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An Intelligent, Interactive, Web-Based Platform for Effective Clinical Education through VR and Distance Learning Modules

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Abstract: The proposed system is an intelligent, interactive, web-based platform that enables real time communication among medical personnel and provides effective clinical education through VR and distance learning modules. It aims at the optimization of the diagnosis; especially in difficult cases or in cases that inexperienced doctors are involved, providing a computer based diagnostic system that will support doctors in decision-making. Furthermore, it enables doctors to monitor their patients during rehabilitation in high-risk cases in order to avoid permanent damage. It also aims at providing health professionals timely interaction with heterogeneous, distributed, medical and other health related databases in order to optimize their performance and facilitate their work. Furthermore, through this system, advanced navigation tools are provided to health professionals for timely retrieval of vital information including health info-structure tools such as user-friendly systems and interfaces as well as mobile systems for ubiquitous, timely and secûre access to medical data at the point of care. This platform makes possible medical knowledge and evidence management. Finally, it provides sophisticated mechanisms for data mining as well as acquirement and retrieval of medical data.

Key Words: Intelligent Web-Based Platform, Distance Learning Modules, Computer Based Diagnostic System, Decision-Making, Health Info-Structure Tools

Introduction

One of the most difficult things in teaching medicine students is that the required knowledge is skill-based and the only way to acquire it is by practice and experience. On the other hand erroneous diagnosis can cause death or treatment's failure. When graduates begin to take responsibility in the clinical setting, they face the reality of practice: the fact that despite their best endeavours, some patients complain about unsatisfactory treatment, some fail to respond to treatment and some die. Serious mistakes commonly happen in the early years of practice, most frequently as a result of ignorance and inexperience. From researches has been proven that 95% of newly qualified doctors made at least one serious mistake within four years of graduation. Young doctors tend to assume responsibility for treatment failures and are very distressed by mistakes. Simulation and role-playing in skill-training centres would allow medical students to experience 'safe failures' with no risk of damage to anyone's health, thing that is unlikely to occur in real practice. If junior doctors are to learn from their inevitable mistakes, they need to make mistakes without any risk for real patients.

We propose an intelligent, interactive, web-based platform that enables real time communication among medical personnel and provides effective clinical education through VR (Virtual Reality) and distance learning modules. It aims at the optimisation of the diagnosis; especially in difficult cases or in cases that inexperienced doctors are involved, providing a computer based diagnostic system that will support doctors in decision-making. Furthermore, it enables doctors to monitor their patients during rehabilitation in high-risk cases in order to avoid further or even permanent damage. Furthermore, it aims at providing health professionals timely interaction with heterogeneous, distributed, medical and other health related databases in order to optimise their performance and facilitate their work. In addition to this, through the advanced navigation tools (Twindale and Nichols, 1996) that are provided to health professionals for timely retrieval of vital information including health info-structure tools such as user-friendly systems and interfaces as well as mobile systems for ubiquitous, timely and secure access to medical data at the point of care. This platform makes possible medical knowledge and evidence management. Finally, it provides sophisticated mechanisms for data mining as well as acquisition and retrieval of medical data.

Focusing mainly on its functional features the proposed system has three main axes that are:

Education: it aims at providing a reliable life-long educative platform based on exhisting primitives. Thus, it provides an integrated system for the continuous clinical education of medicine students and inexperienced/not specialized doctors. The system provides educative material composed of test cases, guidance step by step in diagnostic methodologies based on real situations and individualized educative methodologies for each one actor involved. (Weed, 1991) Furthermore, the system makes monitoring of experience and guiding education possible, both by the intelligent system itself and also through specialized doctors/ professors. This is accomplished by the tracking mechanism included in this system, which is responsible for recording contacts with patients, diagnostic data and results. These data are automatically analyzed to provide a measure of each students developing clinical experience and reviewed so a repetition of relevant units is effectuated in order possible theoretical lack of knowledge in specified arguments to be covered.

Computer Based Supportive Diagnosis: Beside the above it provides an intelligent adaptive mechanism that operates as a support to doctors during diagnosis providing tips and possible diagnosis based on pre-recorded cases and through rule-based decision making mechanisms. It consists a great assistance without restricting the doctor's personal initiative. Furthermore, in compliance with the doctors specialization gives guidelines for the redirection of patients to other medical disciplines if considered necessary and proposes medical exams to be done to have a complete medical view.

