An Integrated System to Support Low Vision Consultation

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ABSTRACT

In the last years we have seen a significant growth in the number of multidisciplinary projects between computer science and medicine. The computer science development and the continuous growth of confidence in its products are some relevant factors to rise in this cooperation. This project was born three years ago, from an association between Instituto Superior Técnico and Hospital de Santa Maria, and produced several computational modules to support low vision consultations.

Technically, the system is based on Artificial Intelligence, Virtual Reality and Distributed Systems techniques, and it results from the integration of several modules, namely: database, knowledge acquisition module, consultation module and rehabilitation exercises. The database stores the patient data (personal data, results from the ophthalmologic examinations, expectations and effective capacities) and the consultation module manages that data and supports the access of several simultaneous users through an Internet browser. To assure information confidentiality we use a security policy, based on data encryption techniques and rigid access controls. Knowledge acquisition module searches for behaviour patterns within the patients' files, stored in the database. With these patterns we hope to find rules to establish a customized rehabilitation plan for each patient and optimise the evaluation tests. Finally, the rehabilitation module provides exercises to train the visual perception, through the creation of Virtual Reality scenes.

With conclusion of these modules, we have finished the construction of the basic elements of an expert system that will help low vision professionals in their work.

PROBLEM DESCRIPTION

Low Vision is a new therapeutic domain where there is a real needs to assess and compare visual rehabilitation methods. It is necessary to record all relevant information to assess the patient's clinical situation, before and after the rehabilitation. This information is essentially composed by personal data (identification and clinical history) and results of ophthalmologic examinations. Beside these traditional exams, each patient's answers to questionnaires, which are created based on his profile. These questionnaires measure the patient's performance in his daily activities. Patient's data is obviously confidential, and can't be accessed by any person other than his doctor. However some hospital staff may introduce identification data and exam results.

Beside the data registration and the existence of a rehabilitation exercises set, there is a real need to analyse relations between the stored records. If this is important to the traditional medical areas, in a domain such low vision, where the maturity isn't strong, this importance is more visible. Identifying behaviour patterns between records will make possible rule discovering, which allow a better patient's assistance at assessment and rehabilitation level.

PROJECT GOALS

A system to support the low vision consultation would allow:

1) to record and access to patient's data;
2) to support a set of rehabilitation exercises;
3) to discover the relations between records.

The integration of these three complementary goals, the system should be capable to support all steps of low vision consultation: the first two concerns to the assessment and rehabilitation step respectively, and the last one with the mapping between the assessment results and the rehabilitation plans design.

SYSTEM DESCRIPTION

In order to achieve the defined goals, at technological level, the system is characterized by the following aspects: data centralization in a single machine, to grant the stored data uniqueness and coherence; data accessibility through a set of machines to grant a generalized and simultaneous application use by several users; the secure data transmissions; the user interfaces adequacy, to facilitate the application learning / usage; the integration of all components to support the entire low vision consultation.

Four main modules compose the system: database, consultation module, rehabilitation module and knowledge acquisition module.

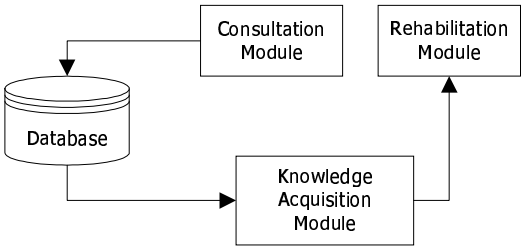

Figure 1 – System's Architecture

Database

The database is a fundamental component in every application with a considerable storage capacity. It is a mechanism, which allows the data access and manipulation, and it's responsible to keep data coherence and integrity, facing multiple and simultaneous accesses. The database is the physical support to the patient's da ta, gathered during assessment and rehabilitation step. Essentially the information stored (following close the proposed by [31]) consists of three main aspects: patients' personal data, ophthalmologic exams results; and answers to the questionnaires – functional evaluation.

Another essential aspect is the user registration (namely doctors and hospital staff). Only having this aspect in mind, it's possible to control the information access, by establishing an access and authorization control policy. Using this technology, part of the first goal is already achieved: it needed to define the way of access to the stored information.

Consultation Module

The consultation module is responsible for the implementation of the access control policy. In a precise way, a client consists on a simple application, working on a browser and presenting a friendly interface, based on forms and menus. In our system it consists in the patient data presentation, and allows its visualization and manipulation.

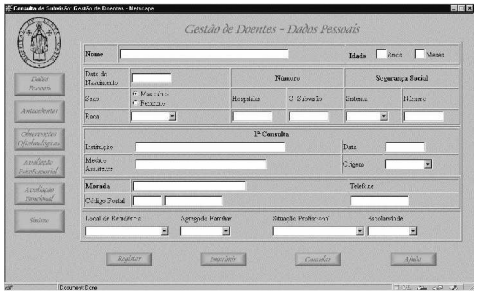

Figure 2 - Consultation Module

A very important aspect of this module is the possibility to two users to access simultaneously the stored information, through two different client instances. Another important aspect is the security of the communication between the database (server) and users machines (clients), granting that the information is only accessible to registered users. To achieve this goal a security policy was implemented, to verify the users authorization and authentication.

