Virtual Environment for the Treatment of Patients with Hemiparesis

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Abstract. This paper proposes the development of a Virtual Environment that facilitates the process of reeducation of the motor and sensory functions of a patient with hemiparesis, through the simulation of physiotherapy exercises. The methodology used for the development of the work was as follows: a characterization of the variables that affect patients with hemiparesis was realized, analyzing the factors that cause this condition, for the determination of the bases of the Virtual Environment; later a model of Virtual Reality Environment was designed that allows the interaction with the patient for its later implementation using a video game engine that leads us to obtain a prototype of applicability in the rehabilitation of patients. Finally, the results are validated with experts in physiotherapy using system tests to verify the rehabilitation of patients with hemiparesis, reviewing the acceptance criteria of the prototype.

Keywords: Hemiparesis · Virtual Environment (VE) · Rehabilitation
Physiotherapy · Kinect

1 Introduction

A Virtual Environment is a graphic representation of a real-world model that is achieved through a rendering process, where a 2D image is generated from a 3D image [1]. On the other hand, Hemiparesis refers to the decrease in motor force or partial paralysis that affects an arm and a leg on the same side of the body. This condition can result from strokes (affecting the blood supply of the central nervous system such as: brain, cerebellum and spinal bulb). It is noteworthy that Hemiparesis deserves special attention within the field of physiotherapy due to the disability problems it causes in the patient and has characteristics in common with Hemiplegic (paralysis of one side of the body) that can also result from this type of accidents [2].

New technologies in the field of health represent a great contribution to the improvement of people suffering from brain injuries, which is why the development of a Virtual Environment (VE) is planned to facilitate the process of reeducation of functions motor and sensory features of a patient with Hemiparesis, through the simulation of physiotherapeutic exercises.

Based on the foregoing, this environment aims to encourage and improve the patient's environment, so that discipline is originated in therapy, thus providing a

comfort zone, where the individual feels motivated to develop the exercises and recreates a set of enjoyable activities, which usually develop in a monotonous way.

This document is organized as follows: in Sect. 2, the characterization of the variables that affect patients with hemiparesis is presented; in Sect. 3, the design and implementation of the VE is detailed; in Sect. 4, the experiments and results are presented; and finally, the conclusions and future works are exposed.

2   Characterization of the Variables that Affect Patients with Hemiparesis

During the investigation, the variables related to this condition were analyzed, such as: the different factors and techniques for the diagnosis and treatment of a patient where the most marked symptom is Hemiparesis. Bobath [3] mentions that there are some special aspects and problems suffered by patients with this condition, such as:

- Body divided: The patient's body seems divided into two halves and one of them has nothing to do with the other.
- Postural tone: The postural tone of both sides is different. At the beginning the patient is limp and seems too weak to move the leg or arm.
- Relearning: The patient does not know how to move. You must relearn how to turn in bed, how to sit and lie down, how to stand, stand and walk.

Before starting the treatment, previously a Neurologist must have made a diagnosis to be later evaluated by the physiotherapist, in such a way that he can initiate a treatment; The first thing is to evaluate the level and capacity of the patient to perform certain exercises.

Given that Hemiparesis has characteristics similar to Hemiplegia (paralysis of one side of the body), Moreno [4], shows how it is a treatment of a patient with Hemiplegia (paralysis of one side of the body), where techniques are defined, which they are established depending on the recovery stages in which the patient is located, or the process in which the improvement has been stopped. These stages are:

1. Initial stage or stroke: in this phase it is possible to determine which hemisphere is affected, but its scope is unknown, it can take minutes, hours, days, months, etc.
2. Flaccid Stage: according to the affected hemisphere in this phase there is clear evidence of inhibition or flaccidity in the hemibody, such as, for example, the fallen shoulder. If the patient does not adequately control the neck, upper and lower trunk, it hardly controls the upper and lower trunk, thus passing to the next stage.
3. Stage of spasticity: if the patient reaches this stage it is because he managed to overcome the flaccid phase thus improving his reflexes a bit, but at this point, he may have muscular contractures so the activities must be adjusted to improve muscle tone to normal levels.
4. Relative recovery stage: to fight against the consequences that can occur due to the condition suffered, is the main objective of this stage, as well as to continue improving the functionality of the person so that he has the greatest possible autonomy, establishing a series of sessions and exercises.

This is why, in the developed Virtual Environment, the epicenter is located in stages 3 and 4 of Hemiparesis on the recommendation of an expert in physiotherapy, which indicates that in these stages there is already a diagnosis, a treatment started and with an initial advance, where the patient can train movements and responses, helping to strengthen their motor skills through software.