Framework: As it is widely accepted medical diagnosis is a problem of great complexity that requires great effort and needs a balanced combination of knowledge, experience and methodology in order to be successful. The fact is that an accurate diagnosis involves a very large amount of knowledge on the different symptoms of each disease, the correspondent treatment and the cross lines. All these should not only be properly associated but at the same time should be combined with the gained experience of the doctor and his medical "instinct". Thus, turning medical experience in a methodology or an algorithm to be taught to young medicine students it is extremely difficult.

Our goal is the provision of a simple to use system that will enable medicine students to gain the needed experience without the risks of real life cases. Through this system they are provided with a simulated ambulatory and are asked to treat patients that even though they are VR simulations their clinical data are real, taken from the patients medical records. The system can guide the students during the process or let the teacher provide tips and guidelines by his direct intervention in the simulated immersive world of the student. Furthermore, the system acts as a supportive diagnostic tool that unexperienced doctors can use as a reference or as an assistant during the diagnostic process in order to minimize the risks of wrong diagnosis.

For this purpose it is designed an intelligent system for health professionals that will help to create a "Health knowledge info-structure". Research on knowledge technologies for access and delivery of personalised health promotion material based on the current health status has taken place, in order to achieve this purpose. The problems that are addressed here include interoperability of databases containing individual's health information, semantic based knowledge representation, knowledge capturing and retrieval. Knowledge management technologies and navigation tools (Twindale and Nichols, 1996) are applied in an innovative way in order to succeed the ultimate goal that is a multimodal system for teaching clinical skills.

From a technical point of view, the aim of this project is to foster the creation of a next generation interoperable application system that meets user demands for flexible access, for everybody, from anywhere, at any time. Working toward this goal the proposed system provides multimodal access from different devices and automatic selection of the format that will be used for transmitting the needed data, according to the device's properties.

The System's Architecture: The mainstream of tertiary education especially in the field of medicine the last decades is to follow an evidence based medicine and clinical education. The difficulty on following any of the until now proposed methodologies consists in the fact that evidence based education along with Problem Based Learning (PBL) in order to be efficient should be life long learning process (Tatman *et al.*, 1987). Of course this is difficultly accomplished by traditional learning processes that are time and place limited. The System aims at providing a reliable life-long educative platform based on PBL primitives. Thus, it provides an integrated platform for the continuous clinical education of medicine students and inexperienced/not specialized doctors. The system provides educative material composed of test cases, guidance step by step in diagnostic methodologies based on real situations and individualized educative methodologies for each actor involved.

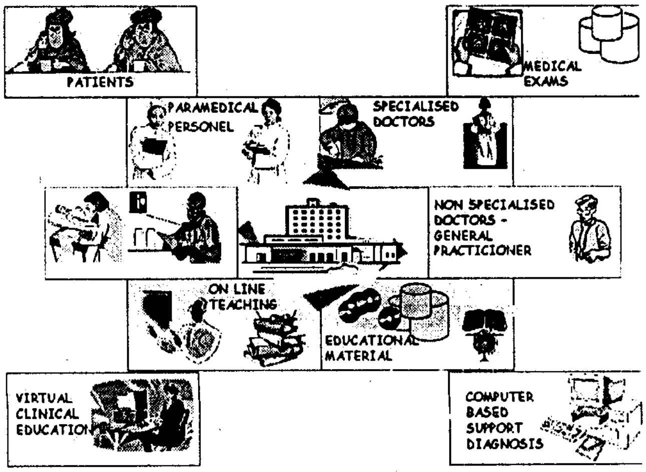

Fig. 1: General Description

Furthermore, it makes monitoring of experience possible and guides education both by the intelligent system itself and specialized doctors/ professors. This is made possible because of the tracking mechanism included in the system, which is responsible for recording contacts with patients, diagnostic data and results. These data are automatically analyzed to provide a measure of each students developing clinical experience and reviewed so a repetition of relevant units is effectuated in order possible theoretical lack of knowledge in specified arguments to be covered. Beside the above it provides an intelligent adaptive mechanism that operates as a support to doctors during diagnosis providing tips and possible diagnosis based on pre-recorded cases and on rule based decision making mechanisms. It is very helpful without being restrictive for doctor's personal initiative. Furthermore, in compliance with the doctors specialization gives guidelines for the redirection of patients to other medical disciplines if it is needed and proposes medical exams that have to be done in order to a complete medical view to be accomplished. Last but not least, is the provision of monitoring services to high risk patients through a simple system that involves exchange of medical data taken from the used by the patient wireless wearable devices to the supervising doctor's system (Director-General Information Society and Immarsat Ltd, 1999).

