A Case Study in Knowledge Acquisition in the Domain of Cataract Surgery

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Abstract

This paper discusses the development of an intelligent information system for cataract surgery. The system shall provide a knowledge base combining formal and informal knowledge to assist ophthalmologists in clinical practice. The application scenario requires application site specific adaptation and long-term maintenance of the knowledge base, ideally performed directly by experts. To comply with these requirements we discuss a customized knowledge acquisition environment and report about early experiences.

1 Introduction

In this paper we describe a case study of a knowledge management project within the domain of cataract surgery. A cataract is a cloud dark lens in the human eye, which is appearing quite frequently, especially affecting older people. Usually, a cataract can only be treated operatively by replacing the lens by an artificial one. The medical methods applied today have quite high success rates while being rather efficient in general. With about 20 million surgical intrusions per year, cataract surgery is the most widely applied type of operation applied on humans worldwide.

There are still ongoing research efforts to improve methods optimizing success rates and cost effectiveness. Practical experiences have shown that about 90% of the cases can be considered ordinary cases were a standardized treatment is applied, providing an extremely high success rate at comparably low costs. The remaining cases however, show a considerable high complexity, making the treatment process much more demanding. A suitable treatment has to be determined choosing from a number of surgery methods by incorporating many boundary conditions. Being demanding even for experienced surgeons, these cases often benefit from new methods evolved recently in the field.

The goal of the Wissass project[1], discussed in this paper, is the development of an intelligent information system that is able to effectively support ophthalmologists in cataract surgery. The focus of this paper considers the aspect of knowledge acquisition and maintenance of that system. The captured knowledge includes informal knowledge (e.g., text and figures) as well as formal knowledge to support automated reasoning. This combination of knowledge at different degrees of formalization poses special challenges to knowledge acquisition. For this purpose a special knowledge acquisition tool is designed. We also report about the experiences made during the collaboration with ophthalmologists considering this aspect.

The remainder of this paper is structured as follows: In Section 2 the application scenario is described, outlining how the developed system is going to support the clinical practice of cataract surgery. A customized knowledge acquisition tool for the described scenario is presented in Section 3. A discussion of the current state of the project is given Section 4. The paper presents related work in Section 5 and concludes with a short summary and outlook.

2 Application Scenario

The goal of the Wissass project is to provide an intelligent information system, that is suitable to assist the physicians in practice. Especially for the treatment of the difficult non-standard cases computer-based assistance by expert knowledge would be valuable. Therefore, a knowledge system was designed serving two use cases:

- **Second Opinion System:** A traditional knowledge-based system is employed routinely to run in parallel with the treatment process of each patient. The anamnesis and examination data of each patient is entered into the knowledge-based system, which checks whether there are deviations from the standard case that need to be considered. If so, the system provides the ophthalmologist hints about special issues that need to be considered for the treatment of this patient. It further determines a proper surgery method if appropriate. The system also demands additional examination data for the patient, if it is required to exclude the prevalence of particular complications.
- **Tutoring System:** In an intelligent information system with simple access, ophthalmologists can look up and study a comprehensive up-to-date presentation of the latest knowledge about the domain of cataract surgery. The content is based on standard text book knowledge on the domain being enhanced and updated with new content when new best practices or research results emerge. The tutoring system provides intelligent interactive navigation and is illustrated with multi-media content. It also shall provide means to further research about hints or propositions made by the second opinion system as this only provides a very scarce explanation.

While the latter application scenario allows surgeons to look up particular aspects they are currently interested in, the second opinion system automatically runs in background providing treatment hints on complicated cases.

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These two major use cases require the combination of formal knowledge, i.e., to generate treatment recommendations, and informal knowledge, such as illustrative contents including text and figures. For the representation of the formal knowledge the concepts of the domain are modeled by an ontology, which is extended by simple derivation rules for the treatment recommendations. Beside a hierarchical organization of the ontology concepts, numerous cross connections between associated concepts are established using a small set of predefined relation types with specific semantics. In that way, a semantic network is established that allows to enable semantic navigation within the tutoring system. Further, these cross connections between concepts can be used to create rules for the second opinion system. Concepts that correspond to values of an anamnestic patient data set (e.g., *eye pressure increased*) can be connected to target concepts using special relations. In surgical practice, if a patient data set matches these source concepts and treatment hint proposing the target concept is generated according to the used relation.