Fernándes [5] proposes a program of physiotherapy exercises for the rehabilitation of patients with Hemiplegic, which can also be applied for Hemiparesis in primary health care. Based on the variety, which are both for the treatment of the lower limb and the upper limb and that can be performed in the comfort of the house independently, although it is always suggested to be in the presence of a responsible adult, the following exercises are selected: for lower and upper limbs, according to Fig. 1.

Fig. 1. Selected exercises: for lower and upper limbs [5]

In the characterization carried out, the variables that can lead to the Hemiparesis condition were analyzed, as well as the stages by which a patient must pass to have a recovery. In order that the patient has interaction with the VE, the physiotherapeutic exercises are simulated and a pleasant environment is developed where the patient performs the exercises in a more dynamic and entertaining way that allows to continue, with the recovery process developing greater interest when interacting with the VE.

3   Development of the Virtual Environment

The VE design is performed, based on the characterized physiotherapeutic exercises and after that, a comparative analysis of the devices was carried out, to determine the most suitable for the detection of the patient's movements. Based on the above, the Kinect device was chosen, since it does not require controls, as well as, because of the possibility of detecting complete bodies and their movements due to the fact that the device has an RGB camera, also, it has a depth sensor that jointly allows to create a 3D map and the capture of the movement of the bodies.

The sensor has a limitation and consists in that being placed in a static position, it does not detect the complete movements of the body and all the extremities when it is located laterally, therefore exercises are chosen that allow the patient to be front or back to the sensor. One of the advantages of Kinect is that it is economically accessible for anyone.

To realize the design of this VE, we opted to use the methodology of video game design SUM [6]. The methodology aims to obtain predictable results, efficiently manage

resources to achieve high productivity of the development team; It was designed to be adapted into small work teams and for short projects. This methodology was used, taking into account designs of attractive environments, characters and elements that allow interaction and entertainment with the Virtual Environment, because it aims to develop quality video games in low time and cost, as well as the continuous improvement of the process, to increase its effectiveness and efficiency.

With this methodology it was possible to evaluate the progress of the work, which allowed to realize changes in time and make decisions to comply with the planned deadlines. In addition, the experience gained allows to improve the way of working in each activity and increase productivity.

The software used are: Unity because it allows to use it in conjunction with other 2D and 3D design platforms; Flash for its ability to create animations with special effects and professional graphics; and Blender, for its capacity of modeling and animation, for the creation of video games.

For the construction of the bases of the prototype, Lanning [7] proposes a series of items, which must be developed for any design methodology in a Video Game. Supported in this, the configuration items, characters and environments, problems, resolution/objectives and actions were identified.

In the simulation, the patient performs exercises with the amount of repetitions that the physiotherapist previously recommended to the patient. The patient will observe a virtual trainer who will indicate the exercises to be performed. The Kinect detects the movements made from these exercises and simulates them through an avatar.

The chosen environment is a natural landscape, to reflect an open and calm space. In addition, there are some types or musical genres that can motivate people to perform exercises, therefore, music is included for the patient to feel motivated. Because it is intended that the patient enjoy the exercises.

In the design, 3D technology features were incorporated and taking into account the characterization, environments and characters were simulated that give a different focus to the environment in which the patient is, allowing the immersion and interaction with the simulated environment; in this way, it allows the patient to feel attracted to perform the exercises and complete the repetitions according to what was proposed by the physiotherapist.

3.1   Implementation of the Virtual Environment

Moncada and Mateus [8], highlight the use of video game engines for the creation of simulators and games, which are also tools that have allowed the design and rendering of contents based on 2D and 3D technologies, as well as providing environments that adapt to the needs of the game or its objectives, introducing elements of the engine for interaction with the platform, known as Assets, which contain all export models for the construction of animations, sounds, scripts, characters, among other contents.

Unity was selected as a tool for the construction of the animations and content in the video game prototype, since it provides all the necessary elements, such as: open spaces,

land, textures and prefabricated models, which were taken into account for the development of each challenge and the necessary coding in order to achieve the objectives proposed in the work.

The Kinect Windows Software Development Kit (SDK) was used to create applications using Kinect sensor technology (for Windows 8, Windows 8.1 and Windows Embedded Standard 8), allowing the recognition of gestures and voice through C++, C#, Visual Basic or any other.NET language; in this specific case, C# was used. The integrated development toolkit includes sample applications with access to full source code, Kinect Studio and resources to simplify and accelerate application development, which was indispensable for VE development. This was downloaded from the Asset Store that comes in Unity for free.

