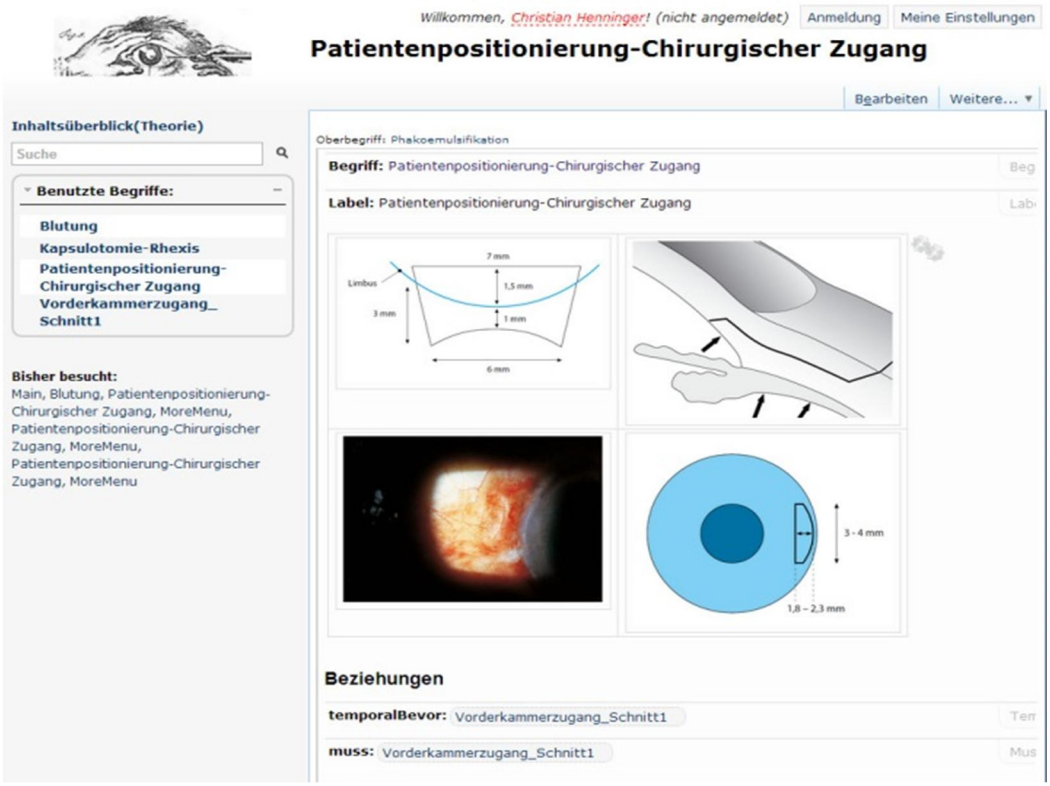

Figure 1: Screenshot of the Semantic Wiki KnowWE

Expansion through new Connection Types

In order to build a semantic net and to provide the users more expressive types of knowledge, more additional relation types were added:

"subconcept": A refinement of the given concept ,used to arrange the concepts in a hierarchical order.

"has to": Connection between complications, which may occur during the operation and their necessary treatments.

"can": A relation used to identify possible reactions to the given state of the patient.

"cave": This relation is used to connect concepts that should be urgently considered.

"before": A relegation used to represent a time period between two concepts.

The resulting ontology is represented in RDF(S) [RDFS, 2004].

At the moment, the ontology consists of 381 concepts. Those are connected by 331 "subconcept", 60 "has to", 49 "*associated with*", 44 "can", 25 "before" and 26 "cave" relations.
In cooperation with the physicians the requirements for the visualizations were identified to guide the development. In conclusion the following use cases were defined:

Use cases

1. Obtain an overview of the knowledge base by reducing complexity by using visualization methods.
2. Obtain an overview of the processes and dependencies between procedure steps of ophthalmic surgery.
3. Browsing through the entire knowledge base to identify interesting spots.
4. Retrieve detailed information on special relations between concepts and procedure steps on demand.
5. Help the user to find quickly the category of a concept.

