A Patient Rehabilitation System using a Man-Machine Interface Design

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Abstract: This paper presents the design of a man machine interface for controlling of a rehabilitation robot that can perform active and passive exercises for lower limbs. The system with man machine interface and robot manipulator can learn physiotherapist manual exercises and perform them by itself like a physiotherapist. Thus the rehabilitation capability is conveyed to the patient directly. The System also provides a graphical user Interface by which the treatment period can be observed and recorded. This interface can also be used for web-based remote therapy. Rehabilitation of knee and hip are carried out and the test results are presented.

I. Introduction

The role of the rehabilitation process is to restore functionality of previously damaged limbs. It is most important to return patients to society, reintegrate them into social life and therefore improve the patients' quality of life. Throughout therapy, physical exercises for extremities like arms and legs have a key-role in the recovery of the patient. Therapeutic exercises consist of active or passive physical movements of the patient, carried out through the therapist, or of movements carried out of the patient with the assistance of the physiotherapist, depending on the condition of the patient. For rehabilitation either the patient has to go to a healthcare center, or the physiotherapist has to come to the patient. Studies for robots in rehabilitation have been increased due to the time-consuming process of rehabilitation.

Studies carried out in the closer past have proved many advantages of rehabilitation robots compared to classic therapy methods [2]. In addition robotic therapy provides better possibilities to acquire and store information such as the therapy response of the patient [3]. There are several studies that use intelligent techniques and their aims are to transfer physiotherapist rehabilitation capacity to patient directly. In this study, a man machine interface (MMI) has been designed in order to control a designed and produced rehabilitation robot. Unlike other existing projects the robot manipulator (RM) that is used in this study can perform active and passive exercises for lower limbs and it can perform knee flexion-extension, hip extension-flexion and hip abduction-adduction movements. Also the rehabilitation system that consists of human machine interface and robot manipulator can learn physiotherapist manual exercises and perform them by itself like a physiotherapist. So this rehabilitation capability is conveyed to patient directly. So, single physiotherapist rehabilitates more than one patient at the same time with this system. The human-machine interface includes an easy-to-use graphical user interface. With this interface, the treatment period can be observed and saved. Furthermore, the interface has been designed to be fit for web-based remote therapy. Thus, difficulties of transferring patients to medical centers can be eradicated. Test results are presented for direct rehabilitation of knee and hip.

II. System Description

The system consists of three basic components (See Figure 1) Physiotherapist, the man machine interface and robot manipulator(RM). The system can perform Physiotherapist's manual exercises as well as to carry out all standard active and passive exercises. The modeling of the manual exercises has been named

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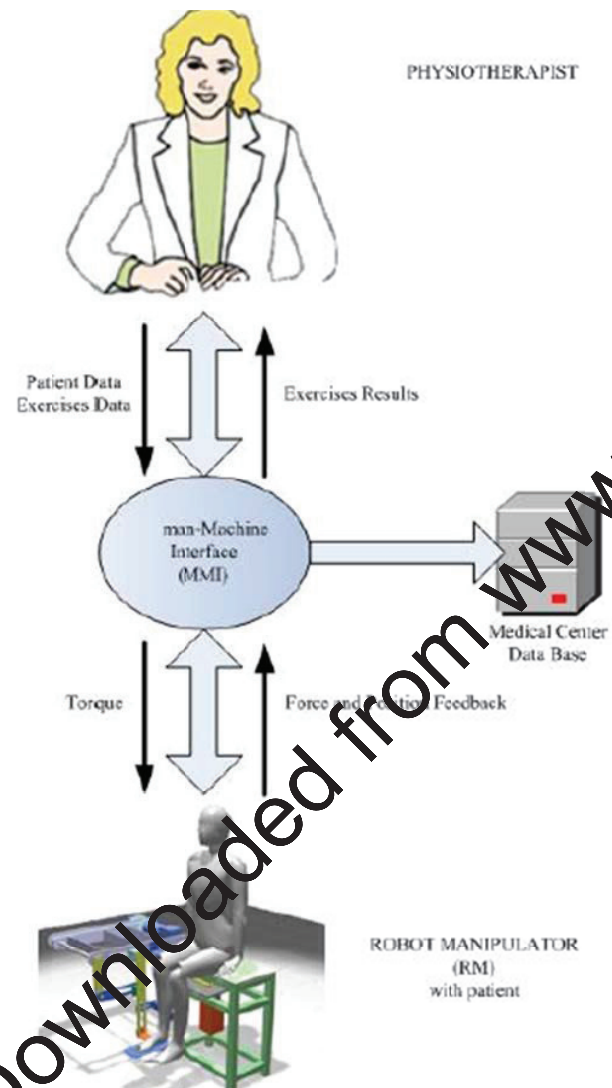
“robotherapy”. In the robotherapy mode, the system operates in two different modes. These modes are direct therapy and reactive therapy. In direct therapy mode, the system can repeat movements taught by the Physiotherapist for any required duration. In reactive therapy mode, the system responds according to the patient’s reactions, the boundary conditions of the exercise carried out keep changing over the duration of the therapy. In this paper, only the direct therapy mode test results have been shown.

