Play for Health: Videogame Platform for Motor and Cognitive Telerehabilitation of Patients

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Abstract - This paper presents Play for Health platform for the rehabilitation of patients suffering from various diseases developed by iBit Foundation and Son Llàtzer Hospital. The platform is basically formed by a management module intended for clinical therapies of telerehabilitation and an unlimited number of games that can be combined with different methods of interaction. Users interact with the computer in different ways according to their needs. These games provide an incentive for patients and promote the realization of the exercises planned by the medical staff in a fun, easy and intuitive way. Furthermore, this system is applicable to other fields such as education and social care.

Keywords - Telerehabilitation; videogame; user interaction

I. INTRODUCTION

Play for Health strategy in iBit Foundation intends to apply ICT (Information and Communication Technologies) to the processes of rehabilitation care through an open and scalable technology platform.

The first phase of this initiative has been funded by the Spanish Government and is called "Telerehabilitation for Elderly People (TeleRHB)", which has implemented a tool to perform remote monitoring of processes and physical therapy to patients with total knee replacement (Fig. 1).

Figure 1. Example of the user interface of "Telerehabilitation for Elderly People".

Currently it is ongoing the second stage of the strategy, which consolidates the platform, developed by the project "General Mobilization System for People with Disabilities (Rehab8)" funded as well by the Spanish Government and it is being prepared for exploitation.

Play for Health Platform is developed by iBit Foundation with the functional collaboration of Son Llàtzer Hospital in Palma de Mallorca. This platform allows patients to follow a rehabilitation program tailored to their needs from their homes or care facilities.

This paper explains the technological platform starting from the related work and following the description and a real case game. Finally it presents the conclusion and the future work in this line.

II. RELATED WORK

In recent decades there has been significant progress in using information and telecommunication technologies in the field of health and more specifically in the case of telerehabilitation, both physical and cognitive. Many national and international pilot projects have been developed but few of them get to the production phase and become a real medical service.

Most projects in this sense refer to telemonitoring of chronic patients. It's briefly described some projects directly related to the remote rehabilitation:

- "Cognitive telerehabilitation platform (PREVIRNEC)". It is a system for conducting cognitive rehabilitation exercises in a virtual space that represents a daily routine for the patients, such as a kitchen. The concept is different from the one posed by iBit Foundation because PREVIRNEC interacts with the computer via a mouse and keyboard and the system can only train cognitive abilities (not both physical and / or cognitive as in the case of Play for Health).
- "Clinical Leading Environment for the Assessment of Rehabilitation protocols in home care (CLEAR)" [1] is implementing a telerehabilitation service at European level to contribute to the harmonization of

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e-Health services in the European Union. This project focuses on the treatment of chronic diseases that are prevalent among the elderly. CLEAR is pursuing the design and implementation, validated by different testbeds, and a European standard for the development of telerehabilitation services.

Furthermore, there are many initiatives that use with good results the capabilities of current video game consoles like Nintendo Wii for the implementation of telerehabilitation projects. In comparison to the use of such technologies that are commercial and closed, Play for Health allows the development of personalized rehabilitation plans, adjustable to patient outcomes, the parameterization of the results to monitor and store and an Application Program Interface (API) for developing new content. Also, while the games used in these consoles are generally oriented to the leisure and wellness, the contents of Play for Health are specifically designed for specific diseases, in close collaboration with clinical teams to treat these diseases.

III. FUNCTIONAL OBJECTIVES

Currently the high rate of aging population in developed countries is an important social concern. In the medium to long term, the number of elderly dependents could become unsustainable for the socio-public health system unless we take appropriate action.

In this scenario, ICT for health and, in this case, telemedicine and more specifically telerehabilitation, can be a powerful tool to address this situation. On one hand, ICT offer great flexibility to adapt to the needs for treatment and allow better use of health resources and improve the quality of life of patients.

Therefore, telemedicine is seen as a tool to keep in line expenses without lowering service quality and effectiveness of treatments.

The principal objective is to enhance patient autonomy. The first step is identifying the patient's functional limitations by the rehabilitation team (rehabilitation physician, physiotherapist and occupational therapist), taking into account its primary disease and the implications or consequences of it. After identifying these functional limitations, the degree of collaboration of patients and their caregivers, mood and motivation, the rehabilitation team may decide therapeutic interventions through telerehabilitation [2].

The platform addresses the design and implementation of a therapeutic program of physical and psychomotor rehabilitation aimed at people with some kind of functional disability, regardless of the disease they have. It provides patients with various exercises to improve remotely the following aspects: functionality for activities of daily living, physical mobility, some cognitive functions and sensory perception (such as attention, memory [3] or visual perception), coordination [4] skills, psychological aspects such as motivation, handling some technical support and posture. In this way, and taking into account the patient's general condition, the functional team indicates games or exercises to be performed, frequency, repetition and rest periods.

IV. TECHNOLOGICAL DESCRIPTION

Play for Health platform provides resources and services needed for game development of the specific pathology. It is easily extensible in terms of functionality, either by adding new games or by the incorporation of new interaction methods.

