Modeling and Visualization of Cataract Ontologies

- A prototypical application in ophthalmic hospitals -

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***Abstract*—For handling the complex ophthalmic knowledge concerning surgical cataract interventions on human eyes knowledge domains are modeled as ontologies to guarantee a consistent knowledge at each moment. The different ophthalmic knowledge domains are developed with special wiki models (Semantic Wiki KnowWe). Based on the concepts and the relations between these concepts, the knowledge is represented by a semantic network. For user specific comfortable handling of the information, different visualization methods are designed, realized and compared. The visualization aims to satisfy the needs of ophthalmic experts (clinical surgeons) as well the knowledge engineers. So, different approaches of visualization are shown and evaluated by the clinical partners of the project.**

Keywords-knowledge base; computer aided assistance; knowledge representations; visualization; wiki representation; surgical intervention; ontology modeling ;semantic net.

I. INTRODUCTION

Concerning the complex surgical interventions on human eyes [1], it is very helpful for the clinical experts to get a support by a computer based knowledge system. Such a support system must guarantee a well-structured consistent information and a comfortable access to this information [2] [3]. The knowledge has to be formalized also for a logical reasoning process of the system. The final aim is to support the decision process of the ophthalmic surgeons by the visualized semantics. Different graphical visualization methods enhance the decision support of the doctors and enhance so the quality of the surgical process.

In Section II, a short medical background for the cataract surgical interventions is illustrated. The complex situation leads to a knowledge based approach, which is performed by the ontologies in Section III. Section IV shows the most important concepts and relations, realized for the cataract situation. In Section V, the same ontologies are represented by different visualizations, which the surgeon can choose and switch, dependent on his demand.

II. MEDICAL BACKGROUND

In the biomechanical system of the human eye, the intraocular lens is the most important component for the refraction process to focus the rays to the retina. Parallel to the human aging process there is no possibility to prevent a fix dark cloudy lens with medical treatments. Cataract surgical interventions on human eyes are the single method to replace the old dark cloudy human lens by a new clear artificial lens [1]. This is performed about 700.000 times per year only in Germany. On the market, a lot of lens systems with different haptics, optics, materials and power refraction values complicate the selection of the most appropriate system (Fig. 1). A special configuration and selection of a patient related lens system can guaranteed by a computer-aided decision support system.

III. CONCEPT OF ONTOLOGY SUPPORT

For the ophthalmic surgical assistance different knowledge domains are used as ontologies, realized as a network of concepts and special relations between these concepts [4]. In order to build a semantic net and provide the users more expressive types of knowledge, domain-specific relation types between the so called concepts are created in the ontology network:

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

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

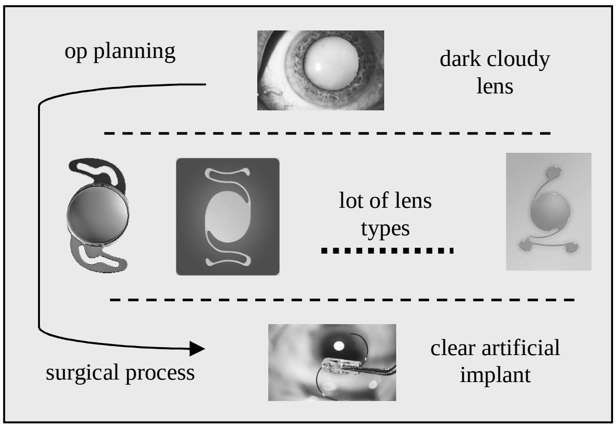

Figure 1. Planning a special lens implantation.

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"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.
The resulting ontology is formalized in the RDF vocabulary description language.

IV. OPHTHALMIC ONTOLOGIES

A. Knowledge concepts and relations

Fig. 2 shows a developed wiki-based knowledge concept, describing the domain "Augenuntersuchung Befund" (eye examination results) in its special structure. In an analogue way each concept is structured under the following two aspects. A custom concept definition markup defines a new concept of the ontology (A). A list of subconcepts defines the hierarchical structure of this given concept ("Unterkonzepte") (C). Furthermore, relations of the selected concept within the semantic network can be defined (D). The informal description of the concepts is described in standard wiki syntax (E) [6].

