Telekin
Tele-rehabilitation System for Musculoskeletal and Cognitive Disorders using Natural Movement Interface Devices

Raúl Velasco Caminero[1], Luis A. Méndez Herrero[1], Francisco J. Díaz-Pernas[1], Juan Calabia del Campo[2], Míriam Antón Rodríguez[1] and Mario Martínez-Zarzuela[1]

[1]*Department of Signal Theory and Communications and Telematics Engineering, University of Valladolid, Spain*

[2]*Faculty of Health Sciences, European University Miguel de Cervantes, Spain*

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Abstract: In this paper we describe a virtual rehabilitation system designed to improve different physical and cognitive disorders. Rehabilitation is carried out through virtual reality and serious games. Currently, in this system, we use Microsoft Kinect v2 and Leap Motion sensors. Thanks to the modular development of the system, we can add new rehabilitation devices such as Oculus Rift, as well as create new games depending on the pathology to be treated. Therapists access to the system through a web portal where, depending on their access level, they can create rehabilitation sessions and therapies and track the patients' progress. Patients access to the system through a local application and not using keyboard or mouse devices, using a natural user interface based on their movements. Rehabilitation sessions consist on serious games where the patient performs the exercises of his session programmed by a therapist. There are different types of user with different access levels: administrator, therapist, familiar and patient. The different types of user interact with their respective modules.

1 INTRODUCTION

The increase of life expectancy among the population brings along, in many cases, chronic diseases that reduce their mobility and prevent them from developing routine tasks such as getting dressed, showering… becoming dependent people (Christensen K, 2009). In addition, these deficits can reduce the participation in social and leisure activities, and even, affect in a negative way the person's mood (W. Gabriele, 2009). One of the visible consequences is the saturation in clinics and hospitals. The main factors that contribute to this increase are the need of cares for these people (prevention and detection of disabilities) as well as the need of rehabilitation (Nichols-Larsen D.S., 2005). A huge amount of physiotherapists and professionals indicate that the number of exercises in a therapy session is generally insufficient and the lack of regularity of the execution of them prevent rehabilitation from being completely effective (C. Lang, 2007).

Researchers suggest that an occupational therapy can stimulate the brain enough to improve patients´ motor skills. The creation and development of motivating and effective methods to encourage these kind of patients to perform the proposed exercises is crucial to help them improve their motor skills and increase their independence (J. Kleim, 2003).

An interesting strategy to follow is the incorporation and use of various technologies focused on occupational therapies in several environments. Specifically, virtual reality and serious games based on patients´ movement are gaining relevance (D. Jack, 2000) (Beaulieu-Boire, et al., 2015) .

One of the most common problems for the establishment of motion capture systems is their high cost and the complexity of their assembly. However, with the emergence of new technologies like sensors for motion capture (Kinect v2, Intel Real Sense, Leap Motion…), they have given rise to tools for the objective analysis of the movement, as well as the interaction with serious games by virtual reality (Chang C-Y, 2012).

Several studies confirm the improvement in the rehabilitation services of the patients by improving their motor skills and creating an adherence to the therapies proposed through virtual reality, using the

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sensors previously mentioned (Yao-Jen Chang, 2011).

Our research group designs and implements virtual reality therapies based on serious games.

This paper shows the technical specification of the rehabilitation system (TELEKIN) under development by our research group. There are other virtual reality systems that use Microsoft Kinect Sensor such as KiRes (Antón D., 2013) and EPIK (Garrote, et al., 2015), developed by our research group, among others. Other researchers (Muñoz J., 2013) (Pirovano M., 2012) also use Kinect based systems in the physical rehabilitation area. The difference between these systems previously mentioned and TELEKIN is that, with this new system under development, we seek to provide a tool of support for doctors and therapists to take a more precise and detailed control of the evolution of the patients without having to carry out this follow-up on a face-to-face basis while the patients perform the rehabilitation sessions. This system is developed in a modular way, that is to say, you can add new devices for rehabilitation that will emerge over time. Currently the system includes Microsoft Kinect v2 and Leap Motion sensors.