Figure 1. Basic components of the system.



The graphical user interface enables the PT access to all information concerning the patient and therapy mode, exercise type etc. The standard active and passive exercises are carried out through the RM. However, for direct therapy the physiotherapist carries out movements while the patient is on the RM. In the meantime, the MMI monitors and stores position and force values. All process parameters are stored in the database. This mode has been named “direct therapy teaching” mode. The next step is to switch over to “direct therapy-therapy” mode. The RM is now reproducing the same positions and forces applied to the patient as in the previous teaching mode.

A. Physiotherapist

The system has been designed to be an aid for the physiotherapist considering a fixed number of physiotherapist in society, more patients could be helped in a better way using this technology. Furthermore, rehabilitation sessions could be held longer, which is an additional advantage. The system's aim isn't to replace the physiotherapist, it is to support him or her. The physiotherapist decides on the specific exercises to be carried out by the patient and teaches those to the RM. The RM is fed with information about the patient (age-weight body length) and details about the exercise to be carried out. The physiotherapist then carries out the exercises together with the patient. In the next step, the RM carries out the exercises with the patient in the same way as done before with the physiotherapist.

B. Man Machine Interface

The MMI is the central unit between physiotherapist and the RM. It consists of the impedance controller, rule base, data base, graphical user interface and central interface units. A detailed block diagram of the

MMI is given in Figure 2 which is also known as Human machine interface(HMI). The MMI programming is realized in Matlab/Simulink.

