Stride Analyzing Patients' Leg muscles Remotely from Home

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Abstract— **In this document, we propose a health care system which could allow physicians to monitor their patients' leg muscle activity in real time while the patient is at home. Patients receive prompt advice and necessary information from a tutoring agent (a computer program on a home computer or mobile device) that is in direct communication with a physician who monitors the patients and helps them better handle their current condition, prior to paramedic arrival. With this system, physicians can monitor their patients' leg muscle activity in real time, thus reducing patient load in emergency rooms.**

Keywords: Cognitive Tutoring Agent, Health care services, Data mining

I. INTRODUCTION

With the world wide use of computers, mobile devices, and the Internet, it is imperative that physicians also take advantage of this technology to remotely monitor their patients. Many research projects offer technologies to monitor patients from homes [1, 2]. However, these technologies are limited to monitoring patients' blood pressure, heart rate, weight, etc. In this paper, we present our first attempt to monitor patients' leg muscle activity from the home, and provide them with medical advice through current technological systems, such as Short Message Service (SMS) and e-mail. Furthermore, we propose a system that allows patients to monitor their leg muscle activity at home. There are many medical devices that a patient can use at home to provide medical data that is important to his physician. This medical information can be obtained from a wide variety of devices. Gathered data will be verified and analyzed by software that we call an "agent". In our context, the agent will decide what to do. If the information does not suggest a very risky situation, then preliminary advice will be issued to the patient by the agent. At this point, the agent will send the information to the physician. If the patient's medical condition is serious, then the agent will automatically contact his physician for further immediate assistance.

Our proposal encompasses the following: 1) use hardware devices such as wireless communication devices or special mobile systems to obtain signals from a patient's leg muscle activity; 2) use an agent to monitor patients' leg muscle activity on-line, and provide them with prompt advice and the necessary information to solve unexpected problems; 3) encourage patients to use our training system based on Conscious Emotional Learning Tutoring System (CELTS); 4) allow on-line interaction among physicians-agent-patients by sending information to the physician and/or hospital and vice-versa for further examination and send precautionary advice to patients; 5) Use mobile devices and services instead of a Radio Frequency Identification (RFID) Card.

II. CURRENT WORKS

To track patients' health issues, current commercial systems in hospitals use the Radio Frequency Identification (RFID) technology. RFID is used by pharmacies, libraries, and hospitals for administrative, theft detection and coordination purposes [3]. It consists of devices that read, write, and store patients' information on tags and labels. These devices can also read patients medical information and transmit the information to where ever it is needed. RFID technology helps to associate a unique patient number (i.e. using a patient's social security number) to his/her medical history and personal information. This information is stored in a chip and is used for all patient-hospital communication. These chips also maintain the financial information of the patient up-to-date.

However, RFID technology is very expensive and difficult to maintain. This is especially true in hospital and clinics: 1) to be capable of using health care services, we need to issue a card to each patient; 2) to issue a RDIF card for each patient; 3) to read, maintain and update patients information, we also need to install special card readers and writers throughout the hospital;

It must be noted that RDIF cards also have the following disadvantages: 1) malfunctioning; 2) they may be lost; 3) be torn; 4) after a while, the card readers lose their accuracy and their quality. Moreover, each time patients lose their cards they must request a new card which imposes extra expenses for patients and the hospital. For these reasons, we discourage the use of RFID technology. Given that most people already use mobile devices, we suggest that these RFID services could be replaced with mobile services technology. Using mobile devices, we can facilitate users' knowledge about their health condition. Our proposal encompasses to use mobile service instead of RFID services as an Identification procedure. Furthermore, given that the hospital is very large and patients often require assistance to locate various rooms in the hospital, mobiles can help them as a navigation tool. Thus, we propose the use of computers and mobile devices, such as smart cell phones, Ipads, Ipods.

III. An Architecture for Monitoring Patients from Distance

The proposed architecture in this study contains two parts: 1) the patient; and 2) the physician and/or hospital.

Patient Part

We propose the following steps:

A. *Gathering data from patients*

The first step consists of gathering the patients' legs muscles information and sending it either to a local computer, a gateway modem, a mobile phone and or other device. This can be done, for instance, by using an electronic stethoscope, a digital thermometer, a digital sphygmomanometer, a digital hand dynamometer, or digital pinch gauge. In our case to analyze muscles we use Stride Analyzer. The Stride Analyzer is a microprocessor / PC system designed to record foot-floor contact data from foot switches and calculate all the gait parameters obtainable from this data (See section IV for more detail). Patient tests may be performed in any convenient walking area. Permanent records of the gait parameters and foot-floor contact patterns can be printed immediately following each test or later at the user's convenience. Thus, Stride Analyzer helps a physician answer the question: How well does my patient walk?

