EPIK
Virtual Rehabilitation Platform Devised to Increase Self-reliance of People with Limited Mobility

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Abstract: In this paper we describe a virtual rehabilitation platform designed to improve balance of people with physical impairment using the Microsoft® Kinect® sensor. Different types of users can interact with the platform: Administrators, therapists, and final users (patients), using their own interfaces and modules. Six modules have been designed: Profile, Administrator, Evaluation, Therapist, Game and Results; but only four have been implemented so far: Administrator, Evaluation, Therapist and Game. The Administrator's module is used to generate a database of exercises. The Therapist's module allows therapists to configure the game training session using combinations of exercises from the database. The patients' or game module includes a 3D immersive environment, where they perform the prescribed rehabilitation exercises, previously configured by a therapist. The platform is in its first beta version and ready to be tested.

1 INTRODUCTION

The live expectancy in countries like Spain is about 79 years for males and 85 years for females (World Health Organization –WHO-, 2012). Different factors like medical advances, allow a lot of people to survive until their seventies or so far. However, in many cases elderly people suffer chronic illness and pathologies that reduce their mobility and make them being dependent. Nowadays, one of the health problems with a higher incidence in elderly subjects is stroke. The risk of stroke doubles every decade after age 55 (Mackay and Mensha, 2004). Patients who suffer a stroke spend prolonged stays in intensive care units and have a markedly higher mortality rate (Hornero et al, 2013). These patients usually suffer a paralysis that compromises their ability to perform activities of daily living (ADLs) (Nichols-Larsen et al., 2005). In order to maximize patient outcomes and reduce disability it is essential to carry out programs of physical rehabilitation (Saunders, 2014).

Some programs applied to stroke patients during the acute phase are based on Early Supported Discharge (ESD). ESD consists on attending to the acute stroke care and rehabilitation unit and pretend an early discharge from hospital performing a supervised rehabilitation program at home. These programs can reduce long-term dependency, the length of hospital stays and admission to institutional care units (Fisher, 2011; Fearon and Langhorne, 2012).

Nonetheless, what happens after the acute phase of a stoke patient? Should patients continue the rehabilitation programs in the chronic/late post stroke period? The Evidence Based Review of Stroke Rehabilitation states that there is strong evidence about the effectiveness of balance training programs to improve health-related outcomes. This review also asserts that task-specific gait training improves the gait after stroke, treadmill training alone (without partial weight support) increases gait velocity, and virtual reality training enhances gait recovery (Teasell et al., 2013).

The Spanish healthcare system does not provide these rehabilitation programs to stroke patients

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during the chronic phase of the illness. Stroke patients have to pay for these programs and have to attend to special health centers to receive the therapy. Nevertheless, what happens if patients live too far from the rehabilitation institutions? Moreover, how could patients continue and reinforce their rehabilitation at home?

Virtual reality systems, including video games, can help to reach this purpose. In a recently published review, it was concluded that video games improve health outcomes in areas like psychological therapy and physical therapy. However, the authors suggest that more rigorous Random Clinical Trials are needed to confirm this effectiveness (Primack et al., 2012). Other researchers denote an increment in the motivation of the patients towards physical rehabilitation (Kato, 2010; Chang et al., 2011), improvements in their motor skills and physical condition (Jansen-Kosterink et al., 2013) or, encouraging results for recovery of muscle force and power of the lower limb for individuals with chronic hemiparesis (Mirelman et al., 2010). These kinds of developments are cost effective since they can benefit a large number of patients and can improve patients' health.

Our multidisciplinary research group, which includes physiotherapist, professionals in physical activity and sport sciences, computer science engineers and telecommunications engineers, aims to design and implement virtual reality therapies based on serious games.

This paper shows the technical specification of a rehabilitation platform (EPIK) under development by our research group. EPIK is similar to other virtual rehabilitation systems like KiRes (Anton, 2013) that uses the Microsoft Kinect sensor to interact with the users. In contrast to KiRes, the administrator does not need to record his postures using Kinect to create new exercises, so the time that is needed to include a new exercises program into the database is significantly decreased. Gamification techniques such as an immersive 3D environment, game levels, game modes, velocity, game session time and victory points have been used to develop EPIK. For this reason, the patient enjoys a "game sensation" that increases his motivation, distracts him from his illness and engages him to the system decreasing the rate of neglect.