Play for Health is based on the development of:

- The contents or games, each of them designed to improve skills within the rehabilitation process.
- The methods of interaction or interfaces. They are the tools with which the patient can interact. They may vary depending on the functional goal established by the medical team.
- The module for clinical staff interaction with the platform for the management of rehabilitation plans for each patient. Both the number of games and methods for interaction that can manage the platform are unlimited.

A. Contents

The contents are the games aimed at the rehabilitation of motor and cognitive functions. They are jointly designed by the technicians and clinical personnel.

Each game is developed independently, using the existing platform and methods of interaction available. Sometimes it is necessary to develop a new module for specific interaction for a game but once developed it can be reused in other games.

An example of the first games developed is a puzzle of pieces that aims to stimulate cognitive and motor functions. The patient may choose the right piece to put in the puzzle to develop the cognitive function. To improve the motor function the patient may move the piece of the puzzle to the right place using the hand.

During play sessions, the system is able to record interesting values such as response time, time to perform the movement, the precision of movement, the number of errors made and the number of steps needed to complete the puzzle. These data will be transmitted to the server system so that medical personnel can analyze and compare the evolution of these variables during therapy. Subsequently, the system may be changing the difficulty of the games automatically or manually by medical personnel, so that the patient continues to be challenged, to maintain its motivation and allowing a steady and gradual improvement of its capacities.

As for the customization of the games, the system adjusts its level of difficulty depending on both the results achieved by the patient and the clinical staff. In the first case, the games are designed to fit the clinical profile of patients. Different profiles of patients according to medical conditions (e. g., elderly profile, multiple sclerosis patient profile, etc.) adjust the scores to the results of the game. In the second case, clinicians analyze the results of the game and may change data and parameters of the game for that patient.

In terms of content, it has been created the games: “Puzzle Training” (see this game as a real case example on the next section), Rhythm (the game is to remember a

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sequence of sounds) and Molobolos (it is to direct a ball through a maze).

B. *Clinical management system*

Play for Health Platform has a clinical module for:

- Setting up rehabilitation plans tailored to each patient by selecting the difficulty level, type of exercise, the location of the stimuli, providing reinforcement to the patient by positive or negative feedback, the type of activity and the execution time of that activity.
- Recording the activity of the patients.
- Viewing the progress: increase improvement of accuracy, decrease errors, increase responsiveness, speed of execution of the exercise, increase resistance to work.
- The use not only in private homes but also in public hospitals, health centers, nursing homes, etc.

C. *Interaction methods*

A method of interaction is composed of devices (mouse, camera, keyboard, tablet, dance mat, etc.) that record values such as motion, pressure, speed, etc. through different types of sensors that can capture functional changes of the patient, and the software needed to interpret and translate the data into commands that allow the execution of the game.

These interaction devices (interaction event producers) integrate with the video games (consumers of events) through a plug-in dynamic interaction system.

Currently it is implemented the following methods of interaction on the platform: detection of movement in one part of the body through webcam (recognition of the palm), dance mat, Wii Remote (Wiimote), keyboard and mouse.

To date it is combined with Puzzle Training the motion detection technology in an area with webcam, mouse and keyboard; with Rhythm: motion detection in an area with webcam, mouse and keyboard; and it is intended to integrate Molobolos with the Wii Remote and Wii Balance Board.

V. A REAL CASE: "PUZZLE TRAINING"

This section describes the experience of one of the games, Puzzle Training, and its applications in the field of rehabilitation in order to analyze the results of the project. Moreover, we present the clinical results as the analysis of indications and contraindications of the relevant parameters in the hospital.

A. *Description*

Puzzle Training is a puzzle game developed by iBit Foundation to run on the platform Play for Health, under the functional supervision of a clinical team of Son Llàtzer Hospital Rehabilitation services.

The game builds a puzzle by selecting different pieces, against a variable background. It consists of 9 pieces that must fit together (see Fig. 2). At the start, the game requests the piece to be fit. There are three possibilities, one correct and two incorrect.

The execution of the game is based on different systems: recognition of a sequence number, color recognition and image recognition. The program treatment clinical team defines the level of difficulty determining the pace, speed, number of games and the duration in the patient's session.

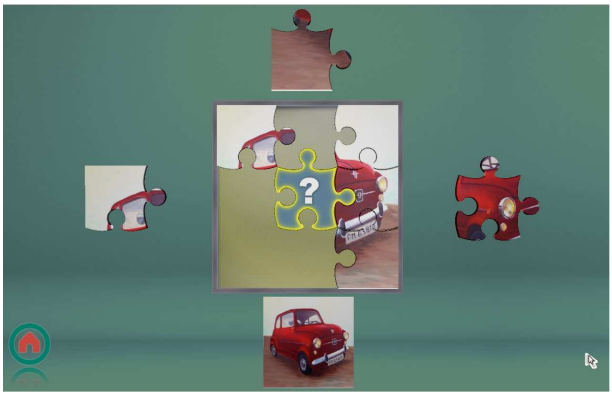

Figure 2. "Puzzle Training" screenshot.

