Developing a Multilateral Telerehabilitation System for Hand

Fereshteh Ghasemi

Abstract—**Telerehabilitation or e-rehabilitation is the delivery of rehabilitation services over telecom networks. According to the World Health Organization (WHO), there are about 650 million people with disabilities worldwide; these statistics drive the need for more applicable Telehealthcare Systems. This paper aims to provide a design description of a novel multilateral telerehabilitation system for Patient with diminished hand function which needs minimum interaction between patient and therapist. The proposed configuration consists of the central intelligent system (CIS) including multi-function modules in a homepage for patient in physiotherapy office, and a Hand Rehabilitation System including a Robot, Motion Analysis Module as well as body area network (BAN) in patient's home. This system works by a diagnostic feedback from a Hand Rehabilitation System to the central intelligent system (CIS). Patient fixes sensors on his hand and doing daily activity. Data transmitted by BAN will be analyzed by the motion analysis module in order to diagnose the latest degree of recovery. Information is feed backed automatically to the CIS through network. An appropriate program corresponding to the feed-backed information will be prepared by CIS and transmitted into the robot. After doing exercise by the system, joint angles are measured and send to the CIS again to diagnose the level of patient recovery. Cost of care by this configuration will be reduced significantly. This paper presents a prototype that successfully operates as a multilateral telerehabilitation system.**

Index Terms—**Physiotherapy, telerehabilitation, hand rehabilitation system, body area network**

I. Introduction

The rapid growth of telecom industry has faced the world with new revolution. Information technology revolution has noticeable impacts on the economic, social, and political development of a country; this impact can be seen in medicine as well.

The combination of medicine and information technology has created a new science called Telemedicine and Telehealthcare. By using these new sciences, health care professionals can evaluate, diagnose and treat patients in remote. Telerehabilitation is such an e-health service too. It delivers rehabilitation services using telecommunication networks by a therapist at a distance location. This technology has played an important role in healthcare over the last decade. According to the World Health Organization, there are at least 650 million disabled people worldwide and number of them is increasing from year to year. By 2050, the number of persons over 65 years will increase by 73 percent in the industrialized countries and by 207 percent worldwide [1]-[2]. On the other hand, going to the hospital and visiting the therapists are time consuming, difficult, expensive and sometimes may be impossible for the patients; especially for who lives in the depopulated areas.

Different kind of telerehabilitation systems have been proposed in the past decade. Real-time web-base monitoring system is from initial telerehabilitation devices, in which the therapist has ability to communicate with the patient, or judge his activity, as well as the ability to make modifications of the routines before and during an exercise; this structure works by a two-way video conferencing [3].

Other kind of Telerehabilitation system has been constructed using WSNs; in some cases Body Area Networks and gaming have been combined to assist in physiotherapy treatments; in a proposed system, framework has three main components, the body area WSN, the game, and the data acquisition manager; The body WSN is fixed to the patient's body and data is collected and stored in real-time. This data in parallel is feed directly into the control services allowing gaming objects, i.e., virtual representations of patient's, to control by physically moving his/her body parts. Whilst the patient plays the game, data is regularly collected from body sensor nodes. This allows real-time data from sensor nodes to be used by the game to adjust game levels according to the medical status of the patient [4].

In the other designs, a new game has been created helping a patient to conduct his/her rehabilitation program. For each exercise, the patient is instructed to wear sensors on specified movable body parts; the system will then estimate the quality of the movements and give scores as if it is advised by a therapist. In this way, patients will no longer feel painful and boring as that in traditional rehabilitation, which is typically done in hospitals [5].

Some new architecture has been implemented to assist in telerehabilitation. As an example a remote heart rate monitoring system is proposed; the monitoring system integrates the wireless ECG signal recorder with a mobile device in a Bluetooth-based body surface network (BSN). The monitoring system integrates the current heart rate of the patient with the GPS data (position, speed, altitude). This gives the opportunity to observe the dependence of heart rate variability and speed. The application allows the physician to build a cardiac rehabilitation program which can be divided into several levels. Each level let the physician to customize parameters as: duration, maximal and minimal speed, maximal and minimal heart rate and the difference in altitude. Finally, the proposed system has a detection and classification algorithm for abnormal events which makes the rehabilitation effective and safe [6].