In order to create the animations and contents of the VE prototype, to achieve the proposed objectives and to have a clear definition of the technical factors; Unity Software, was used to create the scenario (terrain, open space), movement of the characters and menu; while with the help of Software Blender, prefabricated models were implemented as characters and animations of them.

The VE for its execution requires few requirements in terms of video and processing, for which the rendering and performance properties were key points in its development.

- Main menu: A main menu has been designed that allows the selection of repetitions for the exercises as well as the start and exit options of the VE.
- Music Player: A rhythmic music player is designed on the main screen with the intention of motivating the patient and generating extra energy so that he is comfortable and can also practice the exercises driven by music. This includes buttons to play/pause, next and previous.
- Simulated Physiotherapeutic Exercises: The patient must initially choose the number of repetitions to perform in the session, before beginning to use the VE.

For the VE were implemented 3D objects that allow the movement of an avatar with the movements performed by the patient, the Kinect through the sensors throws information on the position of each of the limbs of the person in front of it, so that the information can be manipulated from a programming language that uses the SDK libraries.

In addition, the environment has a coach in which previously the movements that are executed have been created until the patient completes the exercises or wishes to move to a new one (to pass the exercise without completing the repetitions the patient must raise one of their two hands above the head) the screen where the avatar of the virtual trainer and the patient is located is shown in Fig. 2.
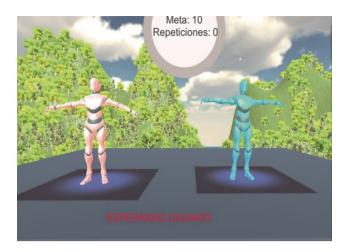
Fig. 2. Main view VE.

Based on the implementation, flexibility can be observed in the handling, export of 3D objects through the Unity Engine and integration with other tools, allowing to maintain an appropriate control for the coding of the necessary movements; likewise, the configuration required for the rendering of built environments does not require high levels of performance for the computer.

4   Experiments and Results

For the validation of the model, surveys were realized to experts, to a patient and not patients; On the one hand, the experts can consider, if the model and the VE are adequate and give the expected results; on the other, the patients are the people who benefit directly from the VE and also determine when interacting with it, if it is appropriate and of their liking. The surveys were conducted after these people interacted with the created VE.

4.1   Results of Surveys of Patients and Non-patients

The VE prototype is viable because patients find a new way to complement their treatment, whether implemented in consultation with the physiotherapist or at home, feeling attracted by the VE, dynamism and entertainment, with many benefits in the future. In addition to this, they found the VE of easy interaction and manipulation as a complement to their treatment to remember the exercises to be performed and how to perform them.

In Fig. 3a we observe a person who does not have this condition using the prototype, however, this person has interacted with a relative who suffers from hemiparesis, so he understands very well how is the treatment for these patients. In Fig. 3b a patient can be observed using the prototype.

a.   b.

Fig. 3.   Validation a. with non-patient user, b. with a patient.

4.2   Results of Surveys of Experts

The VE prototype is viable in an initial process of treatment for stages 3 and 4 (Spasticity Stage and Relative Recovery Stage) because patients constantly need to perform exercises with the amount of repetitions previously recommended by the physiotherapist and for this, it is not enough to only perform them in the consultations but also at home, so the VE serves as a complement to the treatment to be dynamic, as well as easy to manipulate, it is an option for the patient to feel attracted to execute the exercises.

5   Conclusions and Future Works

The Virtual Environments have been of great help in the field of medicine and physiotherapy, since it has been implemented in several areas with satisfactory results, both for the treatment of phobias, as well as diseases and physical conditions.

During the development of this work, it was necessary to investigate how patients can develop the condition of Hemiparesis and developed EVs, finding implementations of these in favor of reeducation, motivation and improvement of motor skills, which allowed to determine the video game engine to be used, the characteristics and the exercises to simulate.

It is for this, that, counting today with a variety of devices, motors of video games and tools with specialized features, can facilitate the construction of software for treating various diseases, illnesses and phobias, motivating the patient to perform the treatments when offering a practical alternative.

The VE prototype can be used as a complement to traditional physiotherapy, since it can define to the patient the number of repetitions to be made, either in consultation with the expert or in the comfort of the home.

As future work, it is possible to deepen and create a protocol (rules) for the patient's condition, in this way that is more personalized, because the rehabilitation process depends on the individual's progress. Therefore, it also considers the integration of other

devices that allow greater interaction with the environment and, in turn, a greater sense of immersion.

The creation of virtual environments in areas of health and psychology among other areas is also proposed, where it will generate greater interest for the execution of certain activities in patients.

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