WEB BASED INFORMATION SYSTEM USED FOR EARLY DETECTION OF GLAUCOMA DISEASE

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ABSTRACT

According to the WHO global data on visual impairment [4], glaucoma is the second leading cause of blindness. Glaucoma diagnosis is based on a set of various parameters and investigation results, usually repeatedly and during a time period. This data is acquired by various eye examinations, sometimes by different eye specialists. The first aim of this project was to create an anonymous patient account with the possibility to store and share all essential medical data relating to this disease and be able to return back to the concrete patient. Based on the three-dimensional image from the Heidelberg Retinal Tomograph and implementation of the fundus photographic data fusion, visualization of the optic nerve head surface is then provided.

1. MEDICAL BACKGROUND

For glaucoma, it is the characteristic atrophy of eye nerve fibers, which results in optic nerve head (ONH) changes and blindness. ONH is known as the blind spot, papilla or optic disk. This is the place, where the eye nerve fibers come together and continue to the brain. Internal margin of Elsching's ring defines the border of the ONH, which is not always obvious. In addition, to the ONH structures are the neuroretinal rim and the cup determining excavation; see below (Figure 1).

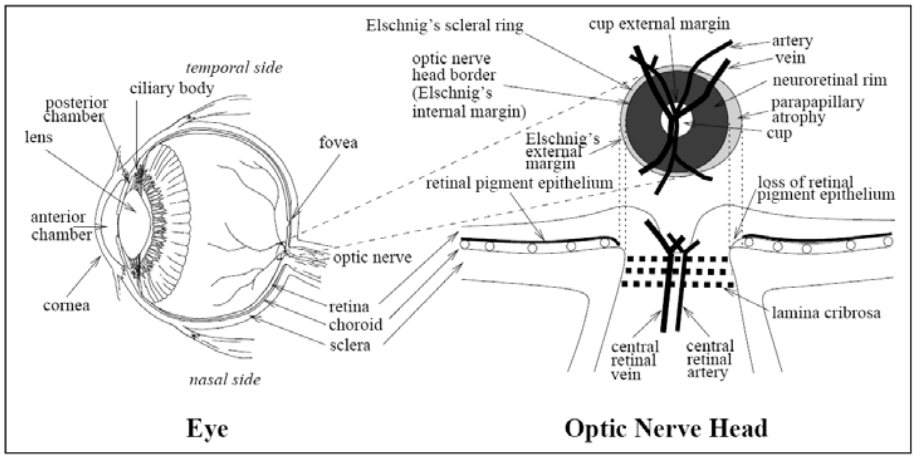

Figure 1: Schematic anatomy of the eye and the optic nerve head [1]

2. THE SYSTEM STRUCTURE

Web application is commonly structured as a three-tiered application: client-server-database. The client is usually software installed on a user computer, which presents data sending from server as a respond. There are implemented Java runtime environment (JRE), JavaScript, HTML and CSS on the client side. The server is a middle tier which services the client's request by making queries and updates against the third tier – database. As a web server is used the Apache HTTP server developed by an open community Apache Software Foundation. To provide dynamic web content to the client, the server-side scripting language PHP is used. The database management is guaranteed by MySQL. HTTP is a stateless communication protocol used for data transfer over the Internet using request/response HTTP messages. The HTTPS URI scheme is used to establish secure HTTP connection. It signals to the browser to use an added encryption layer of SSL/TLS to protect the traffic over Internet.

2.1. THE DATABASE MODEL

The Entity-Relation Diagram is bellow on the Figure 2. There is an M:N relation between user and patient, because it has to be presumed, that one user (ophthalmologist) can take care of more patients and one patient can be cared for by more users. This relation is then also used to determine user's right to edit and delete concrete patient's data. The results from medical examination are stored in three main entities - entity Anamnesis, Medical_check (results from classical eye examination methods) an entity Registration_data (information about image data needed for image fusion and visualization).