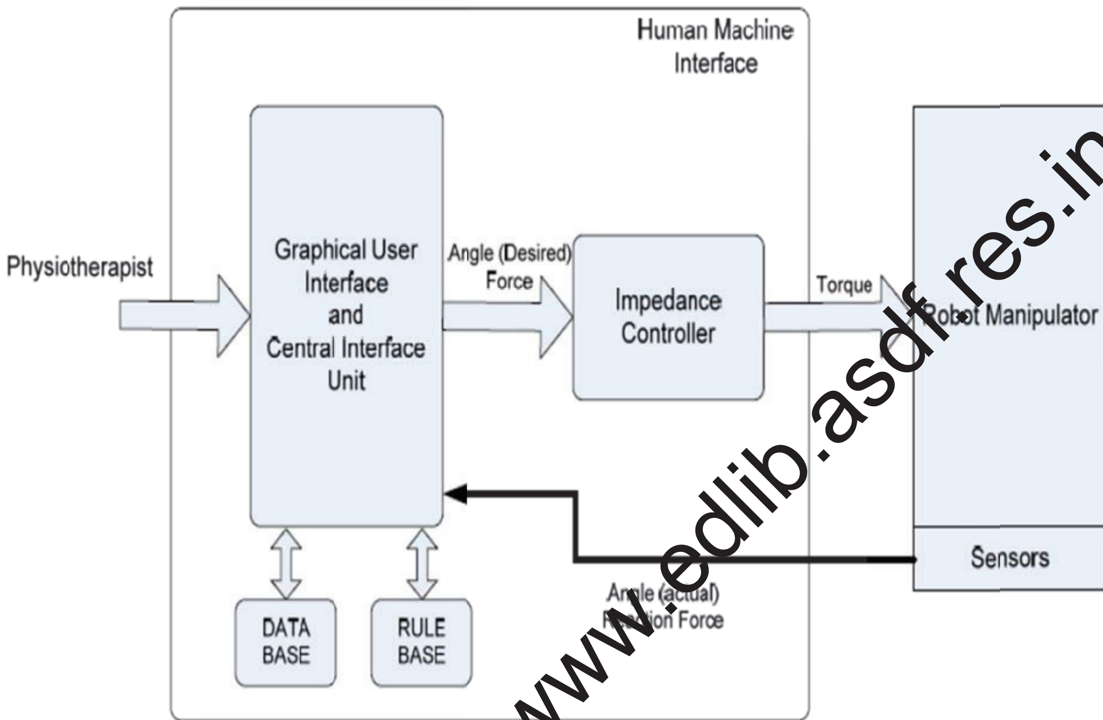


Figure 2. Detailed Block Diagram of the HMI/MMI

Central Interface Unit: The central interface unit provides communication between all system components.

Graphical User Interface (GUI): Enables the user to communicate with the HMI. The main menu as shown in Figure 3 is used to input the patients' data. These data is used in order to calculate a number of mechanical parameters. The body limb which is to be exercised and the exercise type are selected from the main menu as well. Results from previously carried out exercises can be accessed from the main menu and are displayed graphically as shown in Figure 4. The graphics display the patients' range of motion (ROM) and corresponding forces. These results are stored in the database for documentation and can be printed out optionally.

Impedance Controller: Impedance control aims at controlling position and force by adjusting the mechanical impedance of the end-effector to external forces generated by contact with the manipulator's environment. Mechanical impedance is roughly an extended concept of the stiffness of a mechanism against a force applied to it. It is accepted to be the most appropriate control technique for the physiotherapy and is used in many rehabilitation robot applications [5,6] [8] [11,12]). Because of this it was used in this application as main control method. For direct rehabilitation, its parameters were selected as appropriate for PT moves patient limbs smoothly and easily. In order to select appropriate impedance parameters values, some experiments were realized with different parameters in different speeds.

Data and Rule Base: All data relevant to the patient is stored in the data and rule base. The stored information contains personal data, impedance controller parameters, saved exercises from the teaching mode and exercise results.

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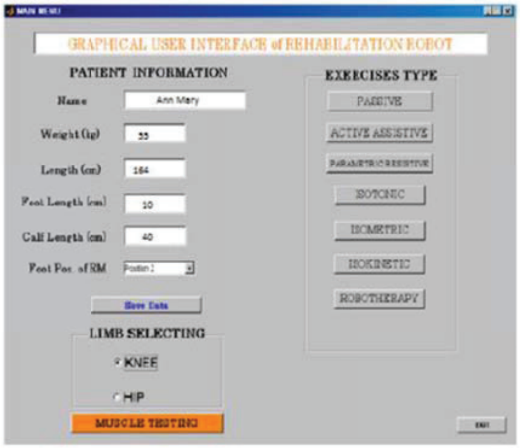


Figure 3. Graphical User Interface Main Menu

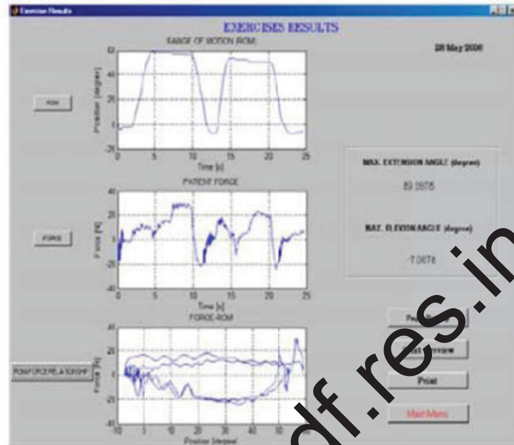
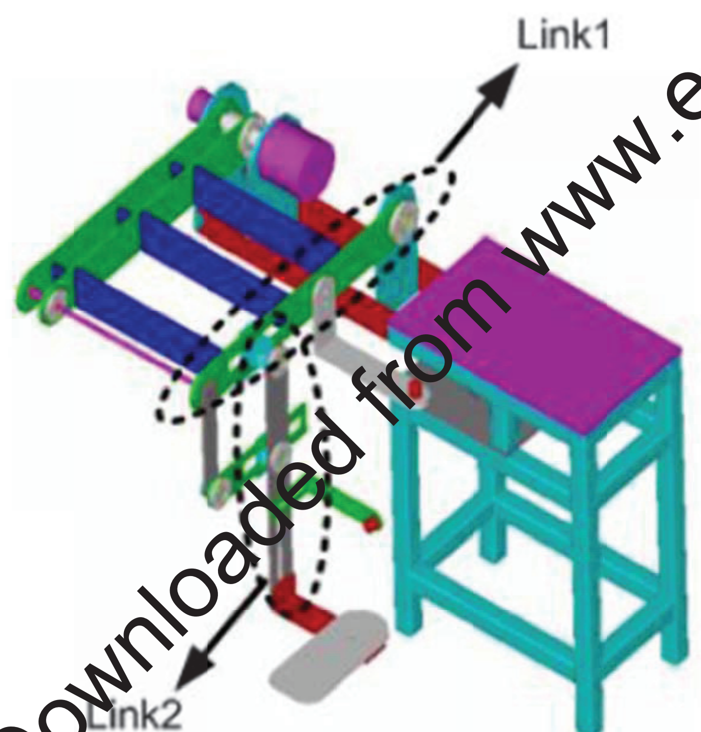


