KNOWLEDGE REPRESENTATIONS OF CONSTRAINTS FOR PATIENT SPECIFIC IOL-DESTINATION

K. P. Scherer
Forschungszentrum Karlsruhe GmbH, Institut für Angewandte Informatik , P.O. Box 3640, 76021 Karlsruhe, Germany

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Abstract: A knowledge based system is a computer program, which simulates the problem solving process of a human, who is an expert in this discipline. In the medical area there exist a lot of expert system components for diagnosis of different diseases. In the ophthalmology, after a cataract surgical incision, the human lens is removed and an artificial intraocular lens (IOL) is implanted. Because of many preconditions (patient situation, operation technologies and IOL specifics) a knowledge based system is developed to support the decision process of the IOL destination under the related (sometimes contradictory) constraints. A computer aided IOL destination and decision support for a patient related individual optimized lens system can help to enhance the life style of the bresbyope human. In comparison to classical software systems the heuristic knowledge from the surgeons (aggregated over many years by research and clinical praxis) can be regarded and user specific communication with the software system and an explanation part is available for the decision making process. Useful representations of the situation are formalised knowledge representation methods.

1 INTRODUCTION

Concerning reconstitute the vision quality for presbyopes human eyes, a novel artificial accommodation system (AAS) will be investigated and developed in the institute of applied computer science in the research centre Karlsruhe. This is essential to guarantee life quality at an advanced age. An optimized configuration and selection of such a lens system can only guaranteed by a computer aided decision support system. To do this, it is necessary to generate and dispose of software structures for storing and processing the information used in a consistent manner (Scherer et al., 2006). Formal representations have to be designed such, that the information is accessed in a natural language. Based on this acquired expert knowledge, new knowledge can be produced and hypotheses and recommendations can be validated or disproved. In this proposal, the software components concern on the selection and destination of parameterized classical intraocular lenses. A transformation to the ASS will be performed when the technical development of the mechatronic system is nearly finished.

2 BIOLOGICAL BACKGROUNDS

From the biological and medical point of view, a mechatronic system is researched and developed for the implantation into the capsule bag of a presbyope

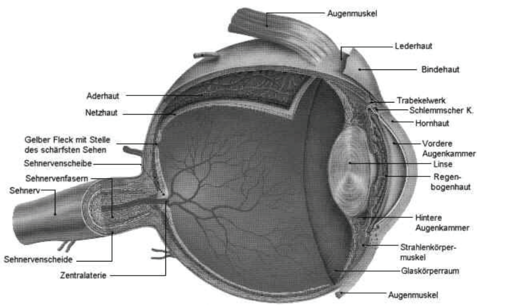

Figure 1: Natural human eye as complex biological tissue.

human being after a cataract disease (Bergemann et al, 2006). Fig. 1 shows a natural eye with a capsule bag and an intraocular lens system before the cataract operation. After extraction of the human lens, the empty capsule bag should be filled with a miniaturised complex self sustaining

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accommodation system, which is nowhere existent at time.

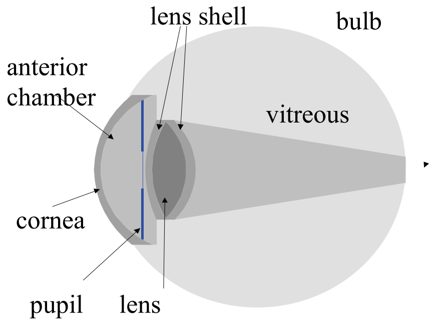

Figure 2: Abstract model of the human eye with the cornea and the lens as refractive components.

Responsible for the refractive behaviour of the human eye are the two components cornea with different anterior and posterior surfaces and furthermore the clear intraocular lens system (see Fig. 2). The combination of these ray fractioning surfaces leads to a more or less sharp image at the retina. By replacing the human intraocular lens and implanting a new technical lens system the characteristic IOL features have to be configured in such a way, that the desired refraction is performed for each situation. This selection and component characterisation must be performed by knowledge based intelligent methods.

3 KNOWLEDGE DOMAINS

To destine a patient specific well parameterized IOL, the following constraints must be regarded. The eye parameter values, resulting from the ophthalmologic measurement methods content systematic measurement errors, which must be corrected in an adequate manner. Furthermore the IOL's designed for implantations have fabrication errors and must be accounted for the IOL parameter calculation.