B. *Interaction methods*

To date it is combined with Puzzle Training the motion detection technology in an area with webcam, mouse and keyboard. The methods of interaction intended to be used with Puzzle Training are:

- Detection of the palm of the hand through a webcam. It allows the detection of movement by using computer vision techniques. You can determine the position, velocity and relative size. Its handling does not require precise movement; it is possible to capture a global and gross upper limb movement when the user selects the correct puzzle piece that appears in different places on the screen (top, left or right) and also it allows use of the superior bilateral limb.
- Detection of a colored glove. It provides greater precision in the selection of the piece, upper limb coordination of shoulder elevation and elbow flexion and extension.
- Dance mat. It allows: improving standing balance (static or dynamic) and/or standing resistance (tolerance to the maintenance of that position); unipodal balance; the possibility of regulating the speed of stimulus presentation and response time; increasing the coordination of movement.
- Mouse. It allows focusing the patient's goals at the cognitive level. If the patient's requirements are physical, the use of this type of interaction permits to work the coordination shoulder - elbow - hand more accurately.
- Keyboard. It develops cognitive and mobility aspects of fine hand as is the identification of the fingers.
- Touch screen. It works the muscles of the hand: bidigital or three-digit clip, and the intrinsic muscles

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of the hand. It can be combined with lifting exercises and elbow flexion and extension.

C. Getting results

When the patient completes the scheduled session, it automatically generates a document showing the minimum and maximum reaction time, the environment characteristics, the medals collected by the patient, the number of hits and misses, medals for speed and skill, etc.

It has been established the measurement of the sessions of patients from November 5, 2010 until December 12, 2010.

The patient age ranges from 31 to 83 years and the types of diseases treated are:

- Multiple Sclerosis (4)
- Brown Sequard Disease (1)
- Cerebrovascular accident (CVA) effects (4): hemiplegia / hemiparesis.
- Supraspinatus rupture (1)
- Parkinson (1).

The objectives for the patients using Play for Health are:

- Increase / maintain balance unipodal / bipodal.
- Increase / maintain laterality.
- Increase / maintain joint range of shoulder.
- Increase / maintain joint range of elbow.
- Increase / maintain joint range of wrist.
- Improvement of flexor and extensor muscles.
- Increase of resistance.
- Improvement / maintenance of grip.
- Improvement / maintenance of heavy manipulation with finger exercises.
- Improvement of body image.
- Improvement of coordination and trembling.
- Improvement of hand-eye coordination.

D. Analysis of indications and contraindications

The indications for this game provided by the clinicians are:

- Improvement of the limitations caused by diseases of diverse etiology: traumatic, neurological, neuromuscular and cognitive, always requiring mobility training, cognition, speed, coordination and balance.
- Completion of a treatment to be taken place in a rehabilitation center.
- Keeping the patient's functional status in chronic stages of the diseases mentioned above.
- Occasionally as a substitute for inside hospital treatments.

The contraindications for this game provided by the clinicians are:

- Lack of patient acceptance.
- Severe cognitive or sensory deficits that prevent learning.
- Severe physical deficits that impede the management of interaction interfaces

VI. CONCLUSION AND FUTURE WORK

The results of the use and management of the platform by both patients and therapists are:

- Good acceptance by the patient.
- Relative ease of programming from the therapists.
- Dynamic and stimulating treatment thanks to the existence of multiple programs.
- It permits the individualization of programs (response time, difficulty level, location of stimuli, the possibility to repeat many times) and a record of evolution (response capacity, working time, trial and error).
- Robust so far except for the hand movement that is vague.

The difficulties to face are due to ignorance of the elderly population, mainly the use of new technologies and the difficulty of learning, which is probably higher for patients with acquired brain injury (large group of current users).

So far the tests are being made only in the occupational therapy department and have not begun at home. This will need monitoring the patient by the healthcare professionals.

In cases where the work is only at home, it will be important to keep contact with the therapist to avoid frustration and ensure collaboration and stimulation of the patient.

In terms of objectives achieved it has been perceived:

- Better use of health resources.
- Treatment tailored to the characteristics and outcome of patients.
- Improved adherence and acceptance of the treatment by patients.
- Increasing role of patients in their own rehabilitation process.
- Facilitation of the progression of the daily work of health personnel.
- Creation of a basic structure, on which to develop a treatment for various diseases.
- Use of low-cost but high implementation system.

It's planned the growth of the system on several fronts: first the use of new interaction technologies to recognize the movements with greater precision and reliability and second the repository of video games will be increased, thus multiplying the number of potential patients who may benefit from using the system.

This platform is not only intended for telerehabilitation. It can also be used in other medical areas such as chronic patients, social health and education.

Video games, in addition to be an entertainment, have many applications. Some analyzed and studied areas are:

- Education.
- Continuing education related to work through the training of certain skills to become professionals and experts.
- Social care, through training programs for the elderly, people with mobility deficits, etc.

The intention of the iBit Foundation for the coming years is to continue working on the technology developed within

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the Play for Health strategy, to extend to other areas and improve its functionality in general.

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