2 METHODS

2.1 Purpose of the System

The purpose of the system is to encourage patients to carry out the training whose doctors have recommended and keep a suitable and personalized routine for their pathology.

Furthermore, it is intended to offer specialists (doctors, therapists) a tool to keep track of their patients' progress wherever they do the exercises, either at home or at the medical center.

2.2 Technologies

The system is divided, as will be shown later, in two different parts: a web platform and a game.

The web platform is programmed using PHP and jQuery languages, using Bootstrap framework (Team Bootstrap, s.f.). For the database that feeds the web, a MySQL language was used.

The game makes use of two devices to catch the user's movement:

- Microsoft Kinect v2 (Microsoft, s.f.) to catch users' body movements.
- Leap Motion (Leap Motion, Inc, s.f.) to catch users' hands movements.

The game has been programmed with the Unity (http://unity3d.com) game engine, that allows developing interactive content for multiplatform systems (PC, Android, Mac, iOS, Linux, consoles).

The recommended hardware and the software configurations needed are: Microsoft Kinect sensor v2, Leap Motion, and a computer running Microsoft Windows 8 or later with the Kinect and Leap Motion drivers installed.

2.3 Main Features

The system has been programmed with a clearly modular design, with the end to make possible to add new modules in an easy way, with no hard changes needed in the system parts.

The tool consists of the following modules:

Administrator Web Module: this module is a web interface with a lateral menu that shows all the actions that the administrator access level can perform. These include the management of all users of the medical center and the configuration of the entire system, among others. The rest of the actions that this access level performs are detailed in the following section (see Account Types section).

Therapist Web Module: this module is similar to the Administrator Web Module. It shows a web interface that shows the actions allowed for this access level (see Account Types section).

Relatives Web Module: this module shows a summary of the patient´s main data and his evolution in the different rehabilitation sessions. It can be accessed by patient's relatives, once they have the proper access rights.

Game Module: The game module is a 3d environment which contains rehabilitation activities for the patients. It starts with a menu in which the user must choose his account and play the activities or games that the therapist has previously assigned. The patient will be able to do the activities that were scheduled. The aim of these activities is to achieve rehabilitation through serious games and patient's range of motion measuring.

2.4 Account Types

Depending on the account type, the patient will have access to different modules and configuration options within one of them. Each access level grants the user also to use functions of lower levels, in a hierarchical manner. The highest level is administrator, followed by doctor, family and patient.

Administrator´s Account: with an administrator´s account, you can manage all the users of the system, configure all the parameters of the system, assign patients to doctors and create or modify the different therapies for the patients.

Therapist´s/medical´s Account: with this type of account, you can create different sessions to the patients who are in charge and observe their progress through the visualizations of statistics obtained when the patients perform the games configured. In addition, you can configure the parameters of each game and the parameters for the gamification offered in the games and customize these parameters for each patient.

Relative´s Account: with this type of account, you can observe the patient´s progress. Several statistics obtained in the realization of the sessions created for the patient are offered. In addition, general data of that patient are shown as the total score, level of play and other data associated with the gamification used.

Patient account: the patient type account is only used in the game module. It allows to access to the sessions created previously by the doctors and to perform the proposed activities.

2.5 Modules of the System

2.5.1 Admin Web Module

The administrator web module manages all the users of the center (CRUD rules), as well as the configuration of all the parameters of the system. Through the web interface (Figure 1), all actions associated with this level of access are performed. In addition, this module allows to assign patients to the allocated doctor.

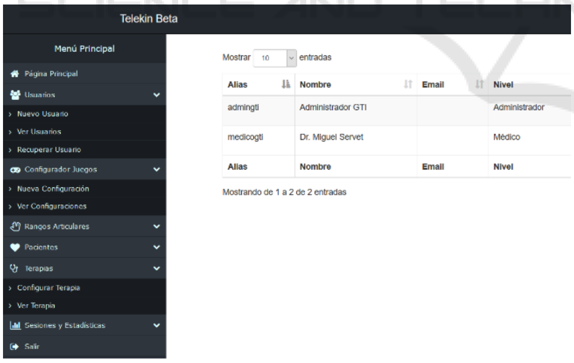

Figure 1: Administrator access level web interface.