3 Visualization approaches

In this section we describe a number of different visualization approaches and we discuss their applicability with respect to the described use cases.
All visualizations try to implement the well-known visualization mantra by Shneiderman: Overview First, Zoom and Filter, Then Details-on-Demand [Shneiderman, 1996].

Hierarchical Forest Visualization

The Hierarchical-Forest-Visualization (see Figure 2) is an approach to represent a pool of relationships in the knowledge base according to the first and second use case. It is based on the classical representation of a graph with hierarchical levels, used in file managers for instance. The graph view makes it possible to form a hierarchical structure of a concept and a selected relation. The user can see an overview of all connected concepts by a specified relation. The overview does not exclude a focused view on sub-concepts. It is also possible to select a certain sub-concept from the overview and open the related sub-concepts. The higher level of a concept shows the broader outline of related concepts. The key aspect of this visualization is the combination of two different relations in order to show a more specific structure in the overview. Both relations have a different layout direction in the visualization. The horizontal direction represents an order likewise a time oriented process. The vertical direction represents a sectioning of the concept by an arbitrary relation.

The implementation was realized with the JavaScript library jsPlumb. It provides a way to visually connect elements on a web page [jsPlumb, 2013].

The following visualizations in the next sections were realized with d3js. This JavaScript library was developed in order to manipulate documents based on data [d3js, 2013].

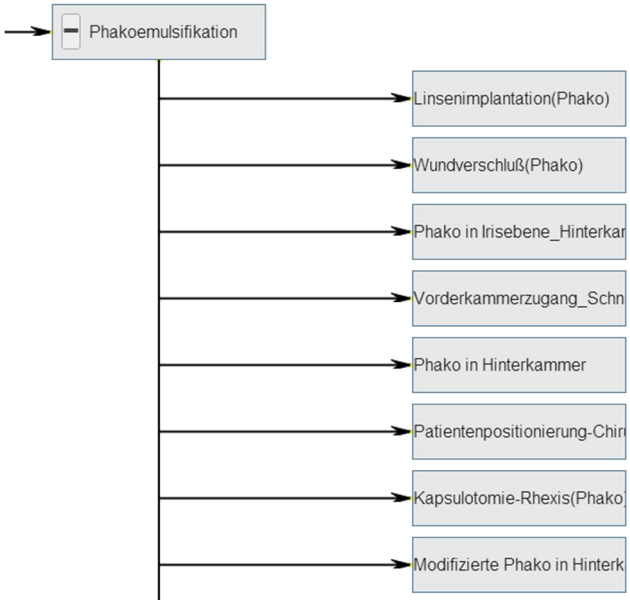

Figure 3: Hierarchical Forest Visualization

Collapsible Tree

In contrast to the Hierarchical-Forest Visualization the idea of the Collapsible Tree Visualization, shown in Figure 3, is to visualize the hierarchy depth of the knowledge base by concentrating on a single type of relation. In this case the use cases three and four were implemented. By selecting a concept it can be expanded to show the following sub-concepts.

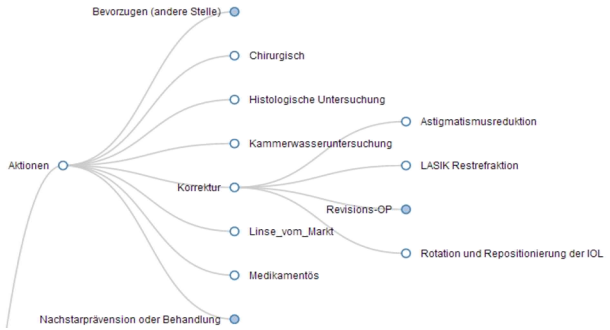

Figure 4: Collapsible Tree Visualization

The user can browse to a topic of interest. Reciprocally the user can also collapse branches of the graph. These techniques allow a suitable display on a single screen without a restraint to scroll. The reason for choosing a classic tree structure to visualize ontologies is that ontologies are graphs and can be often presented as trees. Using this technique is quite common in many research fields and often helps to organize large hierarchical information and bring it to a general overview [Song *et al*., 2010].