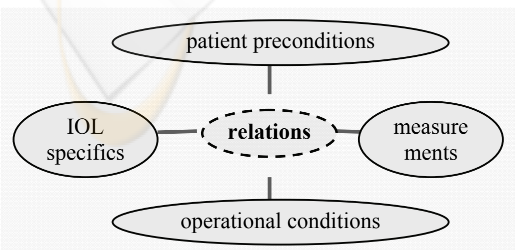

Figure 3: Different domain specific classes with relations.

Also any diseases before the cataract intervention and specific surgeon dependent operational techniques influence probably the results of the IOL destination (Haigis et al, 2006). Additionally the domains (patient preconditions, measurement methods, fabrication related IOL features, operational techniques) correlate among each other, so the dependencies are very complex and they are no longer linear (Fig. 3). A formalized description of the different knowledge domains must be performed (Fig. 4).

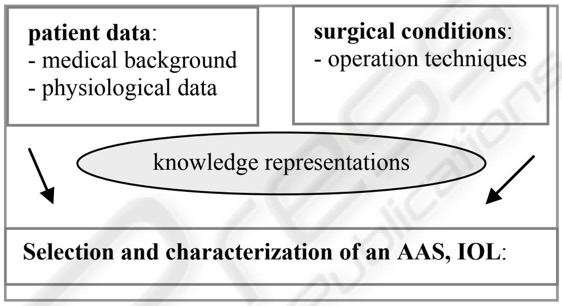

Figure 4: Knowledge based selection and destination of the IOL implant.

4 FRAME REPRESENTATIONS

To describe the basic conditions for logical reasoning a frame based approach is used. (Fig. 5)

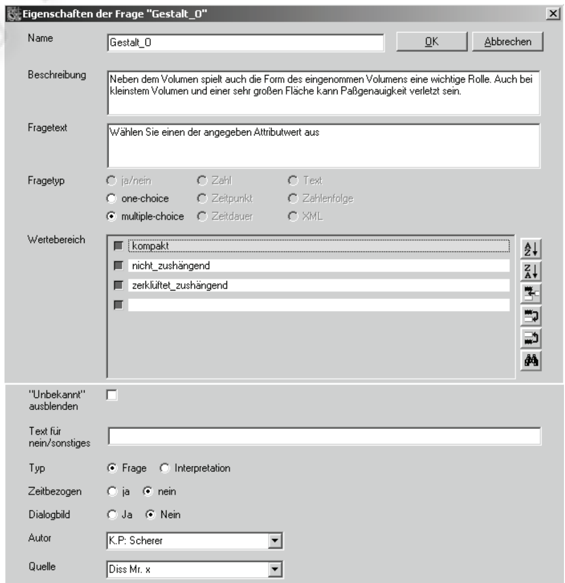

Figure 5: Representation of a special class with attributes.

An extension to a so called concept is given by evaluation of the possible attribute value by type checking and range control (Fig. 5).
The class frame contains the following attributes:

- Name/name: name of the class or of the object
- Beschreibung/description: for more details and specific features of the class
- Fragetext/user question: relevant for the knowledge acquisition concerning filling the knowledge base
- Fragetyp/type: specification of the question to check the validity (real value or multiple-choice or XML-text or other)
- Wertebereich/range: the range of values for checking correct input data
- Autor/author: expert, responsible for the knowledge
- Quelle/source: source of the information

5 RULE BASED APPROACH FOR IOL SELECTION

For the overall correlated information a rule based approach is applied with the known Boolean operators of the predicate calculus of first order. The evaluation of the attributes in the classes *patient precondition, IOL characteristics, operational conditions and the ophthalmic measurements* form the symptom tree, otherwise any information about the selected IOL, the correlated IOL parameters and IOL types compose the diagnostic tree.

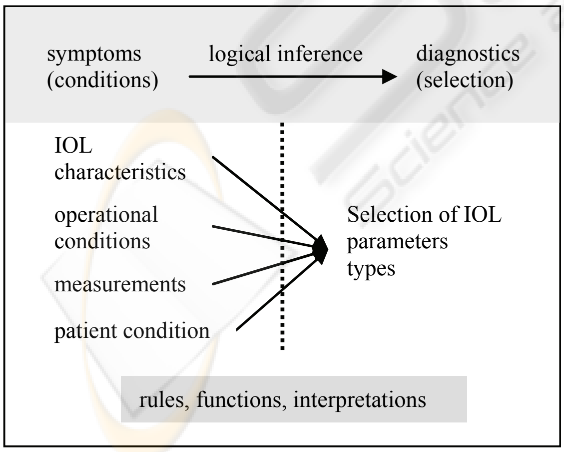

Figure 6: Correlation between symptoms and diagnostics.