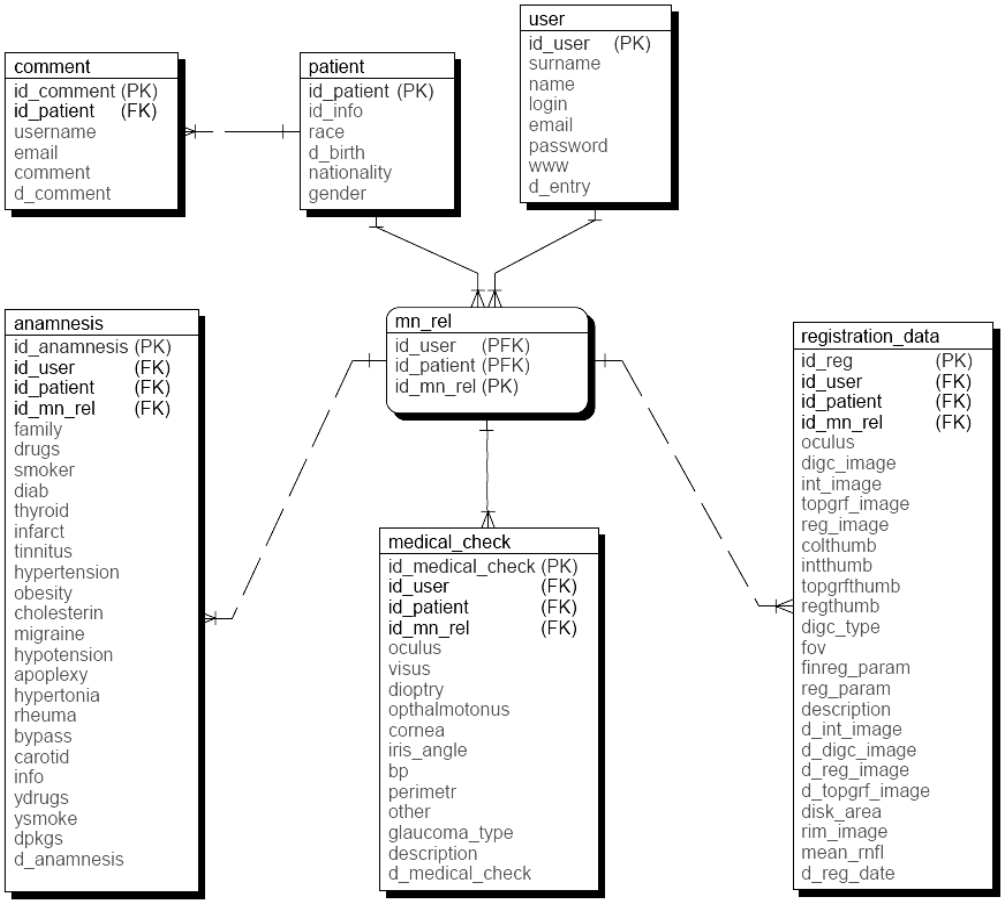

Figure 2: ERD created using Toad Data modeller.

2.2. THE CLIENT-SERVER COMMUNICATION

There are three types of clients: Thin-, Fat- and Hybrid-client. The Thin-client relies on most of the function of the system being in the server. The point of this client is to present data without distributing and installing software on the user computer. The thin client is used for the most data processes in this system, e.g. to insert new, select, update and delete.

In case of the process of creating new or finding concrete patient account, his/her personal data like a name, surname and national identification number are needed. This data may not be sent through Internet and stored without patient agreement because of the Act No. 101/2000 Coll. on the Protection of Personal Data. Thus the only possibility is to encode the data already on the client side (e.g. using a one way SHA1 hash algorithm). Fat-client is the opposite of the thin-client. Most of the application logic is implemented inside and it usually doesn't need a server. Hybrid-client is a combination of both types and thus the best solution in this case. To implement such a client the programming language Java is used. It enables to create a communication applet, which requires JRE (Java Runtime Environment) installed on the client machine. The communication is based on the XML message exchanging, which provides the possibility to create own structure of the messages.