2.5.2 Therapist Web Module

In the medical/therapist web module, the creation and configuration of the specific sessions to each patient can be done. It is possible to configure specific parameters for the sessions´ games, so that they are customized for each patient. In this way, the therapies are specifically adapted to the deficiencies of each patient. In addition, you can observe the evolution of each patient by displaying statistics. Initially, the user of this module has to select the patient to treat. Henceforth, all actions will be performed on the selected patient.

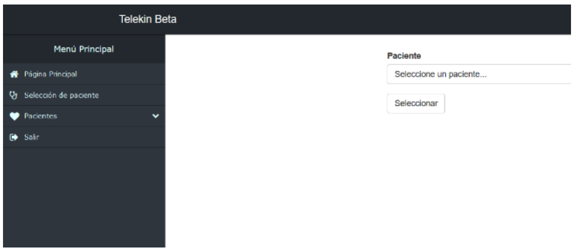

Figure 2: Selection of the patient that be treated.

Once the patient is selected, all the actions associated with this level of access are displayed. Therapies and sessions are generated and configured so that the patient can perform them (Figure 3).

Figure 3: Medical/therapist access level web interface.

2.5.3 Family Members Web Module

In the relative´s web module, you can see the progress of the patient through statistics. Graphs are shown with the data obtained during the different sessions proposed. In addition, you can view the current therapy and the most representative data of the patient´s profile (Figure 4).

Figure 4: Family members access level web interface.

2.5.4 Game Module

This module is only accessible with a patient account. The user enters the module to perform the activities that had been scheduled by the doctor.

This part of the system is developed using Unity, and it is a 3D environment that combine interactive menus with 3D games with the aim of stimulate the patient to do the exercises scheduled by his own therapist.

The game module can be divided in three different parts: menu, evaluation activities and games:

Menu: once the system starts, it displays a welcome screen with an access button. At first, the patient must select his user and confirm that it is him choosing a secret word which was previously selected. Then, the system displays all the activities that the therapist chose for this patient and wait for the starting of the first of them.

The selection of the user (Figure 5) and the activity (Figure 6) can be done automatically depending on the parameters that the doctor has chosen. To handle through the menu buttons, the patient can use the hands to move de pointer on the screen. The movements of the hands are tracked by the sensors (Microsoft Kinect or Leap Motion) and if the pointer stops over a button for a few seconds, this button is pressed the function of said button is executed.

Figure 5: Manual User Selection.

Figure 6: Automatic Activity Selection.

Evaluation activities: these activities are based on goniometers which measure the patient's joint range of specific body joints.

On the left side of the screen a video that represents the movement to perform is displayed, while a message both read out and displayed at the bottom of the screen. On the right side, an avatar reproduces the movements of the patient.

The current angle of the patient's joint and the maximum value that has been reached in previous sessions are showed at the top of the screen.

The activities can track the angles of joints of the body (Figure 7) using the Microsoft Kinect sensor or angles of joint of the hand (Figure 8) using Leap Motion.

Figure 7: Body Joints Evaluation Activity.

Figure 8: Hand Joints Evaluation Activity.

Each exercise must be done for a given time, determined by the doctor. When this time is over, the activity is closed and the next exercise begins. This loop continues until all the exercises that the doctor had chosen are finished.

Games: the games are composed of two parts. First, a user calibration is done to know the limits of the patient when making the movement that is necessary to play the game. When the system has collected this data, the game begins.

The calibration (Figure 9) follows the same steps that the evaluation games, but is focused on the specific movement of a joint. The range limits are saved to configure the game that starts next.

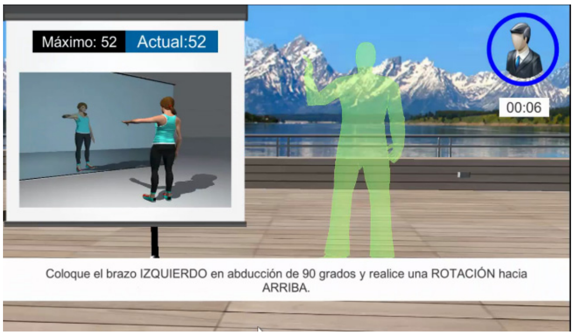

Figure 9: Game Calibration.