A. *CELTS analysis of the information*

The data gathered from the patient is sent to a computer. At the home computer, an agent who has all the crucial knowledge about the patient's appropriate blood glucose levels, body temperature, blood pressure, and many other parameters decides what to do. If there is a serious problem, the agent will take appropriate action, as determined by his physician. If the information does not suggest a very urgent condition, then, the agent will automatically process the raw data and send the results to the physician for his review at a later time. The agent then gives instructions to the patient.

The intermediate agent between the patient and the hospital is the Conscious Emotional Learning Tutoring System (CELTS) [3]. CELTS is a hybrid artificial intelligent tutor which is based on Baars' [4] theory of consciousness. It performs through cognitive cycles. Cognitive cycles in CELTS start by perception and usually end by the execution of an action. CELTS uses its Behavior Network (BN) for action selection. The BN is implemented based on Maes' Behavior Net [5]. It is a network of partial plans that analyses the context to decide what to do and which type of behavior to set off. CELTS' BN is domain independent, so, for a given problem an expert can define different solutions in the BN. CELTS is equipped with different learning mechanisms which allow the agent to have human-like performance and also allow it to intervene to help patients when needed.

CELTS is used for training astronauts while they manipulate Canadarm2, in the International Space Station(ISS) [3] . ISS has been designed and implemented to accommodate scientific experiments and life in space. Thus, it needs to be supplied with food and fuel, and be subjected to inspections regularly. Canadarm2, a mobile and robotic arm installed on the ISS, allows astronauts to do this, by manipulating the arm from one configuration to another. For instance, astronauts may use Canadarm2 to charge or discharge the received food from the space shuttles. Manipulating the robotic arm is a difficult task, and requires astronauts to undergo extensive training.

CELTS is used to give personalized feedback to astronauts who are learning how to handle the remote manipulator. It is equipped with different types of learning, based on human learning mechanisms. These include emotional learning, episodic learning, causal learning and procedural learning mechanisms [3].

B. *Transferring the information to the physician and/or hospital*

Locally gathered information that is transmitted to the local computer or any other device could then be sent to the physician and/or hospital using various technologies such as the Internet, dial-up, wireless or any secure network.

Importantly for the patients, some of these hardware devices are very small and could be carried everywhere. This would allow patients who need to travel to be aware of their medical condition and consult their physicians in real time if needed.

Physician and/or Hospital Side

For the server side, we propose the following steps:

It must be noted that in this text, we do not review all the steps for the integration of the data on the server (i.e., security aspects such as Firewalls).

The information could be sent to the physician's or hospital's servers locally or from afar using point-to-point, Internet, dial up, VPN (Virtual Private Network), or any other standard commercial service. To do so, we propose the use of Enterprise Service Bus (ESB), a new perspective of Service Oriented Architecture (SOA). SOA is essentially a collection of services. These services communicate with each other [6]. The communication can involve either simple data passing or it could involve two or more services coordinating some activity. Some means of connecting services to each other is needed.

ESB services play the role of service adapters for communication between different types of servers and clients' devices. To do so, ESB uses among others, Technology adapters (e.g., CORBA, COM, JDBC, J2EE, NET), Application adapters which facilitate integration with package solutions (e.g., Siebel, PeopleSoft, and SAP, among others.) or

Legacy adapters which facilitate exposing valuable enterprise applications as services [7, 8]. Hospitals may provide some specific services which may be different to those used by patients, such as Windows, web applications, mobile phones, and so forth. Thus, one challenge is that patients may send information and queries from/to their physician or hospital using different web services. The second challenge is that different web services must be capable of accurate communication. ESB routes each input service from/to patients' side to its corresponding in/out-put service and vice versa. Given that our architecture is service-oriented, should a new device be commercialized in the future, the only step required would be to add a new service on the server's side. The communication between the new device and the server would begin automatically. The information may be sent to the hospitals' local servers from windows, web and mobile services locally or externally. In the case that the physician or hospital administration decides to use health care services, each time the nurses or physicians examine patients, the information will be sent directly to the physician's and/or hospital's servers. After the integration of the information to servers in the physician's office or hospital, the patient's physician will analyze the information. Based on the patient's medical condition and history, the physician will provide the patient with the necessary assistance, at that time.

