Creation of Knowledge Base

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***Abstract*—This paper is focused on designing a knowledge base in a field of ophthalmology for the NPS diagnostic expert system. Part of the paper is also to introduce the reader to the properties of knowledge systems, their characteristic features and their applications.**

***Index Terms*—knowledge base, expert system, artificial intelligence, knowledge engineering, ophthalmology, corneal ectatic disorders, keratoconus, keratoglobus, pellucid marginal degeneration**

I. Introduction

Expert systems are part of narrow artificial intelligence. By properly encoding the knowledge and experience of an expert (or experts) into a knowledge base, an expert system is able to make decisions at a highly expert level in a particular field. These systems are used, among others, mainly in medicine, agriculture, business, in the diagnosis of equipment malfunctions or in the field of psychology. They can be helpful not only in practice, but also in the education of students - in this case, for example, future ophthalmologists.

II. Expert Systems

Expert systems differ from other branches of artificial intelligence mainly by placing more emphasis on the quality of knowledge than on algorithms. The advantage of an expert system is transparency in decision-making. In contrast to artificial neural networks, where we do not know on the basis of which parameters the result was evaluated, with expert systems we can see exactly how the given answers influence the outcome of the consultation.

A. Properties

Distinctive features of expert systems include:

- The expert's knowledge is expressed absolutely explicitly, in the form of a knowledge base, which should be designed in such a way that the expert himself is familiar with it and is able to modulate it himself. The knowledge base must therefore have the possibility of a large degree of modularity.
- Dialog mode of obtaining data from the user. The expert system applies its knowledge to a particular case or problem provided by the user's responses.
- Ability to work with a degree of uncertainty. Similar to experts, an expert system must be able to work with uncertain answers (e.g. a description of the patient's subjective problems) and with uncertain knowledge.
- The drawn conclusion of the expert system is not dependent on a single parameter. The system must be able to provide advice even if the input data is incomplete. Thus, there must be multiple alternative ways to evaluate the hypothesis.
- The expert system is able to provide justification and explanation of the conclusions reached. If we want to replace the expert with an expert system, it is necessary for such a system to be able to explain the derivation process to the user in the same way as an expert.

The enumeration of these properties serves only to clarify the key ideas of expert systems and cannot be considered definitive. A particular system does not have to meet all of the points above in order to qualify as an expert system. [1]

B. Diagnostic Expert Systems

During the consultation, diagnostic expert systems are tasked with evaluating which of the previously given hypotheses is involved, based on the input data. They are the most common type of expert systems. They determine which hypothesis from a predefined number of target hypotheses best corresponds to the data related to a particular case. Thus, diagnostic expert systems work with a finite number of goals (hypotheses, diagnoses), from which they select the most suitable ones. [2]

The figure below shows a block diagram of the diagnostic expert system.

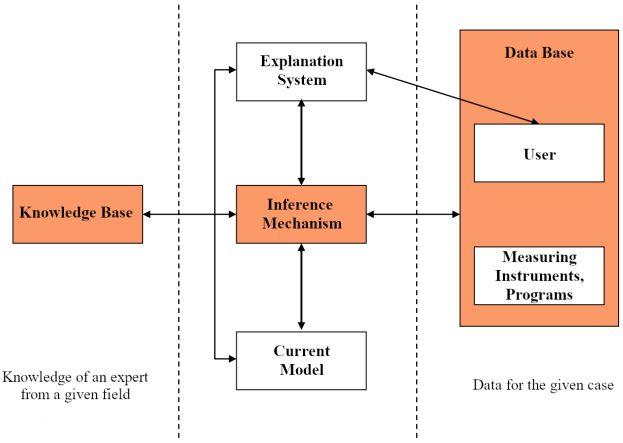

Fig. 1. A block diagram of a diagnostic expert system, *modified*. [2]

We can see that the system consists of three main parts which are highlighted orange.

- The knowledge base contains explicit, appropriately coded knowledge of the expert on the given issue, which is necessary for the proper functioning of the expert system.
- The data base represents data that we can obtain either from the user in the form of answers to asked questions or data read directly from measuring devices or programs. The data base affects the current diagnosis model.
- The inference mechanism is the core of the expert system. Based on the individual answers received from the data base, it refines the current model using the knowledge base.

When creating expert systems, efforts are made to make the program as modular as possible for future expansion and modifications. [3]

C. NPS Expert System

It is an expert system that was used for this application. The system is based on the original NPS32 computer application. NPS is a diagnostic expert system whose principle is based on rules. It is therefore a rule-based expert system. Today's form of the NPS web interface was developed by Ing. Lukáš Kořínek. It is based on the original NPS32 computer application and program implementation of the NPSCore computing core, which was originally developed without an user interface.