For each concept illustrative content is included describing the role of the concept in the domain. Additional narrative content in text book style is included, being interlinked with relevant domain concepts.

The body of knowledge developed within the scope of this project however is only forming a basic seed of knowledge. At any application site, such as hospitals or doctor's practices, the knowledge base needs to be adapted to the local conditions and requirements. This includes modifications with respect to the available examination equipment and surgery methods as well as the predominant category of patients. Therefore, the ability for performing changes in a simple way at reasonable costs is an important selling factor for the overall product. Consequently, one major challenge of the project is to provide a knowledge acquisition concept that allows for easy adaptation and maintenance of the knowledge. The goal is to enable the clinic personnel to perform minor adaptations of the knowledge on their own. For more complex modifications, easy remote collaboration on the content between a knowledge engineer and local experts should be supported. Hence, beside the formation of a knowledge seed also the design and development of a knowledge acquisition tool, that is fulfilling these requirements, is an important goal of the Wissass project.

3 A Custom Knowledge Acquisition Tool

The developed knowledge acquisition tool is based upon the wiki system KnowWE [1]. For the project specific customization of the tool the meta-engineering approach for document-centered knowledge acquisition has been employed [2]. It allows for smooth and ongoing adaptation of the tool towards the requirements of the project settings. The tool modifications were designed in close cooperation with the medical expert in joint sessions of discussion and assessment. Beside special markup languages for the knowledge formalization, this includes components for navigation, search, visualization, and authoring support.

In document-centered knowledge acquisition the presentation of the knowledge within the tool very much relies on the structure of the documents. While technically not being a characteristic of the tool, we also consider the establishment of a suitable and understandable document structure as part of the meta-engineering process. In the following we describe the knowledge acquisition tool resulting from that customization process.

Figure 1 shows the developed wiki-based knowledge acquisition tool presenting a document describing the domain concept *Augenuntersuchung Befund* (eye examination results) in a particular structure. The structure, which any domain concept of the ontology is/should be described in, is a follows:

1. A custom concept definition markup defines a new concept of the ontology . (A)
2. The label of the concept is defined using the custom markup for concept labels. *(optional)* (B)
3. A list of the sub-concepts of the local concept defines the hierarchical structure of the ontology. Introduced by 'Unterkonzepte:', the comma-separated list markup specifies which concepts are sub-concepts of the local concept of this document. *(optional)* (C)
4. Then, further relations of the local concept within the semantic network can be defined. Therefore, the comma-separated list-based markup with the respective keyword are used. *(optional)* (D)
5. Concluding, the informal description of the concept is defined using normal wiki syntax. (E)

The structure defined above only defines a convention recommended to authors not being enforced by the system.

Navigation & Search Underneath the rendering of the document content, a graph visualization is shown (F). It presents a view on an excerpt of the semantic network displaying the concept described on this document and its neighbors, including relations that are defined in other documents (e.g., association from *Anamnese Patientensituation*). In that way, the user at one glance can get an overview of the concept and its role within the semantic network, also providing instant feedback after editing the document content. Any node can be used to open the corresponding document by click. At the bottom of the left panel the history of recently visited pages is shown (G). The search slot, also located in the left panel (I), provides access to a search mechanism, combining semantic search and full-text search.

Authoring Assistance Figure 2 shows the source text of the document, which is managed by the document-centered knowledge acquisition environment. It can be edited in different ways. Any parts of the contents can freely be edited, using (extended) wiki syntax.

The user can edit the document content in source mode, as shown in Figure 2, or in a section-editing mode which allows to edit any paragraph within the document view as shown in Figure 1.