It is apparent that robotics researchers have significantly helped to developing Telerehabilitation systems; and till now, some hand rehabilitation systems have been constructed using different types of technologies as well. Some of them

Manuscript received December 20, 2011; revised February 10, 2012.This work financially supported by Payame Noor University, Research Centre.

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which is set up for tele-care purposes have targeted in bending the hand joints to relieve the tension of the hands. A project presents a new hand motion assist robot for rehabilitation therapy. The robot is a self-motion control, which allows the impaired hand of a patient to be driven by his or her healthy hand on the opposite side; To provide such potential that the impaired hand is able to recover its ability to the level of a functional hand, the hand motion assist robot is designed to support the flexion/extension and abduction/adduction motions of fingers and thumb independently as well as the opposability of the thumb. Moreover, it is designed to support a combination motion of the hand and the wrist [7].

There is another system which consists of a Hand Rehabilitation System for patients, a complete anthropomorphic robot hand system for therapist and a remote monitoring system for diagnosing the degree of recovery. The force which is applied to robot hand by therapist would transmit to patient's hand through a special network [8]. However, therapists have to make an interactive online connection with patients using robotic hand system.

The aim of this paper is to propose a novel multilateral telerehabilitation system by a diagnostic feedback from a Hand Rehabilitation System to the Central Intelligent System (CIS) in order to speed up recovery and minimizing interaction between patient and therapist. Cost of care by this configuration will be reduced significantly because the CIS needs to a small office and limited employee. In another word, it provides an appropriate service for low income and low literacy patients at their homes.

II. Novel Hand Telerehabilitation System

In this paper, the author has presents a novel telerehabilitation system by a diagnostic feedback from Hand Rehabilitation System to the Central Intelligent System (CIS). This multilateral system aims to speed up recovery of the hand function by diagnostic feedback and minimizing interaction between patient and therapist. The whole system is divided in to two parts. One part is located in physiotherapy office and the other part can be located in patient's home.

III. Systems in Physiotherapy Office

There is a main configuration consists of the central intelligent system (CIS) including multi-function modules in a homepage for a patient in physiotherapy office; these modules are intelligent and listed as below:

A. Alarm Module

This module lets therapist to receive essential alarms from patient or Hand Rehabilitation System. These alerts are received via therapist's mobile phone too; the alert module would send emergency alerts after receiving emergency messages. In this way, therapist who uses a mobile device such as a mobile phone to communicate with the CIS in the care center can go around without restrictions.

It is possible to set up a complete intelligent health care chain with mobile monitoring and healthcare service via the assistance of a complete mobile care system along with alert mechanism. In this system physiological parameters of the patient are constantly monitored, there is a developed physiological signal recognition algorithms that built-in in the mobile phone without affecting its original communication functions. It is thus possible to integrate several front-end mobile care devices with Bluetooth communication capability to extract patients' various physiological parameters [9].

B. Log Module

This module collects the statistics of communications between CIS and hand rehabilitation System. Furthermore it is affected by other modules; and it can keep an archive of all therapist activity.

C. Processing Module

This main module consists of received and sent databases. Some uploaded databases (rehabilitation program) can be selected and send, corresponding to a net request to Hand Rehabilitation System; this database is updated by therapist to meet patient needs.

D. Analysis and Reports Module

This module allows to analysis generated information placed in Processing Module and Alarm Module. Analyzed received data is then prepared to report therapist by some graphs. The highlighted graph in this module is the percentage of improvement.

E. Database Backup Module

This allows therapist to dump the contents of received database and information into a text file, and/or restore from such a file. This text file can be easily backed up to a directory or remote server.