B. Realisation by special wikis

In the left panel of Fig. 2, a hierarchical collection of concepts is shown (H). It resembles a selection of the domain concepts from the ontology that recently were within the focus of the user, i.e., that have been used for editing or appeared on the visited documents. For the editing of the formalized parts of the content, i.e., the comma-separated lists of sub-concepts or other kinds of relations, the system enables drag-and-drop editing. Any concept within the left panel can be dragged onto a list of the document content and will be appended to it in the source text of the document. When a desired concept is currently not present in the left panel, it can be looked up using the search slot above it. The auto-completion functionality allows selecting the concept and adds it to the collection of concepts. In this way, the whole semantic network can easily changed by using drag-and-drop methods, while freedom and simplicity of document editing is retained [8].

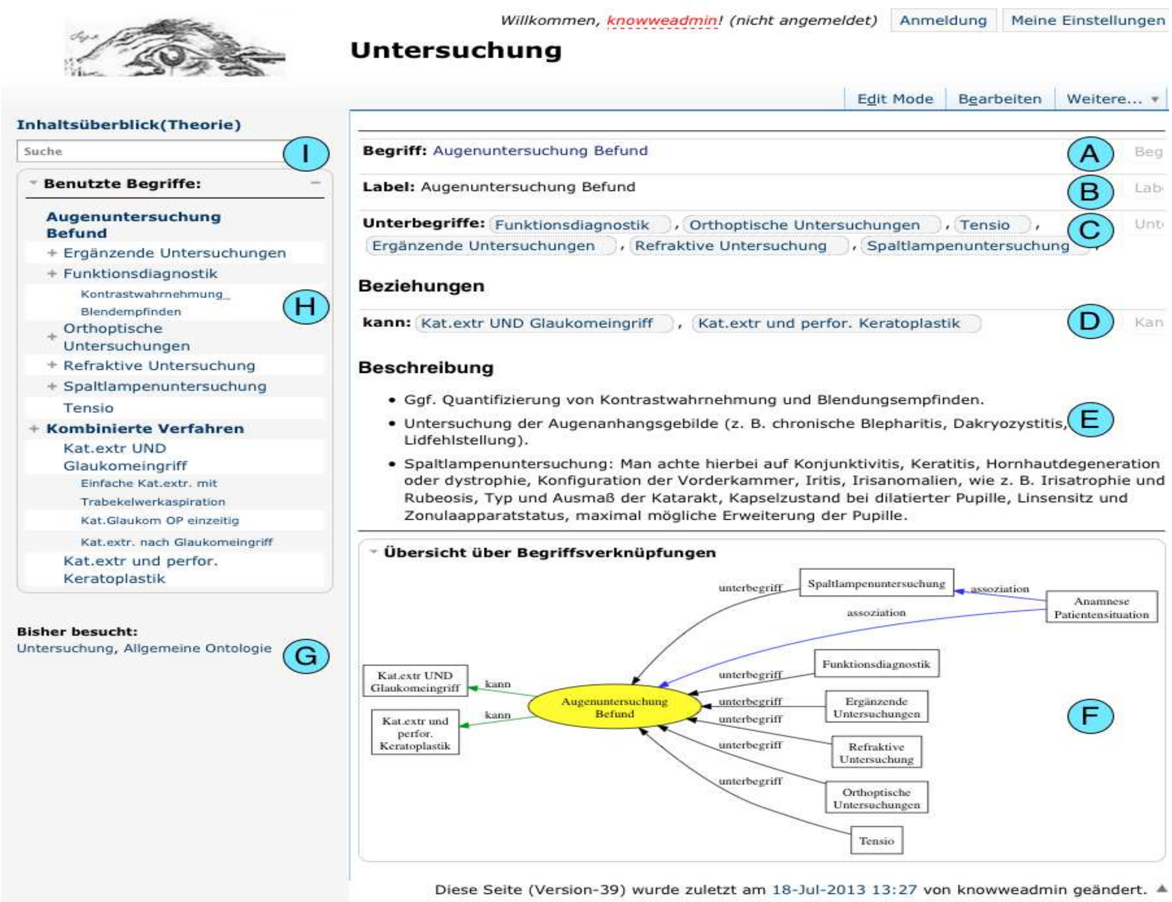

Figure 2. The wiki document of the concept "Augenuntersuchung" with subconcepts and relations.