In conclusion, using this architecture, we can have a real time access to the medical conditions of our patients while they are in the airplane, at home or any other area in which they can access the Internet or use any other mobile device.

We here demonstrate our primitive attempt for the implementation of such a system.

IV. A CONCRETE IMPLEMENTATION

In this part of our paper we demonstrate the use of the Stride Analyzer, a portable gait analysis device, as part of the health care system we propose. The patient can use the Stride Analyzer, with minimal assistance to acquire and transmit foot/floor contact information to a home computer. To do so, CELTS will first perform primitive analyses of the gait parameters. It then, sends the information to the servers (our simulated physician's office or hospital) in real time. There, the information is processed and the required instructions are given to the CELTS which shows them to the patient. In what follows we briefly explain how the aforementioned steps should be realized:

A. Gathering data from patients

The first step consists of gathering the patients' health state information and sending it to a local computer by using wireless communication and a USB port.

To do so, in our case, footswitches[1] are worn as insoles in the subject's shoes or taped to the bottom of bare feet, and indicate the total time each foot is and is not bearing weight. Each Footswitch is connected to a wireless transmitter by a thin cable. The information is wirelessly transmitted to a receiver which connected to home computer or mobile device and analyzed by the Stride Analyzer (SA) software. If a mobile service is used to gather non-critical patient data and send it to the hospital, the physician analyzes information in an off line manner. However, when a PC is used to send critical patient data, the physician analyzes the information in an online manner.

With SA, many walking parameters are computed: Velocity, Cadence, Stride Length, Gait Cycle Duration, Left and Right Single Limb Support, Double Limb Support, and Swing / Stance Ratios.

B. Communication between the Stride Analyzer and other devices

The communication between the Stride Analyzer and personal computer is done by using an economical and efficient wireless services protocol called Zigbee [2] for transferring data. Zigbee technology is simpler and less expensive than other wireless technology such as Bluetooth. It is conceived to provide short rate data communications, long battery life, and secure networking.

B. CELTS analysis of the information

To analyze muscle activity information gathered from patients' leg muscles, a copy of CELTS will be installed on his/her computer. CELTS will use the knowledge from an expert system in its BN and patient information gathered at home. Using that information, CELTS can compare the patient's leg muscle activity with normal muscle activity during walking. For instance, Figure 1.A shows a 6 year old girl who is diagnosed with spastic diplegia. Figure 1.A shows muscle activity of three leg muscles: Medial Hamstrings (MED HAMS), Soleus (SOL), and CALF. In Figure 1.A, the blue bar |———| shows normal muscle timing during each gait cycle. Thus, as shown in Figure 1.A the muscles activation should occur under the blue bars. A physician with experience in analyzing raw data can decide whether those muscles are active at the appropriate time in the gait cycle when the patient is walking. For instance, while Figure 1.A shows normal muscle activity under the blue bars, this is not the case in Figure 1.B. Furthermore, in Figure 1.B, all muscle activity occurred outside of the blue bars. Therefore, analyzing received data from patients leg muscles, CELTS can investigate the patient's muscle activities and find problems.

C. Communication Between CELTS and Physician and/or Hospital:

[1] www.bleng.com

[2] ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for wireless home area networks (WHANs), such as wireless light switches with lamps, electrical meters with in-home-displays, consumer electronics equipment via short-range radio.