In the left panel of Figure 1 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 to select the concept and adds it to the collection of concepts. In

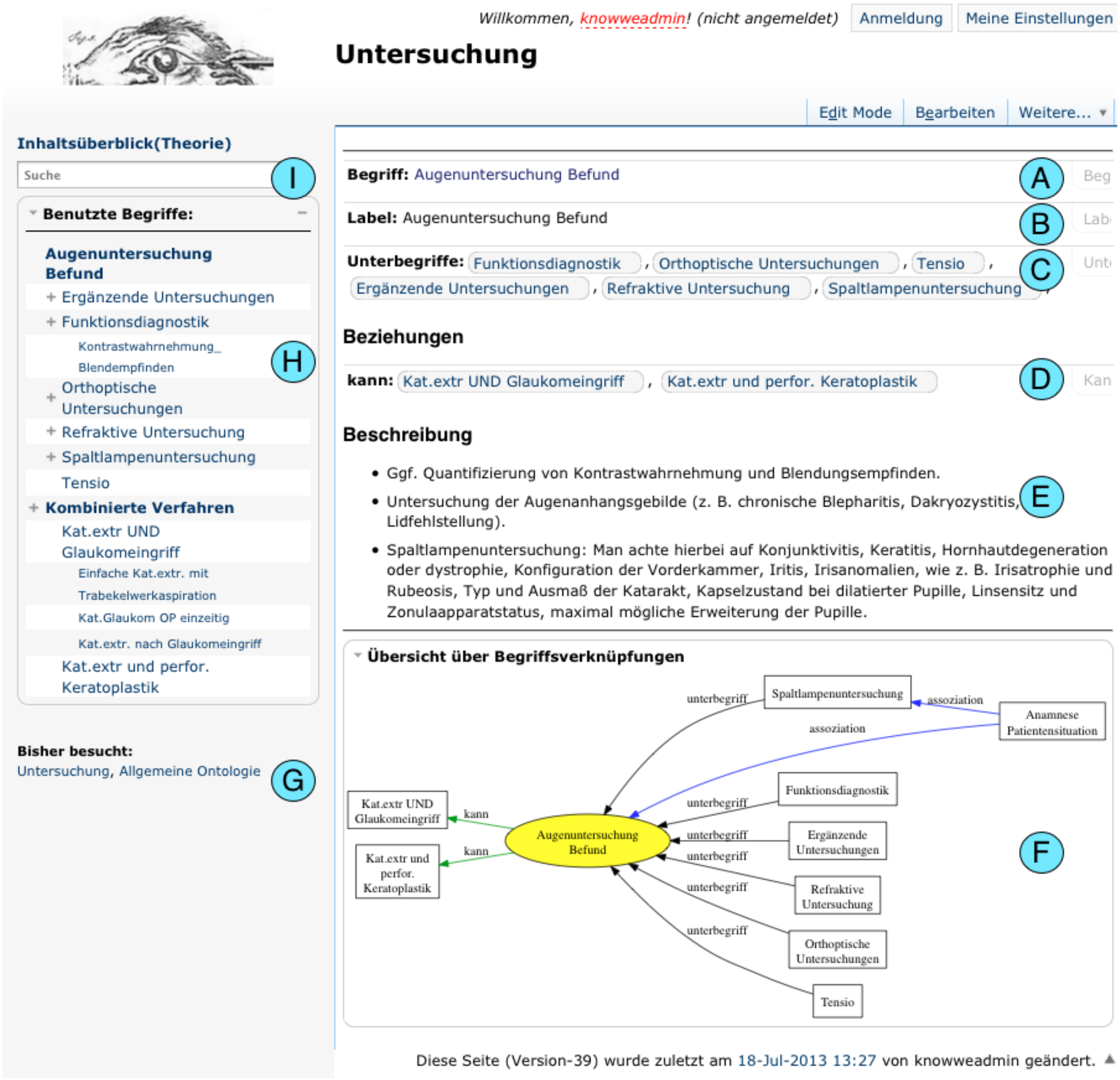

Figure 1: The document describing the concept *Augenuntersuchung Befund* (in German language).

that way, the entire semantic network can easily be edited mostly by using drag-and-drop editing, while the freedom and simplicity of document editing is retained.