Fig. 1. Modules in CIS.

Other modules that should be placed in the CIS are Search Module, Download, and Upload and etc. Fig. 1 shows main modules in a CIS.

The CIS can be seen by patients and used by multiple persons such as physicians, nurses and therapist in different places, therefore everyone has its profile with a special username and password to inter the homepage.

Microsoft's ASP.NET and C# technology has been used to construct the dynamic and interactive CIS and make it easy to manage and maintain [10],[11]; choosing this technology is a good selection since ASP.NET drastically reduces the amount of code required to build large CIS, providing a secure and safe CIS and it has a lot of flexibility to enhance it.

CIS controls hand rehabilitation process so this configuration needs a minimum interaction between patient and therapist. By the above illustration, obviously we just need a standard computer with CIS and a high speed available network in physiotherapy office; that is a hope to have a full virtual physiotherapy office in future.

IV. Systems in Patient's Home

The proposed multilateral configuration consists of hand rehabilitation system including a robot, motion analysis module and body area network (BAN) which are explained as below:

A. Robot

Robot is a hand rehabilitation device which consists of two parts, a microcontroller, and motion assistance mechanisms for fingers and wrist with 5 DoF (degree of freedom); One DoF for 4 fingers (flexion of metacarpophalangeal joints, 0 to 90 degrees/extensions of Metacarpophalangeal joints, 0 to 30 degrees), one DoF for wrist (extension, 0 to 70 degrees/flexion, 0 to 80 degrees). It should be mentioned that we have independent motion assistance for each finger [7]. Because of the complicacy of thumb function, it‘s not included in this robot; As it is possible to construct thumb motion assistance mechanism with the double parallel-link structure [12].

Robot or hand rehabilitation device supports one hand of patient; robots' motors gets appropriate information from a microcontroller and moves targeted joints forcibly. The joint angle is measured by encoders on motors [8]. Microcontroller can be connected to a laptop or standard PC for sending and receiving data through network. If patient feels pain during the training, he can press emergency stop button; this button simultaneously send alarm to therapist and turn the robot off.

B. Body Area Network

Body area networks (BAN), wireless body area network (WBAN) or body sensor network (BSN) are terms used to describe the application of wearable computing devices [13]. BAWSN (body area wireless sensor network) term may be used instead.

Research on BANs can be dated back to 1961 with work from Mackay on radio telemetry within the body [14]. These body nodes can measure physiological data, movement, position, etc. and dispense medication, electric shocks (pacemakers), provide imaging for poor sighted people, etc. The more powerful node can be a mobile device, e.g. a smart phone, personal digital assistant (PDA) or a fixed house central hub [15].

BANs have similarities with WSNs, by having sensor nodes (albeit different) that form a network. BANs have a central component that receives all the information from the nodes and controls all of them. This is done as applications using it deem necessary. A PDA, smart phone or a more powerful node can be this component or can act as a gateway (GW) to the central component (e.g., a PC on a home environment); so the network topology can be a star, where all nodes are one network hop away from this central component, which we call a base station (BS). In BANs, the set of data treated will be very heterogeneous, with possibly complex relationships among the different types of data. BANs are prone to have different types of nodes added to an already deployed network. Fig. 2 shows that the BAN is the network comprised of the nodes surrounding the human body; this network will connect to a local network or a wide area network, either connecting to a home hub in the first case or to a remote monitoring service for the latter [15].

In our project, BANs 'nodes are attached to the hands; there is a base station connected directly with a PC and constantly receives and collects hand movements' data from hand sensor nodes [16]. These data are transmitted to the Motion Analysis module.