V. VISUALISATION CONCEPTS

Additionally to the wiki-based description of knowledge concepts and the relations, a good performed visualization enhances the fast understanding and leads to a better overview about the refinement structure of the semantic network and the relations within the net. The visualization methods are oriented at the different user interesting cases. As user requests by knowledge acquisition following results are found:

- Obtain an overview of the knowledge base by reducing complexity by using visualization methods.
- Obtain an overview of the processes and dependencies between procedure steps of ophthalmic surgery.
- Browsing through the entire knowledge base to identify interesting spots.
- Retrieve detailed information on special relations between concepts and procedure steps on demand.
- Help the user to find quickly the category of a concept. Concerning these demands, the following visualizations are modeled and realized.

A. Hierarchical forest Visualization

The hierarchical forest visualization is a combination of the process history and the classical graph representation with hierarchical refinement (Fig. 3). This representation is very comfortable to combine time dependant concepts with the temporal relation ”before” or “after” and the “consists of” relation of a concept in the vertical direction. Based on this combined workflow-refinement concept, the user can find out the time scale, where special concepts are integrated. Furthermore a class-subclass structure is represented from each basic concept in the upper temporal process chairs.

B. 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

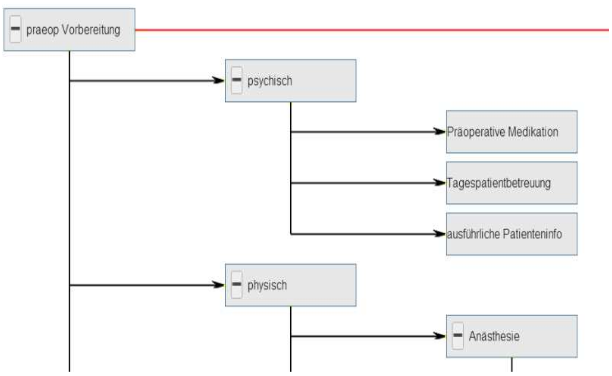

Figure 3. Hierarchical Forest visualization.

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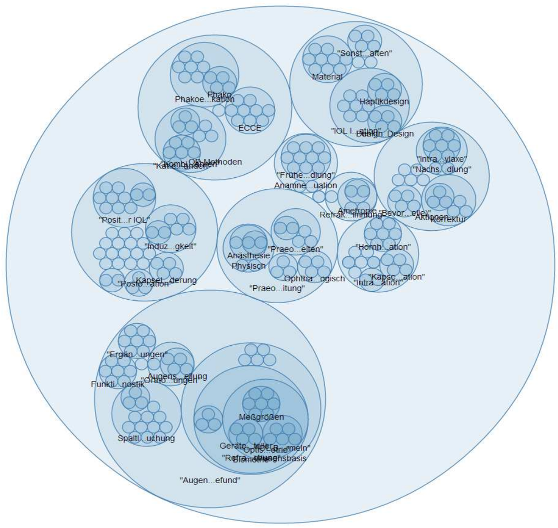

Figure 4. Circle Pack visualization.

becomes too large when too many nodes and branches must be placed on a single page. Addressing those disadvantages, the Circle Pack visualization (Fig. 4) 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.

C. Reingold Tilford tree

The Reingold Tilford tree (Fig. 5) has advantages by concentrating the representation of many concepts with their relations on a very small space.