Once the system knows the patient limits, it starts the game which was selected by de therapists considering the data collected in the calibration.

Two different easy to play games for musculoskeletal disorders rehabilitation have been developed. In one of them, (Figure 10) the patient must move a ball vertically trying to avoid to crash with the obstacles. In the other game, (Figure 11) the patient has to move a platform horizontally in order to bounce a ball and throw it against some blocks which are on the opposite side. Ball and platform are moved by the patient by doing flexion and extension exercises of the joint which has been chosen by the doctor (wrist, hip, shoulder).

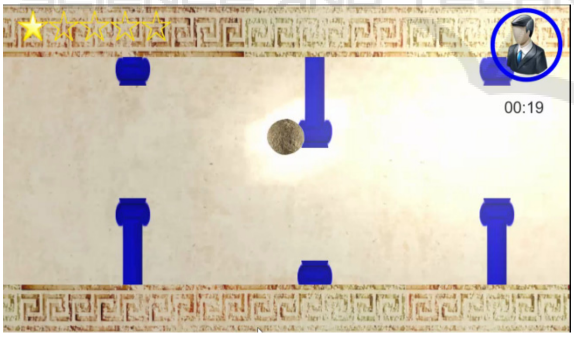

Figure 10: First Musculoskeletal Disorders Game.

Finally, the system includes a game for cognitive disorder rehabilitation. In this game, some words are randomly displayed on the screen and the patient has to use all of them to build a sentence (Figure 12). There are two ways to move words: using Microsoft Kinect or Leap Motion. The patient has to move the pointer with his hands and put it over a word, and when the word is selected, he must move it to a free sentence gap, at the bottom of the screen. There are

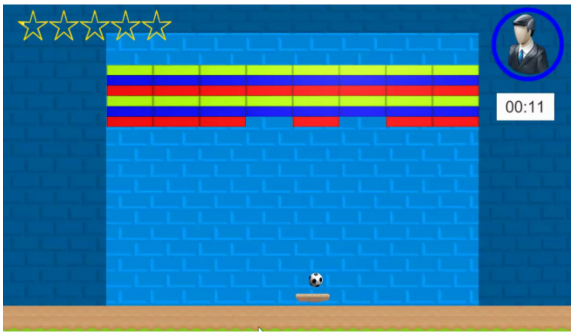

Figure 11: Second Musculoskeletal disorders Game.

some gestures to catch the words: closing the hand, joining the tips of index and thumb fingers or keeping the pointer over the word for a while. The therapist can configure how the patient should grab the words and the difficulty of the sentences that appear in the game.

Figure 12: Cognitive Disorders Game.

3 CONCLUSIONS

This paper presents the beta version of the TELEKIN system. The system includes two clearly differentiated interfaces. The web interface, where therapists configure and evaluate the evolution of their patients, and the serious games interface, that is used for rehabilitation. All training sessions are played in a virtual 3D environment.

This system has a modular design, that is, new rehabilitation devices can be included to the system as they arise. In addition, new modules can also be developed depending on the diseases and needs of each patient. Pathology treated with this system can be both physical and cognitive. Currently, the system includes physical rehabilitation modules for different joints (shoulder, back, balance, coordination…). We are now developing new modules for patients with intellectual disability.

This system is presented as a complementary tool for doctors and therapists. The system tracks the data and the improvement of their patients and can be accessed on a remote way in any moment they need through the web platform of the system.

At this time, the included sensors in the system are Microsoft Kinect v2 and Leap Motion, but thanks to its modular structure, it is planned to add new sensors that can measure more body joints. In the near future, the system will include the Oculus Rift virtual reality glasses and Gloveone haptic gloves to induce different sensations in patients.

The aim is supply a tool to health professionals and patients which makes the rehabilitation, evaluation and treatment tasks easier, simpler and much more effective.

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