Circle Pack Visualization

The Circle Pack Visualization implements the use cases three and five and shows an entire overview of the whole knowledge base.

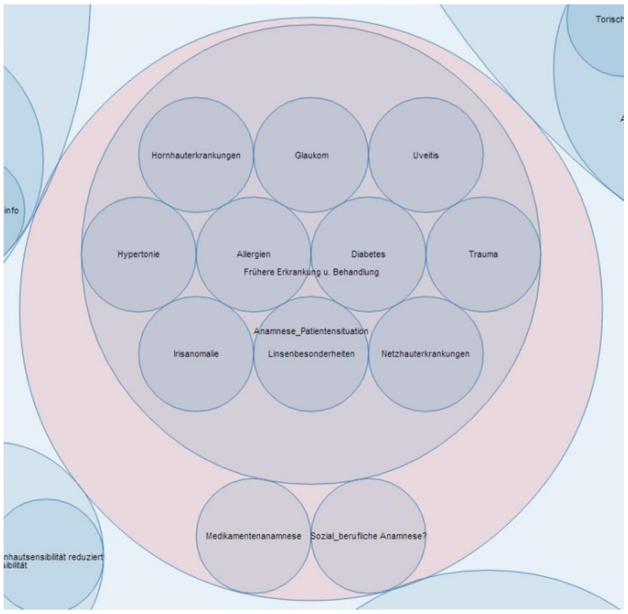

Figure 2: Circle Pack Visualization

As seen before the hierarchical view of concepts is well represented by a tree structure. However, the view becomes confusing very quickly by presenting the entire content of a large knowledge base. The tree diagram becomes too large when too many nodes and branches must be placed on a single page. Addressing those disadvantages, the Circle Pack Visualization provides a useful alternative by representing hierarchical relations through containment. It is possible to see an overview of the overall structure and the position of a certain concept. Concepts are displayed as circles. Child-concepts are located inside their parents. For a better orientation the selected concept is highlighted in the overview (see Figure 4). To increase the readability and to avoid cluttering, only the labels of bigger circles are displayed. The user can zoom by clicking on circles to display the labels of the included circles. The main reason for selecting this kind of visualization is the big advantage that large amounts of hierarchically structured data can be visualized with a clear representation of structural relationships [Wang *et al*., 2006]. Another advantage is the use of size to display the amount of contained sub-concepts.

Wheel Visualization

The Wheel Visualization in Figure 5 shows an overview of the entire knowledge base. This deals with the use case number two and four. The advantage of this ordering is a maximum use of space: many concepts are presented on a single page. The main concept is placed in the middle. The hierarchy depth is presented by circles around the selected concept. Child-nodes use sub-divisions of the space of their parent. The size of Siblings depends on the amount of children they contain themselves. By selecting

a concept it becomes the new center of the wheel. Only the children of the new concept build the new wheel. By using this zoom function, all labels can be read easily and the subsection can be explored.

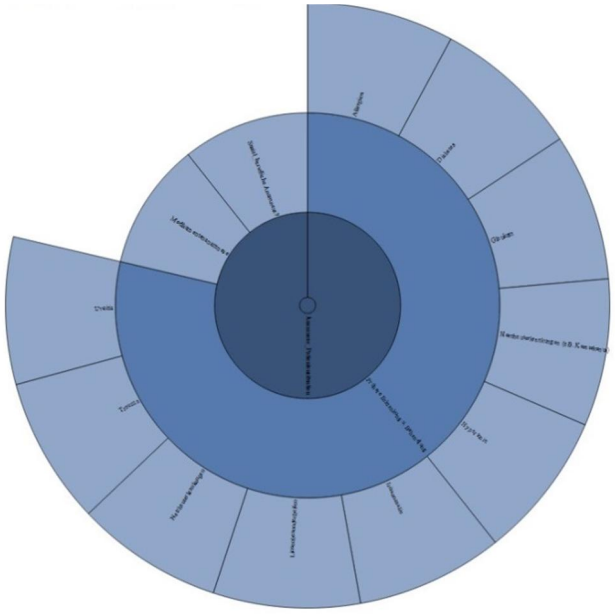

Figure 6: Wheel Visualization

4 Case Study

In order to evaluate the results with a domain specialist, a physician working in an ophthalmic clinic reviewed the developed system. We provided new versions in small iterations and changed details based on the users' feedback. The surgeon takes also part in the development of the knowledge base.