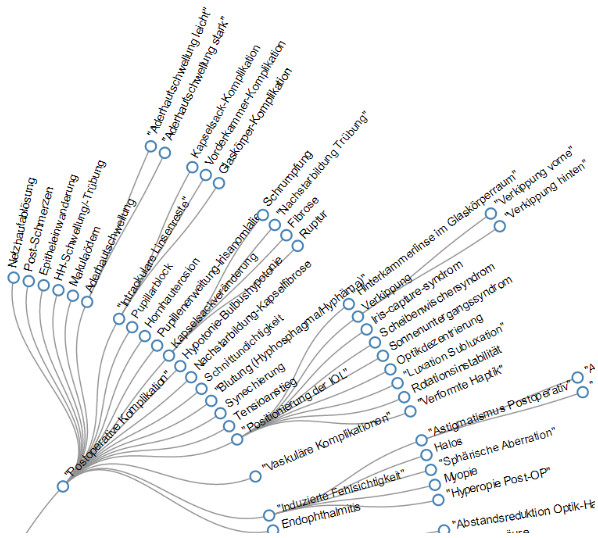

Figure 5. Reingold Tilford tree with radial orientation.

The semantic refinement, based on the subgraphes is performed by a radial orientation. The basic nodes are in the centre. The different sublevels are represented by concentrated circles around the superclass. The level of refinement is shown very directly. The semantic topology is the same as for the other representations, but the graphical visualization is different.

D. Collapsle Tree

A collapsible tree (Fig. 6) is a classical representation of hierarchical graphs, well known from the structure of explorer data files. This concept is accepted and very easy understandable. The hierarchical structure is based on the concepts and the refinement method by subconcepts. So, the information, embedded in concepts, can be refined to a very special subclass with specific features (attributes). This fact allows a very comfortable navigation on each semantic level. By selecting interactively a concept, the following subtree is expanded and the specialized subconcepts are graphically represented. Otherwise, concepts, not interesting at the moment can be retracted. The semantic relation is “consists of” with the inverse relation “belongs to”.

All visualizations try to implement the well-known visualization mantra by Shneiderman: Overview First, Zoom and Filter, Then Details-on-Demand [9]. The implementation was realized with the JavaScript library jsPlumb and with d3js.

VI. CONCLUSIONS

The developed knowledge based assistance system is suitable to support the surgeon’s decision for complex cataract operations. Especially the model of the knowledge continuum based on ontologies is responsible and necessary for a correct consistent enhancement of the knowledge domains. The different visualization methods are useful for the development of the ontology as well as for the application in user cases. Situation dependent and user dependent, classical hierarchical tree representations or semantic networks with their refinement possibilities are modeled and realized. They are used from the clinical experts (surgeons) in use of decision support and for tutoring system. The user has also the possibility to switch from one visualization model to another and can select the currently best for him. So, the user has a comfortable access to the information he needs. Because of that the ontology visualization models and their realization are accepted in the clinical process.

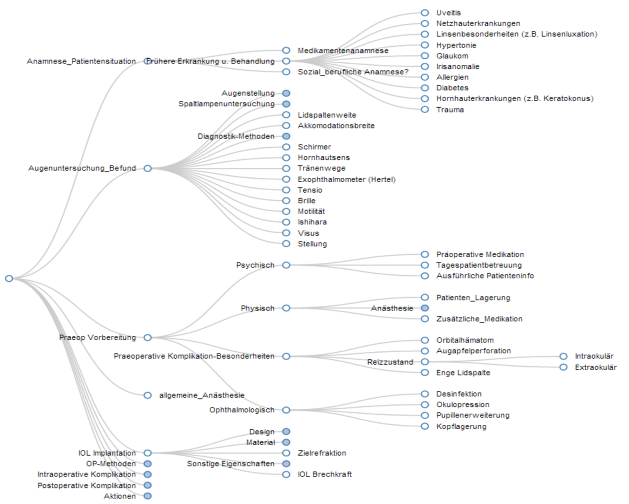

Figure 6. Collapsible Tree visualization.

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