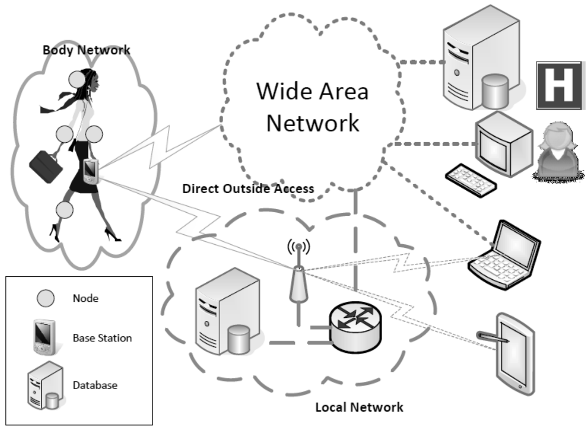

Fig. 2. Networks involved in a BAN [15].

C. Motion Analysis Module

This module is a program which written in the java language; it is installed in a PC or laptop and able to collect hand movements' data from base station and analysis them in order to diagnose the latest degree of recovery. The module communicates with processing module in CIS through network. This program is set in start up of the PC to run promptly even by illiterate patient.

V. Whole System Configuration and Operation

This Telerehabilitation system works by a diagnostic feedback from hand rehabilitation system to the central intelligent system (CIS). Patient should fix sensors on his hands and doing daily activity in a specific time. Data transmitted by body area network will be analyzed by the motion analysis module in order to diagnose the latest degree of recovery; Information can be also feed backed automatically to the CIS by PC through network. An appropriate program corresponding to the feed-backed information will be prepared by CIS and transmitted into the system.

Finger and wrist of patient is put in robot and it moves patient's hand joints using local and internal information which is already prepared; after doing appropriate exercise by the robot, joint angle is measured by encoders on motors; afterwards the data is sent to the CIS again to diagnose the level of patient recovery and uploading new rehabilitation program in CIS by therapist. If there is a new condition or if there is not enough information requesting by hand rehabilitation system, the CIS send an alarm to the expert to update its information Fig. 3.

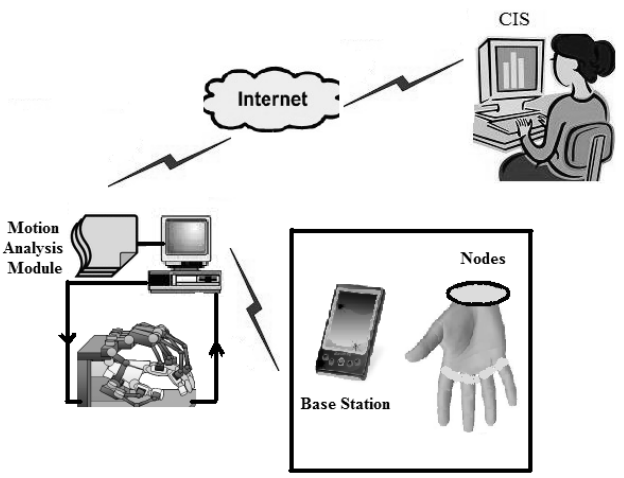

Fig. 3. Multilateral Telerehabilitation System.

VI. Conclusion

The proposed configuration consists of the central intelligent system (CIS) including multi-function modules in a homepage for a patient in physiotherapy office, and a hand rehabilitation system including a robot, motion analysis module as well as BAN in patient's home. This multilateral system aims to speed up recovery of the hand function since it has a diagnostic feedback from a hand rehabilitation system to the CIS. Using this method allows long-term care and Cost of care by this configuration will be reduced significantly because the CIS needs to a small office and limited employee. Some experiments were carried out with healthy right hands of females and shows the transmitting information is done between CIS and hand rehabilitation system successfully and Human hand follow the motion of the robot rehabilitation device very well. This configuration needs a minimum interaction between patient and therapist. In the future, by developing a CIS server, a group of patient would be serviced concurrently and safety parameter of the system can be considered strongly in order to avoiding permanent disabilities. In order to evaluate the effectiveness of the system, the control system can be demonstrated as well.

Acknowledgment

The author would like to express her sincere gratitude to all persons who helped her for their suggestions in developing project and editing paper.

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