Other researchers (Su, 2013, Robertson et al., 2013, Rajaratnam et al., 2013, Pirovano et al., 2012, Muñoz et al., 2013), use Kinect based systems in the physical rehabilitation area. However, those works do not present a complete platform and do not either include gamification nor have been tested using random clinical trials. In a recent systematic review (Da Gama et al., 2015) it is pointed that a complete system must be developed to include aspects like therapeutic configuration, different exercise possibilities, guidance and feedback. EPIK has the aim to pave the way to resolve all these lacks.

At this moment, we have designed a random clinical trial (RCT), following the CONSORT recommendations (Boutron et al., 2008) to test this first prototype with users with reduced mobility problems caused by a stroke. The RCT has been performed in a physiotherapy research center. The patients are in the chronic stage of their illness. The results obtained in the tests will serve to improve the platform and obtain the first operative release.

2 METHODS

2.1 Purpose of the System

The aim of the system is to improve the level of independency of people with reduced mobility such as elderly, subjects with physical disabilities or physical damage, using a virtual platform for physical training.

Although anyone can use this virtual platform as a training tool, it has been designed with the aim of improving the balance of users with reduced mobility.

2.2 Technologies

The EPIK platform employs the Microsoft Kinect v.2 sensor (http://www.microsoft.com/en-us/kinect forwindows) to capture users' movements and includes a game module to train the users' body.

The platform has been programmed with Unity (http://unity3d.com/), a "game development ecosystem" able to create interactive 3D and 2D content and run it in multiplatform systems like Desktop (PC, Mac and Linux), Web, iOS, Android and consoles (i.e. Xbox, Wii, PS4).

The recommended hardware and software configurations for EPIK are: a Microsoft Kinect sensor v.2, a PC with Microsoft Windows v.8 or later with the Kinect drivers installed and the Microsoft recommended hardware configuration.

2.3 Main Features

The EPIK platform is comprised of these modules:

Profile module: it is used to maintain user's basic

information: username, password, permissions, patient's clinical records. This module is under development.

Administrator's module: it is used to create a database of exercises and classify them in levels. In each level we can create groups of exercises – specific human body positions that we call 'silhouettes'–. Thus, a level can have different groups. In beta version.

Evaluation module: it is used to evaluate the range of movement (ROM) of the user joints. In beta version.

Therapists' module: the therapist can design the game sessions for the user choosing groups of exercises. In beta version.

Results module: to analyze the evolution of the patient. This module is under development.

Game module: in the game module, two human figures are showed to the patient. The first figure is the virtual image of the user that is training, that is, the user's avatar. The second figure is a silhouette moving towards the user's avatar under a configurable velocity. The user must adopt the pose of the silhouette so that his avatar matches it in order obtain different scores in the game (Figure 1). In beta version.

Figure 1: The user's avatar (in first plane) must to adopt the position of the silhouette to imitate (in second plane). The silhouette to imitate comes towards the user's avatar with a predefined velocity.

2.4 Account Types

Depending on the type of user account, the user is able (or not) to access a given module in the EPIK platform, with more or less permissions.

Patient's account: if you have a patient account, you are the person who uses the platform for your physical training. You can access to the next modules: profile module with read permission, evaluation module with execution permission, game module to play the game sessions configured for you and results module with read permission.

Administrator's account: the administrator has full access to all modules with full permissions. His main job is to create the silhouettes by configuring their positions and save them in the database. The therapist uses this database to design the game sessions of a patient.

Therapist's account: a therapist has full access to the Therapist's module. In this module the therapist can see all the silhouettes of the database classified into levels and groups by the administrator using the Administrator's module. The therapist selects groups of silhouettes for each patient's game session. The therapist can access the rest of the modules with full permissions, except to the Administrator's module.

2.5 Modules of the System

2.5.1 Administrator's Module

In the Administrator's module silhouettes for a given level of difficulty can be created. Silhouettes can be generated by rotating the skeletal joints of an avatar up to the desired position (Figure 2). Silhouettes being generated can be grouped to ease the configuration of a rehabilitation session afterwards. The Administrator's module does not restrict the type of silhouettes that the administrator can create. It is the administrator who is responsible of following a previously agreed protocol about the type of exercises to be included on a specific level.

Figure 2: Window to create groups of silhouettes in a level.

This protocol has, for each level, the type of recommended movements. In Table 1 we can see the types of exercises that protocol has for level 1. A higher level should imply a greater difficulty. Our physiotherapists and professionals in physical activity and sport sciences have created this protocol

based in their experience with physically disabled patients. The protocol has six levels of difficulty. Here, we show only the first one, as an example.

In case that the protocol needs to be changed in the future, it would not be necessary to change any line of source code of the Administrator's module, because there are no restrictions to create whatever silhouette that the administrator desires.