The System's Functionality: The system is addressed to medicine students as well as health care professionals. It aims at providing an integrated interactive educational platform for actuation of knowledge and clinical experience. Besides that, the system itself acts as a supportive diagnostic tool for inexperienced doctors or in extraordinary complicated cases. Furthermore, in cases that the diagnosed illness can cause permanent damages or encloses vital threat, the system provides a supplementary monitoring tool for the patient.

It definitely has great advantages in confront with existing systems mainly because of the extremely personalised educational method that is used. Furthermore it provides a fully integrated collaborative environment, where students and teachers can interact with each other during the educational process and act as a team. On the other hand the system itself provides valuable tools in order to operate as a standalone system that promotes individuals and enhances their own abilities and capabilities. Below the functionality of the system is depicted:

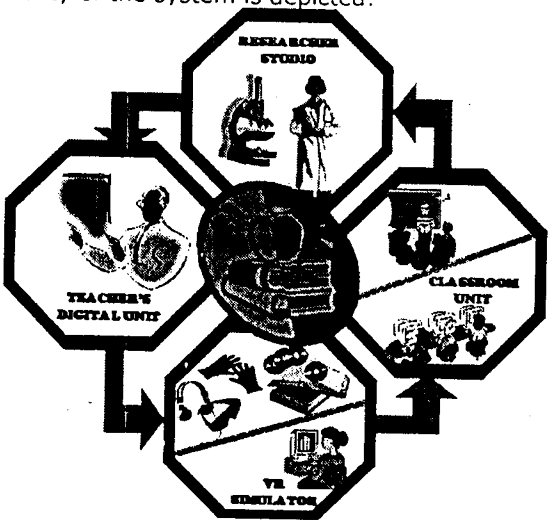

Fig. 2: Functional Description

The proposed system is a multidimensional tool addressed to health professionals, educators and medicine students. It enables educators to select and adjust the existing educational material according to the audience and the educative targets that they want to meet. Furthermore, they are authorised to add or update the contained data and to change the methodologies used to extract the test cases. Finally, using this system they are able to check and improve the adaptive capabilities of the system, feeding it with plasmatic properly selected data.

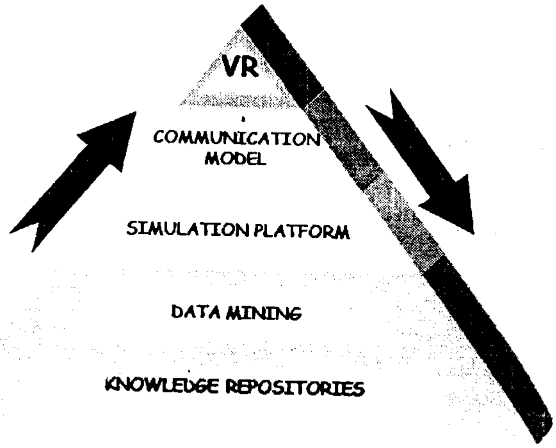

Fig. 3: System Layers

On the other hand, students acquire valuable clinical experience on a great variety of cases that would never encounter in the short time of their clinical practice in real life. Furthermore, the realistic environment provided by the virtual reality Simulator enhances their reflects and minimises the time needed to make a diagnosis due to the virtually collected experience and the acquired problem solving capabilities. At the same time and that is maybe the most important thing, the clinical experience is acquired without any danger for the patients because of the simulated environment. Of course, the face-to-face communication and the classrooms dynamics are not underestimated, thus the system provides the possibility to share the same virtual case and environment more than one students and/or teachers at each time and to have audio/visual interaction.

The backbone of the system is its intelligent knowledge extraction mechanism and the use of the acquired results in order to implement a valuable Decision making system. The target consists in creating an optimal scheme for the treatment of a selected number of common diseases that are characterized by low rate of success when diagnosed by regular physicians. Thus, these diseases require the use of human experts. Computational intelligence is especially useful in decision-making problems, as is in the case of performing medical diagnosis when the borderline between different health conditions is not clearly drawn. Therefore, computational intelligence can play the role of an expert assistant in a physician's decision procedure.