6 DOMAIN SPECIFIC KNOWLEDGE REPRESENTATION

The modelling of the natural information about the mentioned semantic topics means the development of structures, which are formulised in class-subclass-element relations. Along the relation "is a" between classes and subclasses and elements an inheritance mechanism is available. For the attribute slots, constraints can be formulated. These frame based approaches form a well defined hierarchical tree structure for the new information system and are a prerequisite for starting logical conclusions (Görz et al, 2007).

6.1 IOL factors

One class-subclass tree concern the different IOL specific factors, which are relevant for the selection of a good implant. Not only the thickness of the lens or design or fabrication related data are responsible for the choose, also the used mathematical formulas (Haigis, Hoffer, SRKII) leads to different IOL parameters, because different preconditions in the formulas are integrated (Fig. 7) (Findl et al, 2007).

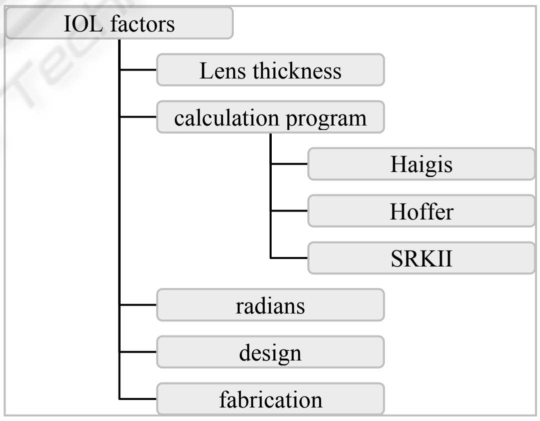

Figure 7: Class hierarchy of IOL factors (excerpt).

6.2 Diagnostics

For the implantation of the AAS or a classical lens system different diagnostic methods are analysed. A representation class is needed. The attributes of these classes have both numerical and also linguistic values. A basic a priori action of the ophthalmic surgeons to destine a good lens system is the ceratometry and the axis length measurement at the patient's eye. The measurement errors concern the different submethods within the two necessary measurements and they must be taken into account for IOL destination (see Fig. 8).

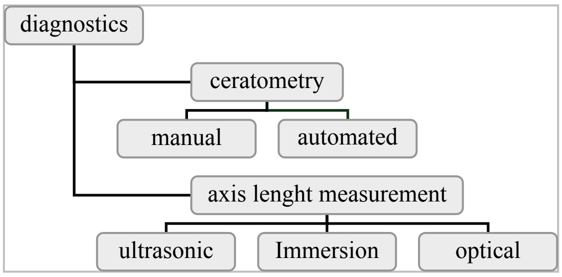

Figure 8: Class hierarchy of diagnostics (excerpt).

6.3 Patient Situation

Also the patient specific situation and the history of personal diseases and former refractive interventions must be regarded for a correct destination of the IOL. Patient specific diseases or an ametropia like myopia or hyperopia and furthermore the age of the patient or the presence of contact lenses affect the possible measurement methods and so directly the IOL destination (see Fig. 9).

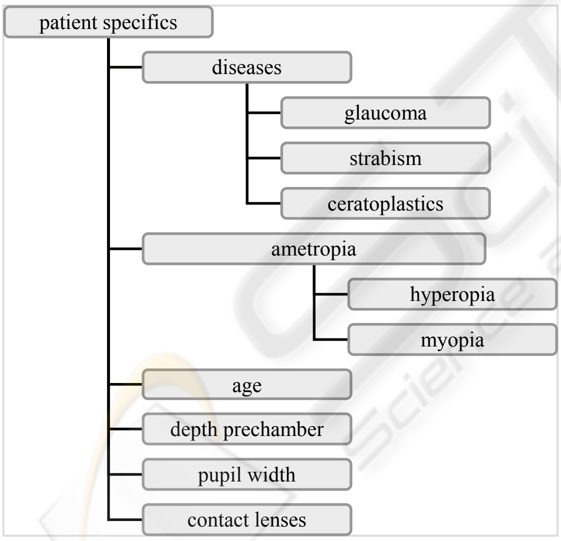

Figure 9: Class hierarchy of patient specifics (excerpt).