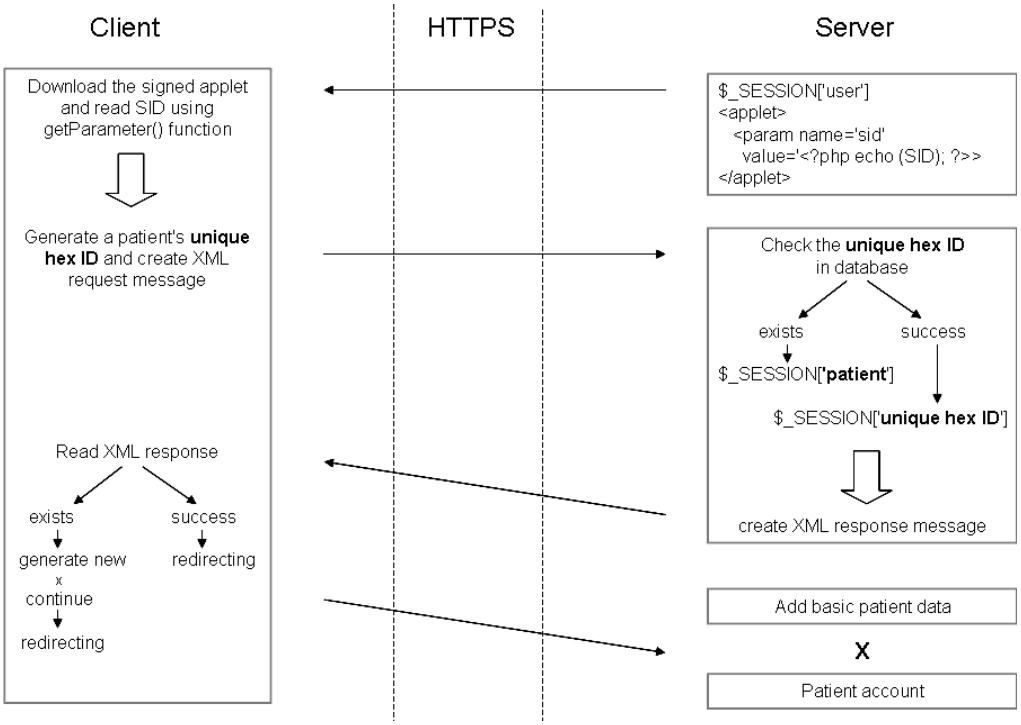

Figure 3: The communication model used to create new patient account

2.3. THE IMAGE PROCESSING PART

Into the image processing part belongs the implementation of 2D image registration, three-dimensional surface visualization, file uploading and downloading, format conversion, thumbnails creating and storing all necessary information to the database.

2.3.1. THE 2D IMAGE REGISTRATION

The image registration is defined as a searching for the best geometric transform, which describes the relationship between the reference image and the floated image. The used affine transform T is supposed to depend on a vector parameter α, encompassing shift, rotation, scale and skew. The parameter is found by optimization, equation 1:

$$\alpha_0 = \arg\{\min_{\alpha} C(R, T_\alpha(F))\} \quad (1)$$

R is the reference image and F is the floating image to be registered, which is transformed by $T_{(\alpha)}$ to coordinates of the reference image. The registration quality, corresponding to the transform T, is evaluated by the criterion function C. T_{α_0} is then the optimal registering transform with respect to the criterion. [3] Image registration is necessary, when the data has been obtained from different measurements, in this case the HRT and the digital fundus camera. To register the fundus image and the HRT intensity image algorithm is used, which was created in the Department of Biomedical Engineering, Brno University of Technology by Ing. Libor Kubečka, Ph.D. The registration process is executed using PHP and the server command line and is available only if the fundus and the intensity images have been already uploaded. Registration parameters are stored in text files, archived and stored in the database.

2.3.2. THE 3D VIZUALIZATION OF THE ONH

Visualization is available only when the registered and the topographic (Figure 4, left) images are stored in the database. An open source of Interactive 3D surface plot plug-in (Prof. Dr.-Ing. Kai Uwe Barthel) and ImageJ are used in the case of visualization. The plug-in has been modified to the java applet and the ONH surface can be displayed with the possibility to change the scale, light and smooth level. The rotation is possible in all three dimensions. All other parameters of visualization are set by default. As the surface texture of the ONH the registered fundus image is used, which provides original colors and for the more exact diagnosis useful information. The result is bellow on Figure 4, right.

Figure 4: The HRT topographic image (left) and the 3D surface of the ONH with the original texture (right)

3. CONCLUSION

This web-based information system provides support for medical experts in the field of glaucoma diagnosis. The system is freely open to registered users, with the reading access to already stored data and the possibility to include further data provided by the user. The database may contain, besides the images (in full size and quality), also many other data, e.g. anamnesis, measured parameters and results of other examinations, incl. comments of the medical expert. The system provides algorithms for advanced image processing like 2D multimodal image registration and the ONH surface visualization. The beta version is available online at http://ophthalmo.feec.vutbr.cz.

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