A slight disadvantage is the absence of an explanation system and the fact that user responses are the only possible source of the data base. However, the most fundamental advantage is the universality of the system, which is caused by a clearly defined syntax for knowledge base. [4]

III. Knowledge Base

The knowledge base is separate from the expert system. Until we provide a knowledge base to the expert system, it is an empty expert system. These systems are of much less value than if they contained a functional knowledge base.

First, it is necessary to be aware of the differences between the terms data, information and knowledge. Data is just filtered noise. We obtain information from data by selection, certain processing and assigning meaning. Knowledge is information that is thoroughly analyzed and organized in such a way that it can be used to solve a particular problem or to make a decision. We acquire knowledge through learning, experience, and interactions with the environment. There is also metaknowledge, which is knowledge about knowledge. [2], [4]

A. Knowledge Engineering

Expert systems have one major drawback, and that is the fact that an expert is needed to make such a system work properly. It is generally known that these gifted people, who devote a large portion of their lives to improving and gaining experience and knowledge in a certain field, are in high demand and do not exactly have an excess of free time. For this reason, it is often very difficult to design a functional and complete knowledge base. The field of knowledge engineering deals with the issue of obtaining knowledge from experts.

Knowledge engineering deals with filling expert systems with the most essential part, i.e. knowledge. In this field, there is therefore the greatest interest in techniques and methods of acquiring, formalizing, coding and testing knowledge. [1]

Great emphasis must be placed on the creation of the knowledge base, because the quality of the entire expert system depends on the quality of the knowledge. Therefore, both a knowledge engineer and an expert participate in this creation. The activity of a knowledge engineer can be summarized in several points listed below. [1]

- Identification of the problem - The knowledge engineer must first become acquainted with the issue and precisely formulate the problem.
- Design of the concept - After a deeper acquaintance of the knowledge engineer with the issue, the basic concepts and character of the data, with the active assistance of an expert from the area, the knowledge engineer can propose the conceptual model of the organization of relevant knowledge.
- Knowledge formalization - In this step, the knowledge engineer analyzes the conceptual model in terms of methods, techniques and tools. They choose to represent knowledge and formalize them appropriately.
- Implementation - The result of this phase of the knowledge engineer is a functioning prototype of the knowledge base.
- Testing and tuning - this step is the most time consuming, as it is constantly repeated in the cycle of testing, consulting results with experts and subsequent adjustment of the knowledge base.

The design of the knowledge base is not a linear process, on the contrary, we repeatedly return to the previous steps to iteratively approach the best solution. Each of these steps requires repeated meetings of a knowledge engineer with an expert, thus increasing the time demands. [1]

IV. Ophthalmology

The knowledge base in this paper is focused on the diagnosis of ectatic cornea diseases, which falls within the field of ophthalmology. Ophthalmology is a medical field dealing with the diagnosis and treatment of eye disorders and diseases. [6]

A. Corneal Ectasia

Corneal ectasia is produced by its thinning. More precisely, the stroma of cornea, which has the task of supplying the cornea sufficiently with water, is thinning. The stroma forms one of the corneal layers, consisting of fine collagen fibers and bounded by Bowman's membrane and Descemet's membrane. Patients suffering from ectatic corneal diseases are not recommended to undergo laser refractive procedures, due to the poorly predictable effect and the risk that the procedure will cause progressive deterioration of ectasia. [7], [5], [6]

There are various types of corneal ectasia, such as keratoconus, keratoglobus and pellucid marginal degeneration.

B. Keratoconus

It is a clinical name of the state of the cornea, characterized by its gradual thinning and, as a result, its arching so that it gradually acquires conical shape. Progressive thinning and arching takes place most often in the paracentral part, less often in the central part of the cornea. [5]

It is one of the degenerative non-inflammatory cornea diseases with slow progression, which is manifested by increased corneal irregularity and deterioration of its optical properties, which often leads to a serious reduction in patient's visual acuity. It almost always occurs in each eye in different development stages. Keratoconus is classified by Amsler or Krumeich to four stages according to severity. The disease is most common in the second and third decade of life, when the greatest progression can also be observed. As aging progresses, the disease is generally stabilized, and after the age of forty years old, only deteriorates rarely. [5]

The low-degree keratoconus can be corrected by glasses or using soft or hard contact lenses. At the moment when there is further progression of arching, the patient should consider the possibility of available surgical procedures such as Corneal Cross Linking or corneal transplantation. [5]

C. Keratoglobus

It is a very rare, non-inflammatory, bilateral ectatic disease, which often occurs immediately after birth. Keratoglobus is usually not progressive or progresses only minimally. The disease is characterized by thinning and diffuse corneal protrusion, which leads to its typical arching of spherical shape. The treatment is developed for optimal correction using glasses or hard contact lenses. The uniform surgical procedure is not given due to the high risk of postoperative complications. [5]