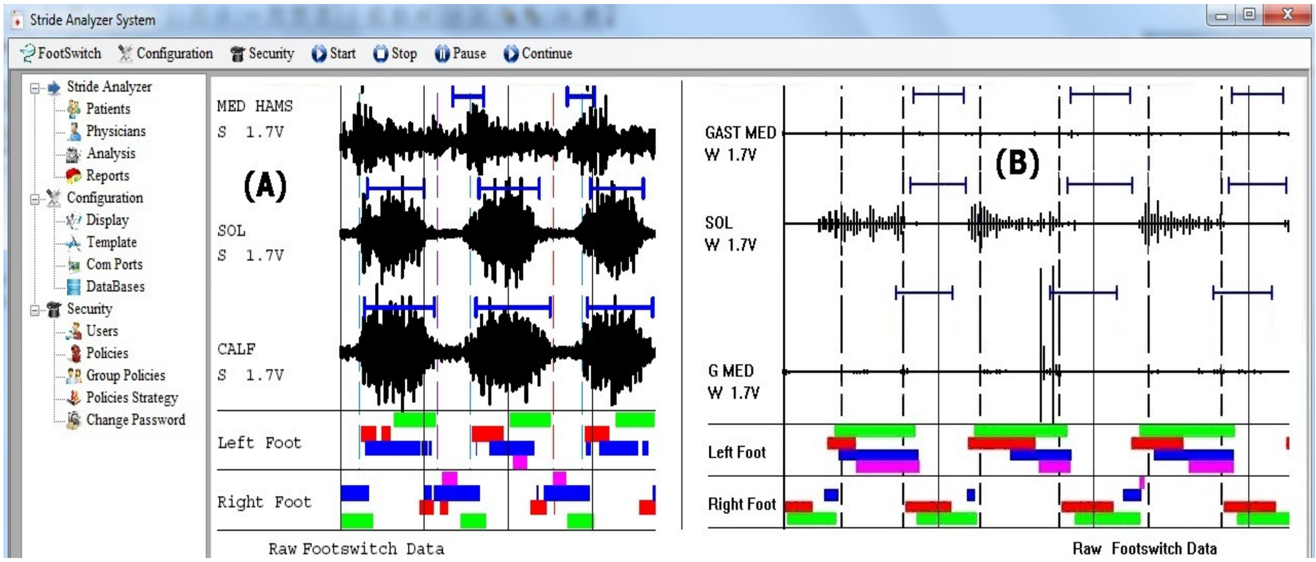

Figure 1 (A) Stride Analyzer samples1 (B) Stride Analyzer samples2

CELTS analyzes data and send them to the server. There, to process SMS and MMS files in the hospital side, a GPRS or GSM modem is required. In the hospital side all the received information such as SMS and MMS files will be processed using web services. That is, before the information is integrated to the central database, they must be adapted by ESB adapters. As it explained above, ESB uses adapter services to adapt different technologies. Furthermore, SMS or MMS files formats should be interpreted and translated to be integrated into the hospital database. After the integration of the information, a physician is assigned to make diagnosis according to the raw data and primitive analyzed information received from CELTS. Afterward, physician advice will be sent from hospital to the patient. To do so, using ESB services in the server side, the same scenario repeats to convert the information to a format that is compatible with client side devices.

V. CONCLUSION

The healthcare industry is a large part of our economy. Providing high quality healthcare at a low cost can only be accomplished by implementing the latest high technology. In this study, we proposed a system with which physicians can remotely monitor patients' leg muscle activity using the stride Analyzer. This includes gathering patients' information about their medical condition as they are at home and giving them helpful advice as well as transmitting urgent data to the patient's physician for immediate review. Using this system, patients can remain up to date with regards to their medical condition. Patients can also receive personalized advice about their medical condition. The project also seeks to determine to what extent the proposed system is capable of connecting patients and physicians in a cost-effective way. With our proposed system, the medical information gathered from different patients can be combined and stored in databases for further analysis. Patients can be categorized by health condition and their medical information can be analyzed to look for trends in the effectiveness of their treatment.

Our future work will be to design and build medical devices that patients can use at home to help their physicians help them.

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REFERENCES

[1] F. Scotté. 2006, The remote patient care : an IBM innovation developed in conjunction with the oncology department of the Hôpital Européen Georges Pompidou.

[2] J. G. Robert, "Continuous Monitoring of Blood Glucose," Hormone research, 2002.

[3] U. Faghihi, P. poirier, P. Fournier-Viger, and R. Nkambou, "Human-Like Learning in a Conscious Agent," Journal of Experimental & Theoretical Artificial Intelligence. In Press, 2010.

[4] B. J. Baars, "In the Theater of Consciousness:The Workspace of the Mind," Oxford: Oxford University Press, 1997.

[5] P. Maes, "How to do the right thing," Connection Science 1, pp. 291-323, 1989.

[6] D. K. Barry. (2010, Service-oriented architecture (SOA) definition. Available: http://www.service-architecture.com/web-services/articles/service-oriented_architecture_soa_definition.html

[7] D. A. Chappell, Enterprise Service Bus: O'Reilly Media, 2004.

[8] M. Keen, J. Bond, J. Denman, S. Foster, S. Husek, B. Thompson, and H. Wylie. (2005). Patterns: Implementing an SOA Using an Enterprise Service Bus.