Table 1: Type of movements for level 1.

Level	1
Description	Postures with trunk movements and unilateral upper limb movements
Movements	Shoulder abduction, horizontal abduction, shoulder flexion, shoulder extension, lateral trunk tilt, trunk flexion and extension
Detail	The silhouettes may adopt combinations of these movements always with bipodal support, legs hip width apart and knee totally extended. Body weight will be evenly distributed between both feet or more weight on one leg than the other.

2.5.2 Evaluation Module

The evaluation module measures the maximum ROM of each joint when certain movements are performed. These movements are defined in the evaluation protocol designed by our physiotherapists and professionals in physical activity and sport sciences (Table 2).

The patient stands opposite to the Microsoft Kinect sensor and can see his own representation in the screen (his avatar) on the right and an avatar performing an exercise that he or she has to imitate on the left (Figure 3).

Figure 3: Evaluation module.

Two performances of the same movements (Table 2) have to be carried out by the patient. The user performs the movements in real time while they are showed in the screen. When the two sequences of movements are finished, the system computes the maximum ROM that he or she reaches, using the information collected during the two performances.

All the movements start from a base position: the body erect with the arms at the sides and the palms forward. In each movement, the user tries to reach his maximum ROM and then, returns to the base position.

Table 2: Sequence of movements during the evaluation phase.

Abduction of the right shoulder, then left and finally both bilaterally
Flexion of the right shoulder, then left and finally both bilaterally
Horizontal abduction of the right shoulder, then left and finally both bilaterally
Extension of the right shoulder, then left and finally both bilaterally
Trunk tilt left and right. Trunk flexion and extension
Abduction right hip and then left (only exercise with unilateral support, not for hip abduction exercises in bilateral support)
Right hip flexion and then left (only for unilateral support exercises and knee flexion)
Bending both knees (squat)
Step to the right side. Step to the left side. Step forward with the right foot. Step forward with the left foot

2.5.3 Therapist's Module

In this module the therapist can configure the game session for each user. A game session represents the groups of exercises. It is possible to choose groups of silhouettes from different levels. For example: the therapist can choose two groups of silhouettes from level one, and one group of silhouettes from level two; or he can choose one group from level two, and one group from level five. There is total flexibility to select whatever the therapist wants.

2.5.4 Game Module

Once the therapist has created the game sessions for a given patient, the game module can be ran.

First, we select the patient that is going to play.

Second, we select the avatar.

Third, we select one of the sessions configured for this user.

Fourth, we set the next parameters (Figure 4):

Speed: time it takes for the silhouette to reach the user's avatar (Figure 1). A higher speed implies a greater difficulty.

Mode: this parameter is used to dynamically adapt the silhouettes to be played using a percentage of the maximum ROM that the user obtained in the

evaluation module. It is used to adjust the difficulty of the game session.

Table 3: Types of Game Modes.

Mode	% of the maximum ROM
Beginner	80%
Official	90%
Master	100%
Doctor	105%
Expert	110%

Suppose that, in the evaluation module, the user performed an abduction movement of the arm and his maximum ROM was 60º. If the therapist sets the game session mode to beginner, the user will need to rise his arm up to the 80% of 60º -48º- to obtain the best score.

Waiting time between silhouettes.

Length of session: duration of a training session. It is measured in minutes and seconds. The user scores when he adopts the correct posture, in other case there is no penalization. The concept of "life" does not exist. Users do not loss a "life" when they perform incorrect movements. The training session

Figure 4: Setting the session parameters in the game module.

Figure 5: The first round of the game starts.

Figure 6: The user playing.

continues until the end or until it is paused. The length of the session is a key configuration parameter from the clinical point of view.

In the last step, the game starts (Figure 5), takes place (Figure 6), finishes and saves results.

3 CONCLUSIONS

This paper presents the beta version of the EPIK platform. A new Microsoft Kinect sensor based system developed to improve balance through training sessions played in a virtual 3D environment. EPIK has a serious exergame that can be easily configured to include exercises oriented to improve patient's movements velocity, coordination, flexibility, etc.

All the EPIK modules have been designed with the support of physical rehabilitation professionals. Moreover, EPIK is being tested with stroke patients today. The results of these tests will be used to further improve the system and to have, in the near future, an effective rehabilitation-assisted technology with a real user centered design.

The aim is to construct a complete system using a low cost sensor like Microsoft Kinect that will address the evaluation and treatment cycle of a patient in a simple and inexpensive way.

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