D. Pellucid Marginal Degeneration

Pellucid marginal degeneration is a bilateral peripheral non-inflammatory ectasia of the cornea, which is characterized by the arch of its peripheral part, most often in lower quadrants. Compared to keratoconus, pellucid marginal degeneration begins at a later age, sometimes between the 20th and 50th years of life and progresses at a slower pace. It is manifested by irregular and non-correctional astigmatism. Treatment of this disease is complex, various types of special lenses or peripheral lamellar keratoplasty, or wedge keratectomy are considered. [5]

V. Knowledge Base Design

The knowledge base contains six main hypotheses and one additional hypothesis:

- Main Hypotheses
  - Keratoconus (first stage)
  - Keratoconus (second stage)
  - Keratoconus (third stage)
  - Keratoconus (fourth stage)
  - Keratoglobus
  - Pellucid Marginal Degeneration
- Additional Hypothesis
  - Normal cornea with astigmatism

The knowledge base consists of fourteen questions, four of which are conditional:

- Does the patient experience deterioration of vision?
  - Yes, significantly in one eye
  - Yes, significantly in both eyes
  - Yes, in one eye
  - Yes, in both eyes
  - No
  - Unknown
- What is the period of occurrence of problems?
  - 0 - 10 years
  - 10 - 20 years
  - 20 - 30 years
  - 30 - 40 years
  - Over 50 years and more
  - Unknown
- What is the refractive state of the eye?
  - Hypermetropia
  - Myopia
  - Unknown
- Occurrence of astigmatism?
  - Occurrence of higher astigmatism (greater than 2 D)
  - Occurrence of lower astigmatism (less than 2 D)
  - Irregular astigmatism
  - Unknown
- What does a topographic map look like?
  - Claws (moon)
  - Oval in the central part
  - Oval in the lower paracentral part
  - Circle
  - Hourglass (figure of eight)
  - Arching in full width
  - Unknown
- What is the thickness of the central part of the cornea?
  - Less than 200 µm
  - $200 - 300$ µm
  - $300 - 450$ µm
  - $450 - 530$ µm
  - More than 530 µm
  - Unknown
- Thinning of the corneal periphery?
  - Yes
  - Unknown
  - No
- Does the top of the cornea match the thinnest part of the cornea?
  - Yes
  - Unknown

  - No
- What is the radius of curvature of the anterior surface of the cornea?
  - Less than 5.8 mm
  - 5.8 - 6.5 mm
  - 6.5 - 7.2 mm
  - 7.2 - 7.5 mm
  - More than 7.5 mm
  - Unknown
- What is the optical cardinality of the cornea?
  - Approximately 43 D
  - 45 - 49 D
  - 49 - 53 D
  - 53 - 55 D
  - 55 - 60 D
  - More than 60 D
  - Unknown
- Is there a Fleischer ring on the cornea?
  - Yes
  - Unknown
  - No
- Are there Vogt striae on the cornea?
  - Yes
  - Unknown
  - No
- Is there hydrops on the cornea?
  - Yes
  - Unknown
  - No
- Is there progression of corneal bulging?
  - Yes
  - Unknown
  - No

After answering these questions, the user should find out what kind of ectatic corneal disease it most likely is - the knowledge base is therefore successfully able to diagnose ectatic corneal diseases. However, it is possible this is not the final version of the knowledge base.

Due to the certain expertise of the questions and the overall focus of knowledge, the knowledge base is primarily intended for ophthalmologists who want to verify their decisions or for students familiar with this issue for the purpose of education.

It is also important to note that the functionality of the knowledge base was proven during testing with real data in cooperation with Mgr. Hana Řeháková. During this testing, questions were answered according to the subjects' actual measured parameters of the cornea.

VI. Conclusion

This paper describes the properties of expert systems. It discusses the diagnostic expert system and its internal structure in more detail. It also deals with an important part of the expert system, which is the knowledge base. It also describes the process of extracting knowledge from experts called knowledge engineering.

Other parts of the paper are focused on the topic for which I chose to implement the knowledge base and also deal with the design of the knowledge base itself. It describes the types of corneal ectasia, their characteristic features and mentions possible methods of treatment. It also contains hypotheses and questions together with answers that are used in the designed knowledge base.

The result of this paper is a functional knowledge base called *Rohovka*, which serves to determine the diagnosis of ectatic corneal diseases. This may not be the final version of the knowledge base, because at the time of writing this paper, the knowledge base is still being worked on. There also may be possible modifications of some questions and relationships between nodes based on the reevaluation of the concept of the knowledge base. The knowledge base require further tuning and testing to make the final knowledge base as factually accurate and useful as possible.

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