The access to the consultation module is done by several hospital employees, who have different permissions to access information. Because of this, we created three access levels: **doctors' access**, **technicians' access** to personal data introduction, and **guests' access** (who may help in the patients' assistance). Then, when a new user is registered, the system assign to him a certain access level accordingly his hospital function. To systematize what has been said, we present the access rights matrix used:

		AGENTS		
		Doctors	**Technicians**	**Guests**
OBJECTS	**Identification**	Read/Write	Read/Write	Read
	Clinical History	Read/Write	X	X
	Ophthalmologic Examinations	Read/Write	X	X
	Functional Assessment	Read/Write	Read/Write	X
	Summary	Read/Write	Read/Write	Read
	Users	Read/Write	X	X

Table 1 – The access rights matrix

As is said in [21]

"To implement a control access policy it's necessary the existence of two basic operations:
***Authentication** – validation operation of the agent identification (...).*
***Authorization** – operation that validates the agent rights over an object, before the operation execution."*

While client authentication is done through the user password verification, authorization is realized by the server, based on the access level assigned to any registered user. At last the transmission security is granted by the encryption of the messages exchanged between clients and server.

Rehabilitation Module

The rehabilitation module's goal is to support a set of exercises with the function to stimulate and to train the residual patient's vision. The selection of these exercises was oriented by the need to train the eye-movements (saccadic and persecution) and the eye-hand co-ordination. With these exercises one expects to recover some of the lost independence caused by the illness state aggravation, such as the autonomy level, the self-esteem and the easiness of cognitive, physical and social development. In order to reach those goals, we use some techniques of Virtual Reality, in the hope of to bride patients to use the application. Thus, the exercises are presented under the form of games, having one reward whenever patient is successful.

The patient's goal is therefore to resolve a group of proposed tasks with the purpose of training the movement of his eyes. On this manner, it was decided to create a **metaphor** related with children's tales, what it led to the creation of a castle, inside of which we find some **fancy scenes**, accessible through the doors and windows of an interior **corridor**. Inside of each scene we find each of the training exercises, presenting them in an integrated form. We can differentiate the scenes in

function of the type of co-ordination or eye-movements that is trained.

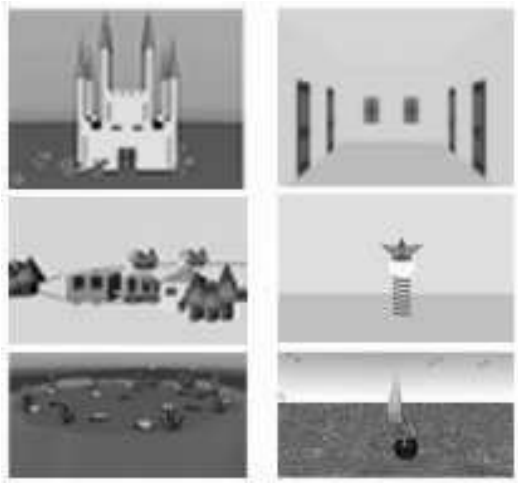

Figure 3 - Rehabilitation Module

According with the experts and practice in the special education sessions, we decided to use simple forms and neutral tones for each scene secondary aspects. Another factor in account had been the psychological state of the child, who is normally enough discouraged and little receptive. This module is characterised by three mainly aspects: the immediate feedback supply to the patient's actions; there is no training interference with any other domain that not it vision and sensory-visual co-ordination; and finally the fact of being attractive and less tedious than the traditional methods. A detailed description of this module can be found in [2].

Knowledge Acquisition Module

At last, the Knowledge Acquisition Module. This module appeals to a set of Artificial Intelligence techniques, in particular of the machine learning field, in the perspective to fulfil the third goal presented - to discover relations between the stored data. To fulfil such goal it is necessary to access the data recorded in the database and to establish relations between the diverse stored patient features. Or either, it must identify behaviour patterns in the patients' records, in this way, becoming explicit the existing implicit relations between the data. These patterns must be represented under the form of rules, such as "All patients with glaucoma may have a significant loss of peripheral vision". In this way, we expect to discover the rules still unknown by the scientific community, and to validate the already known. Another interesting aspect would be to establish the relations between the patient situation and the rehabilitation plan adjusted to his specific case.

We can summarize the stored information in three categories: diagnosis attributes, physiologic attributes and functional attributes. By diagnosis attributes we mean the personal data and clinical history; by physiologic attributes we mean the ophthalmologic exams, and at last, by functional attributes the information relative to the effective patient's performance, gathered through the questionnaires. With this categorization we may classify the discovered relations in different classes, namely relations between attributes that belong to the same category and relations that don't. This way each relation class have a distinct use, and have a different contribution to the system's improvement. For example, Diagnosis ↔ Diagnosis relations may help in the patient's profile realization, and Functional ↔ Functional relations may turn possible the questionnaires optimisation.

CONCLUSIONS AND FUTURE WORK

This project began 3 years ago, with the creation of the first database and an application to manage it [31]; in the following year, the focus had been centred in the improvement of the processes that compose the evaluation of the patient's situation, as well as in the creation of the first set of rehabilitation exercises[29]. At the beginning of 2000, the system was fully integrated, to allow a distributed access to doctors and hospital staff to the system, allowing it to support all consultation steps. We expect to obtain some significant results at the rules discovery level still this year.

As to the future, there is still work to be done in the personalization of the exercises to each individual patient, and to introduce feedback capabilities to adapt rehabilitation plans to the evolution of the patient.

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