4 Discussion

In the current phase of the project the initial body of knowledge to a large extent is captured within the system. Currently, there are more than 320 concepts of the domain contained in the ontology, each being described by a document as discussed in Section 3. There is also a text book chapter about cataract surgery included, where each section is annotated with the relevant domain concepts from the ontology. Further, there are about 200 cross connections defined between concepts. A subset of these relations are used to generate simple rules for treatment recommendations. More complex kinds of rules can be inserted by the use of textual rule syntax [1], which is hardly required by now.

The designed knowledge acquisition tool allows for simple maintenance of the knowledge by a uniform interaction paradigm. This allows to perform minor modifications of the knowledge in a consistent way. The expert supporting the Wissass project is capable to perform most knowledge base editing operations on his own. This includes editing of illustrative knowledge, creation of new concepts, editing of the hierarchy and establishing cross connections between concepts. Currently, we do not have any experiences about knowledge maintenance by independent experts yet. However, we expect the document-centered approach makes it easy for specialists to get involved with the knowledge acquisition activities. The editing of informal content only requires editing of normal wiki content. Further, editing of coma-separated lists supported by drag-and-drop appears to be a simple way to maintain the semantic network. Additionally, the use of a centralized document authoring environment allows for easy (remote) collaboration between experts and knowledge engineers.

For guaranteeing the consistency of the ontology during the development process, automated tests are integrated into the system being executed after editing op-

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Begriff: Augenuntersuchung Befund

Label: Augenuntersuchung Befund

Unterbegriffe: Funktionsdiagnostik, Orthoptische Untersuchungen,
Tensio, Ergaenzende Untersuchungen, Refraktive Untersuchung,
Spaltlampenuntersuchung,

!! Beziehungen

kann: Kat.extr UND Glaukomeingriff, Kat.extr und perfor. Keratoplastik

!! Beschreibung

* Ggf. Quantifizierung von Kontrastwahrnehmung und Blendungsempfinden.

* Untersuchung der Augenanhangsgebilde (z. B. chronische Blepharitis,
  Dakryozystitis, Lidfehlstellung).
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Figure 2: The raw text view of the document describing the concept *Augenuntersuchung Befund*.

erations. The following deficiencies are detected: concepts, which are not integrated into the concept hierarchy (orphans); concepts with multiple parent concepts; cycles within the concept hierarchy; concepts with more than 10 sub-concepts (recommending further categorization). The results of these tests can be viewed on a distinct page and are monitored, and in case of need fixed, by the knowledge engineers.

An important aspect to support the maintenance of the semantic network is visualization. As a distinct sub-project to the development of the knowledge acquisition tool special visualization methods are developed. These visualizations will serve the knowledge maintainer as well as the user of the tutoring system to get an overview of the modeled knowledge. However, the visualizations are not within the focus of this paper.

5 Related Work

The customization of knowledge acquisition tools to ease the knowledge authoring task has long tradition. The specification and development of customized tools, based on graphical user interfaces, have been discussed by Musen et. al. [3; 4]. The use of (active) documents for building knowledge bases has been addressed only by few researchers [5; 6]. With the customization of document-centered knowledge acquisition tools however only very little experiences are reported. Even though the use of documents allow for a rather smooth customization process. Further, one major advantage of the document-centered approach is that informal knowledge can be included in a very flexible way. This is, formal knowledge that is defined by the use of markup languages can be intermixed with illustrative contents for documentation or justification. In this aspect, many GUI-based tools show shortcommings. However, the document-centered approach requires to define and to maintain the document structure. The change of this structure during the project can cause considerable refactoring workload.

6 Conclusion

In this paper we discussed the knowledge acquisition concept of the Wissass project. We introduced a customized authoring environment for editing the knowledge base of cataract surgery. The main goal is the design of a tool that allows for simple knowledge maintenance and adaptations at the customer/clinical site. For this purpose we employed the meta-engineering approach for customizing document-centered knowledge acquisition tools.

We reported about early experiences of using the tool in cooperation of an expert ophthalmologist. For a more meaningful evaluation we plan to test the usability of the knowledge authoring tool with independent experts.

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