Generally the user was satisfied to obtain a visual representation of the ontology. The visualization was further used in the process of knowledge acquisition.

All visualizations suffered from cluttered labels due to long concept names in this domain. To avoid that, the labels of the included concepts will be abbreviated to get a shorter description name. In order to obtain a clear arrangement on the display further abbreviation techniques described in [Stum et al, 1991] will be applied later in the development process.

The hierarchical forest view was the preferred option by the user. He stated that the hierarchical view of knowledge fit the medicals needs best. The extra division of the tree into process steps simplified the comprehension noticeable. It was also the only visualization which was understood without explanations. This opinion is also backed by several surveys, for example in [Rivadeneira and Bederson, 2003].

We recognized that as more data was added to that view, it became more and more complicated to get an overview. It required scrolling and became too complex in more detailed tasks.

The expandable tree is very similar to the user's mental concept. He understands the concept that the hierarchical relation is displayed.

The situation when the knowledge base becomes bigger is also difficult: Not all concepts fit on the screen. On the plus side the expandability enables the user to show only the concepts of interest.

The Circle Pack Visualization needed some explanation: The user stated that he implies values to the different sizes of the circles. He also didn't realize that the leaf nodes were highlighted in a different color.

In our opinion the Circle Pack Visualization is a great choice to get a quick overview about the amount of concepts in different paths. It also shows the level in which the concept is located. The view needs further work to make it easier to understand and it needs to be evaluated whether it adds advantages to the user.

The Wheel Visualization confused the physician at the first glance. He doubted the suitability of this kind of visualization. Therefore we need to focus on simplifying this approach or finding more suitable alternatives.

In summary the visualizations Hierarchical Forrest and Collapsible Tree are best for the physician to obtain a quick overview of all concepts.

The Circle Pack Visualization can assist the Knowledge Engineering process by highlighting over- and under-populated topics.

The Wheel Visualization suits best when the expert tries to obtain detailed information on specific concepts.

Visualization	Use Cases	Feedback
Hierarchical-Forest	1, 2	+
Circle Pack	3, 5	-
Collapsible Tree	3, 4	O
Wheel	2, 4	O

5 Conclusion

Related work

A general overview of visualization of ontologies is given in [Fluit *et al*., 2003].This paper gives an overview of the current state-of-the-art tools that help visualizing ontologies and evaluates those to find out their weaknesses. Based on those results it recommends requirements for a tool for best user experience.

In [Menge, 2007] a visualization add-on was developed and added to the predecessor system. The main focus is to visualize rules and their derivation. The implemented concepts consisted of pie-charts, Cluster Maps and tree charts. Menge suggested the evaluation of cone respectively disc-charts to visualize larger amounts of data. In conclusion, she proposes to visualize the concept of an entire knowledgebase, which is done in our project.

In [Cvjetković et al, 1991] a development process for a web based ontology view is described. The ontologies displayed are limited to ordinary hierarchical trees which are only displayed as trees. The technologies used and the architecture is very similar to those used here.

Summary

We presented visualization methods to be used during the development and use of a decision support and tutoring system. The different approaches are useful in a number of use cases.

In general, the visualization added value for the user and should be considered, when a knowledge based system is

created. Especially the "knowledge formalization continuum" [Baumeister et al, 2011], which enables users to contribute knowledge to an existing system, can profit from the visualization. To get the best option in our case we need to further adjust the systems to the users' needs.

Future work

To verify the results and to evaluate the benefit of the visualizations, data and experience from the daily use of the system is required. By applying ontologies from different domains which contain bigger amounts of data the plugin can be tested whether the visualization is also useful in states where the knowledge base has increased. Also the performance can be measured and optimized. This will help to achieve an acceleration of response times for a faster way of displaying of the results. It may also reveal if it is necessary to develop specified representations.

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