6.4 Operational Conditions

Last not least the operational methods themselves like the length of the intracorneal section or the special location of the surgical intervention of the eye gives a contribution to the postoperative behaviour of the selected IOL. Therefore it must be regarded before a selection is performed (Fig. 10).

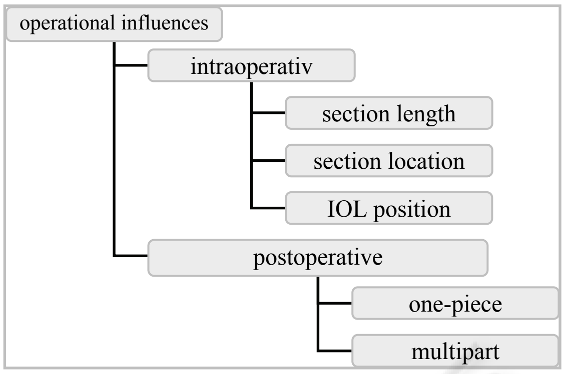

Figure 10: Class hierarchy of operational features.

The knowledge entities are inputted into the class-objects-attribute variables (see also frame based structures). The knowledge acquisition can be enhanced by consistency checking during the acquisition step. Consistence means a validation of values in a predefined numerical range or linguistic values within a predefined term set or the number of allowed values from the whole acquisition set.
This indirect constraint representation prevents formally correct conclusions from being drawn on the basis of data that are not allowed.

7 KNOWLEDGE ACQUISITION

Related to many national ophthalmic conferences in Germany information and statements, published in different literature are acquired in natural language. The natural language based predicates are given to a special medical expert for validation. The question concerning each special medical statement could be answered by the possible values

1) The statement is absolutely correct
2) The statement is absolutely wrong
3) Truth is given by a interval [0, 1] value as a gradually evidence
4) The question is formulated in a wrong way
5) no comment to this knowledge statement.

The catalogue of questions concern the IOL destination for a cataract patient, dependant on IOL specifics, the operational conditions regarding equipment failures and the patient specific situation. The result of the interview and the comments of the expert are following (the answers were given in this first step of knowledge acquisition only by one expert)
- 65 predicates were formalized.
- 20 statements were absolutely correct.
- 7 statements were absolutely wrong.

- There was no gradually acceptance of information.
- 34 statements remain without any comment.
- 4 statements were formulated in a wrong way.

This procedure has to be performed again by other experts and the set of formulas has to be enhanced. But the analysis of the prototypical answers is very interesting and the conclusion is following (here only concerning IOL destination)

1) The knowledge concerning the IOL destination including the different preconditions and situations is distributed on different experts.
2) The knowledge is not available any time for each human specialist.
3) The meaning can be contradictory.

The human expert expressions concerning the IOL destination have to be transformed into rules. Premises of the rules will be to the domain specific class and object, conclusions will be results, attentions and other IOL specifics.

8 EXPLANATION OF REASONING

The warnings, recommendations and results must be comprehensible. The explanation component is responsible for providing the user with explanations as to how the selection process was performed. It is essential to understand the reasoning process and to obtain new ideas for further advanced solution processes. In this way, the confidence into the conclusion and the developed knowledge based system is enhanced.

Due to the probably very complex and wide solution paths (numerous conditions and constraints) the user specific results have to be analysed by backward chaining processes. This requires a comfortable capacity to interact with the system through text and graphics.

9 CONCLUSIONS

The benefit and necessity of knowledge based structures for selection of an optimized parameterized accommodation system (ASS) are outlined. The acquired knowledge (in this proposal for the selection of a classical IOL) must be managed using intelligent processes, because absolute information is lacking in the instantaneous state. Original rules developed may be rewritten later and redefined. The complex knowledge is more circular than linear. In this meaning comfortable formulised structures and refinement mechanisms must be developed as well as comfortable decision making processes including their explanation (configuration and selection).

Hence, the classical algorithmic based system has to be extended to a knowledge based system for selection and optimizing the IOL's with following advantages:

- Natural language based user access
- Object oriented knowledge structuring
- Generation of network with causal relations
- Consistent extension of knowledge base
- Comfortable consistent refinement process

The advantage of a frame based information system could be demonstrated. Formal representations are designed for knowledge acquisition and the static knowledge base, where an inference engine starts with logical methods to select the desired patient specific implant. Furthermore, causal relations and interactive effects between the different preoperational conditions have to be regarded in the configuration and selection process.

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