Figure 4. Graphical User Interface Exercise Results Screen

Figure 5. Robot Manipulator



III. Results and Discussion

In the experiments with the RM, healthy test persons are used. Each test person's leg is connected to the RM with two points, thigh and ankle. “Direct therapy - teaching” mode is selected from the GUI. The experiments carried out cover knee flexion-extension, hip flexion-extension and abduction-adduction. The physiotherapist teaches the exercises together with the test person directly on the RM. Position and force measurement results from taught exercises are stored in the database. In the following step “direct therapy – therapy” mode is selected from the GUI. The RM now carries out every stored exercise for the patient independently from the physiotherapist. Figure 6 shows exemplary test results for knee extension-flexion. In this figure, first graphic shows physiotherapist’s exercise trajectory in teaching mode, second graphic shows RM’ exercise trajectory in therapy mode and the last graphic shows trajectory error between physiotherapist and RM exercises. The results show a very much accurate repetition of the PT's movements as learned in teaching mode. In Figure 7, teaching and therapy results are shown for hip flexion-extension movements. RM’s Link 1 is the hip link, Link 2 is the knee link. For hip flexion and extension both hip joint and knee joint are moving simultaneously. Every graph shows the teaching trajectory as well as the therapy trajectory. As for Figure 8, abduction-adduction movements are shown. Abduction-adduction movement is realized by the drive mounted underneath the patient, by moving the hip about the vertical z-axis of the

RM. Both Figures 7 and 8 show successful realization of hip movement previously taught by a physiotherapist.