The Educational Platform Architectural Components: Main effort should be given in the architectural deployment of the system due to its multi-functionality and the integration of a great variety of different technologies. As made clear before, the project is about developing an intelligent and educative platform, with enhanced interactivity and tools for immersive navigation in Virtual Reality

worlds, especially those representing medical cases either in hospital or outdoors.
The picture bellow depicts the main system's components along with the main data flow:

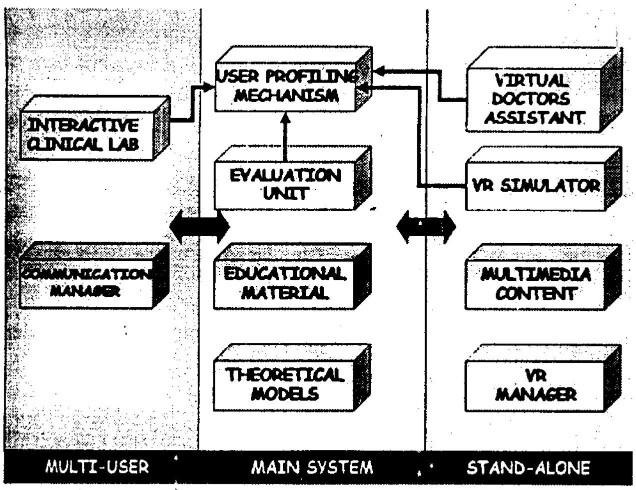

Fig. 4: The Educational Platform Architectural Components

The components off the Educational Platform are:
Interactive VR Clinic: It provides a virtual place where individuals can acquire theoretical knowledge or have clinical practice. They are provided with a 3D virtual world that represents real life scenery and are asked to act as a part of it. According to their educational profile and the pedagogical strategies that were intelligently selected by the system in order to meet their individual needs, they are guided through the teaching/diagnostic process. This can be done either individually on a standalone basis or with other fellow-students. The process can be supervised and guided by the educator.
Real Cases Simulator: This component is mainly addressed to inexperienced doctors and GPs (General Practicioners) that want to feed the system with a real case situation and get guidance by the system to effectuate proper medical examinations and extract the most suitable diagnosis, minimizing the fault risks. This ways doctors have an auxiliary diagnostic tool and at the same time the possibility of life long education in their domain of expertise.
Evaluation System: It has double functionality, as concerned students, evaluates their performance during virtual clinical case studies. Besides that, evaluates the system's success and localizes the failures of the diagnostic module in order to be adapted on new data.
Intelligent User Manager: It is on charge of collecting personal profiles, handling them and providing all the need information to the other system's modules. The teaching process needs internal check and guidance and these needs, which can be covered thoroughly by the expert system, are briefly mentioned below:

- Creation and update of the student's model.
- Selection of the proper teaching methodology
- Teacher's familiarization with his students' characteristics in distance education.
- Progress evaluation

The Monitoring System: The module operates on the server side (Clinical Centre Unit) and is responsible for the pre-processing and the partial analysis -if necessary- of the received measurement signals (vital signs). An intelligent software agent is activated when new medical measurements are sent to the Clinical Centre Unit and initiates the monitoring procedure by analysing and pre-processing the received data (vital signs). Typically we explain the case of the ECG (electrocardiogram) processing, which is one of the most complex measured signals. The Vital Signs Monitoring Module is also responsible for the overall co-ordination and synchronisation of the other server-side modules.
The Intelligent Diagnosis Module: The recorded vital signs can provide useful diagnostic data about the user's current or future health status and progress. The Intelligent Diagnosis module is a decision making system that combines user's vital sign measurements, user's profile (medical history and other personal characteristics e.g. age, weight) with medical knowledge stored in the form of relations and rules in order to extract valuable diagnostic and , where applicable, prognostic information. Due to the nature of the acquired signals and the intra - and inter - individual variability, traditional signal analysis systems based on inferential statistics often lack robustness and adaptability. Several solutions will be addressed to the above kinds of problems. However, our main effort will be concentrated on the use of intelligent techniques for the analysis and classification and knowledge extraction for the recorded signals. A knowledge database will be created and conclusions will be drawn from the application of techniques such as:

- Computational intelligence methods: Inductive decision trees neural networks, fuzzy logic, genetic algorithms or combinations
- Inductive logic programming
- Statistical based techniques

The methods that will be used are data - driven (i.e they are not based on qualitative rules provided by a medical doctor). The advantage of these methods is twofold:

- They are not based on an expert knowledge.
- Those systems often lead to relations and rules, which are not already discovered (knowledge extraction).