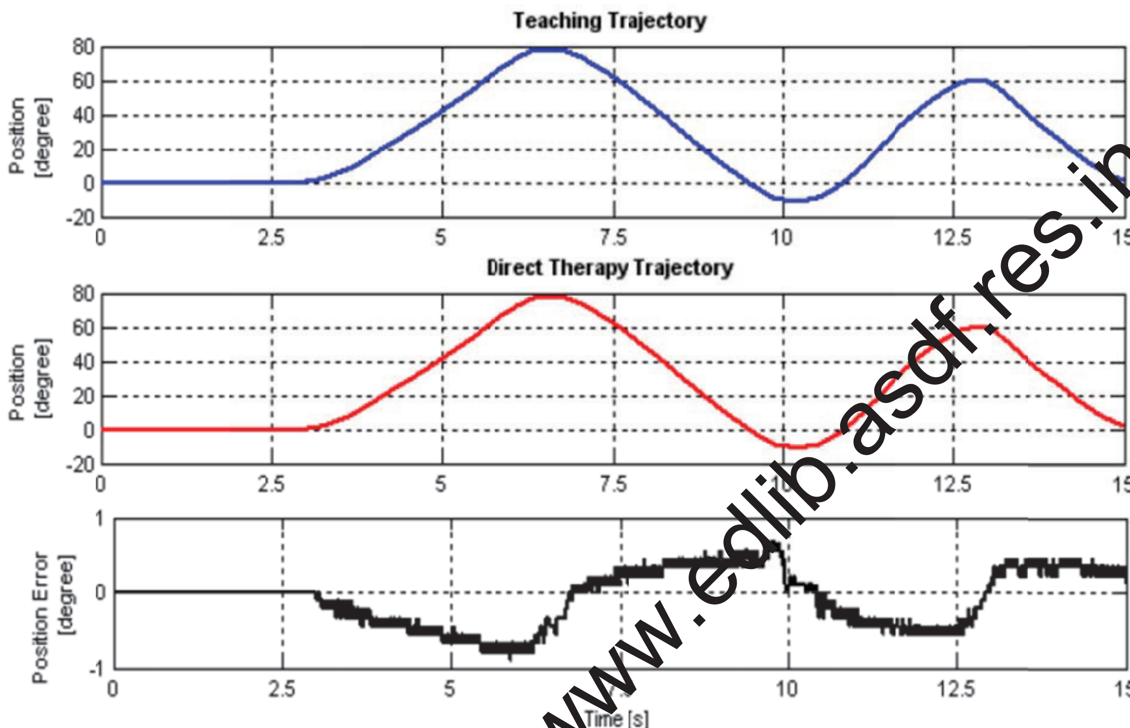
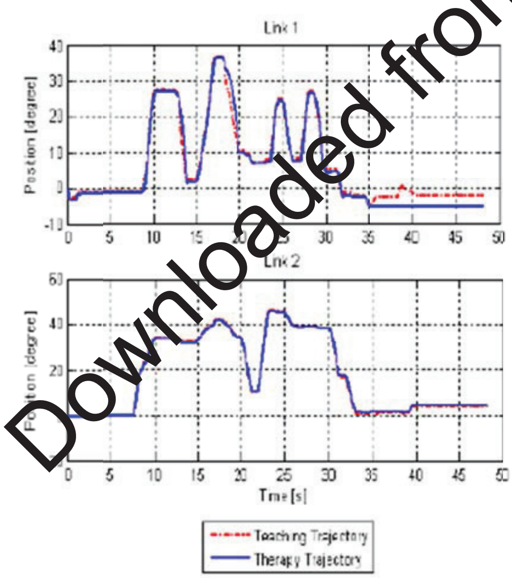


Figure 6. Teaching Position, Direct Therapy Position and Error



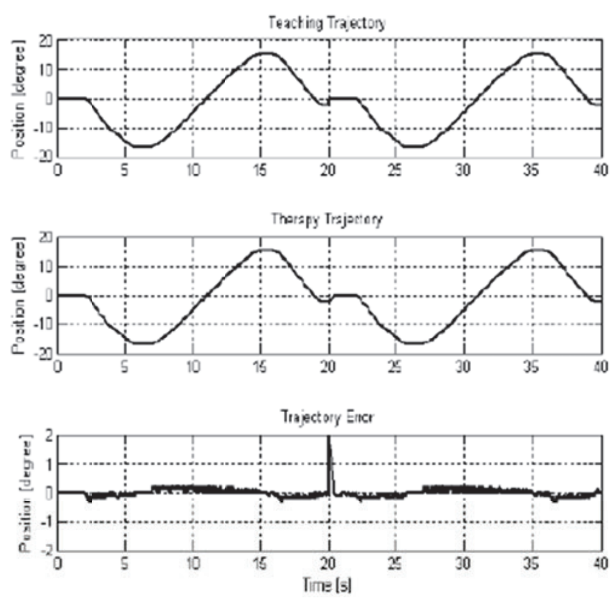


Figure 7. Hip Flexion-Extension Movements Teaching and Figure Therapy Results

8. Hip Abduction-Adduction Movement Teaching and Therapy Results

IV.Conclusion

The paper describes a Man-machine-interface to translate the capabilities of a physiotherapist directly to a robot manipulator. Furthermore, standard active and passive exercises can be performed by this HMI. The graphical user interface created for the HMI gives the user an easy access to all functions of the HMI. Using the developed HMI the physiotherapist can teach exercises into RM through performing exercises directly on the patient. The exercises covered are knee and hip flexion-extension as well as hip abduction-adduction. The previously taught exercises can be repeated effectively by the RM itself. The exercise results are evaluated automatically and displayed by numerical and graphical means. The results are stored in a database for later use. The realized interfacing system is made of flexible nature to be fit for web-based application.

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