In the past, different approaches have been used to address similar problems. Emphasis has been given to state-of-the-art hybrid and adaptive systems. A new class of emerging hybrid computational intelligent methods is based on the application of rule extraction techniques either cooperative (e.g genetic algorithms-based rule systems) or competitive (e.g. fuzzy rule-based systems). However, the application of computational intelligent tools is not restricted to rule-discovering systems, but includes other CI (computational intelligent) -applications as well -that can be seen either as black-boxes (e.g. neural networks) or grey-boxes (e.g neuro-fuzzy systems) - with respect to their efficiency and effectiveness.

However, data mining techniques seem to lead the way to the extraction of hidden predictive information from large databases and therefore to accurate medical diagnosis, elaboration of factual epidemiological studies and extraction of valuable statistical information. Data mining tools enable the prediction of future trends and behaviours, supporting early diagnosis and prediction of potential health problems. The automated, prospective analyses offered by data mining move beyond the analyses of past events provided by retrospective tools typical of decision making systems. Data mining tools can answer "questions" that traditionally were too time consuming to resolve. They scour databases for hidden patterns, finding predictive information that experts may miss because it lies outside their expectations.

From a functional point of view the intelligent diagnosis module will be responsible to check whether or not the receiving information corresponds a health status deserving warnings. This refers to the medical measurements (vital signs) that Clinical Centre Unit (server) receives from the User Monitoring Unit. When the received vital signs correspond to a health status deserving a warning (in comparison to the user historical medical data), the Alert and Notification module is activated to notify both the end-user and the supervisor doctor of the unusual values.

The signal is send to the Clinical Centre Unit where the pre-processing and analysis takes place (Vital Signs Monitoring Module). In the final stage of ECG signal processing all the above features are evaluated and diagnosis is reached. In the literature several methods have been reported using different computational paradigms: rule-based expert systems, artificial neural networks, fuzzy expert systems, wavelet theory or other signal processing techniques. All these methods have been tested by means of accurate diagnosis of cardiovascular disorders and resulted quite well. A similar procedure is followed for all other vital signs measured, except in cases where diagnosis relies simply on comparison of explicit measurement values with predefined thresholds.

It must be noted that the Intelligent Diagnosis module should in no case be considered as a stand-alone diagnosis tool but as a supplementary decision making system for health professionals, since the actual diagnosis is valid only when certified by the corresponding health professional.

Security considerations: Considering the pace at which the healthcare sector is adopting electronic means for the exchange of information and the highly personal and potentially sensitive nature of this information, it is critical for the healthcare organisations to ensure that sensitive information is carefully guarded and secured to maintain user confidence. Additionally, e-health systems, such as this platform, must secure user information in order to protect themselves from liability exposure and possible legal sanctions. The security provisions of the proposed infrastructure will be in accordance to the guidelines published by the Data Protection Working Party (an EU Advisory Body on Data Protection and Privacy), the ITF (Internet Task Force) and the HCFA (Health Care Financing Administration) (Privacy on the Internethttp://europa.eu.int/comm/ internal_ market /en/media/ dataprot /wpdocs/ p37en.pdf)

In this context, the security practices are 5-fold:

To Protect the Resources: The protection of resources (data and application) is primarily achieved through firewalls. Firewalls are a standard approach used to protect local computer assets from external threats. A firewall protects networked computers from intentional hostile intrusion that could compromise confidentiality or result in data corruption or denial of service.

To Authenticate the Users: The Authentication Module identifies all legitimate users, all of whom are registered in the User Repository. The most widely used technique in this area is passwords. More up-to-date technologies will be considered too, such as the Digital Certificates that bind an identity to a pair of electronic keys that can be used to encrypt and sign digital information (Digital Signature) or even pseudonymisation that scrambles the real ID of the user while maintaining the ability to group data by specific keys that are often related to identity. Those two technologies require the involvement of Trusted Third Parties (also known as Certificate Authorities).

To Authorise the Users: Whenever access to the services, the Data Repositories or the Shared Resources of the system is involved, an access control mechanism must be invoked, involving access control lists and security filters (Access Control Shield). In this way, only specific authorised users are granted privileges to data and services and the distinct roles of the systems actors are ensured.

To Ensure Privacy of Information: Security over the Web is achieved using a combination of cryptography (PKI – Public Key Infrastructure) and widely approved security standards (SSL, TLS, S-HTTP, PGP, S-MIME). Extra considerations must be made for the wireless networks (The path Towards UMTS, 1998); *WTLS* and the UMTS Security Toolkit will be applied for transmitting encrypted Web messages over GSM/WAP and UMTS.

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