VR TRAINING SYSTEM FOR POST-STROKE REHABILITATION BASED ON COMPENSATORY ANALYSIS

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SUMMARY

Stroke is one of the most common diseases that lead to impairment of upper limb dexterity. Nowadays, serious games are a common approach to help stroke patient's recovery. However, the lack of compensatory movement detection, during motor rehabilitation protocols, can lead the patient to learn new and incorrect movement patterns, compromising training sessions. Thus, this project consists of a system that differentiates real upper limb functional improvements from compensatory movement patterns, through a highly customizable serious game, with adaptable levels and tasks. Interaction with the game is done through a handle of a robotic platform. In the game, the subject must control a bird of prey to hunt and to run from predators. 3D motion trackers are placed in different points of the subject paretic arm to detect compensatory movements and to lead back the patient to correctly guide the bird of prey. Therefore, we believe that the proposed method will be a useful supporting tool for helping both the patient during his training sessions and the physiotherapist for better analysis of movements and more specific stroke rehabilitation protocols.

KEYWORDS

Stroke, Virtual Reality, Serious Game, Motor Rehabilitation, Compensatory Movement Detection

1 Introduction

According to the World Health Organization, stroke is the second leading cause of death in the world and occurs predominantly in middle-aged and elderly adults [1, 7]. Despite the large number of existing rehabilitation programs, the complete recovery of motor function, especially of the upper limbs, through conventional therapies, is still a challenge [4, 10].

An increasingly promising alternative for this purpose is serious games, which can promote neuroplasticity by providing task-oriented training, with high repetitions and adjustment of parameters such as therapy time, intensity, and goals [3].

However, the loss of limb functions requires major adjustments in interactions with the physical world. A common response to this loss after a stroke is to learn compensatory ways of a movement, including using the non-paretic hand. There are also compensatory changes in the coordination of movements of both hands and of the paretic forearm with the trunk [8]. Some forms of compensation are obvious, but others are subtle enough to go undetected in the absence of sensitive behavioral measures, making them easily confused with real recovery [6].

New therapeutic approaches are increasingly concerned with improving sensorimotor evaluative and individualized protocols, which integrate sensory rehabilitation for greater functional recovery of the upper limb functions and motor skills [4].

Thus, a serious game associated to a compensatory movements analysis, can prove to be quite convenient during rehabilitation. In addition, this approach allows individuals to perform specific therapeutic exercises in a pleasant and motivating way without learning inappropriate and harmful compensatory movements for their full rehabilitation [5, 9].

2 Objective

This work aims to develop an integrated system to assist in the motor rehabilitation of subjects with hemiparesis in the upper limbs resulting from a stroke. The system can identify compensatory movement patterns and differentiate them from real upper limb functional improvements, through a highly customizable serious game, with adaptable levels and tasks. Furthermore, it is intended to evaluate the adequacy of the developed system as a supporting tool in the rehabilitation processes. It is believed that such approach can also help the physiotherapist in the definition of more specific rehabilitation protocols.

3 Materials and Methods

The game was developed in *Unreal Engine 4*, and takes place in a forest, where the subject controls a bird of prey, being able to move freely in different directions and in suitable degrees of freedom, according to objectives and challenges to be met. Initially, three levels were developed in the environment, as well as an interactive tutorial. Each level has different objectives, working on specific movements.

- *Interactive tutorial:* The subject must follow the direction of some arrows. In this session, arm extension in four directions is trained.
- *Level 1:* The subject must pass through several rings scattered around the environment.
- *Level 2:* The subject must catch five fish in the lake. The capture must be fast and accurate, working with elbow flexion and extension.
- *Level 3:* The subject must capture five pieces of meat, while running away from predators. This level works on motor and visuospatial coordination, proprioception, and reaction speed.

The system also consists of a control panel, where the physiotherapist can register, change, and consult patient data, configure the general game parameters, select the game levels in each session and configure the challenges for those selected levels. Therefore, it is possible to create a custom execution protocol, configuring the sessions based on the therapeutic needs of each patient.

For the control interface, we built a platform for assisted support with a mechanism composed by two motors that can return assistance feedback. The physiotherapist can configure this assistance to generate an elastic force in the patient's arm, helping him/her in the execution of the movement, or restrict the movements to require greater muscle activation [2].

To capture hemiparetic limb movements, we use a network of four motion trackers developed by *HTC™ Vive*. The trackers are positioned on the subject's chest, arm, forearm, and hand. The chest tracker aims to identify possible compensatory movements related to the anterior and lateral trunk. The trackers positioned on the arm and forearm have the function of identifying compensations related to shoulder abduction and elevation, trunk rotation, and scapular movements. Finally, the hand-positioned tracker aims to synchronize the positioning of the hand with the platform handle.

To enable the motion capture, we developed a module in *Unreal Engine 4* that implements all these functions and, during the sessions, analyzes and sends all movements captured by trackers to the game, as well as saving them to a file. The saved file can contain both position and orientation of each of the configured trackers.

During training sessions, the patient interacts with the robotic platform by moving its handle. The positions captured by the platform are sent to the game, which are converted into the bird's movements. The game can also act on the platform through motor feedback. At the same time, the outputs of the motion trackers are captured, which allow the calculation of the joint positions of the shoulder and elbow. By evaluating the estimated trajectory for the bird, we can define the correct movement of the subject's arm to be performed. That is, from the outputs of the tracking network and the positions of the robotic platform, it is possible to calculate the difference between the angle executed by the individual and the correct angle for that movement (set by the physiotherapist). The resulting difference may be indicative of a compensatory movement performed by the individual. Taking this error as input, the serious game can adjust to, for example, alter the flight path of the bird in the opposite direction to the error, or even applying a counterforce to the platform motors, requiring the patient to seek for correcting his posture and movement.

4 Conclusions

As preliminary experiments, tests were performed with healthy volunteers. During the game, when any of the predefined compensatory movements is identified by the tracker network, the bird remains in the valid initial position, not obeying the commands until the correct movement is performed. For this identification of the compensatory movement, a threshold was defined for each sensor in the system. A good adhesion of the volunteers was observed during the sessions.

Therefore, the proposed integrated system can be of great value for the stroke rehabilitation process. This can offer tools to help stroke physiotherapist in analyzing the evolution and results during treatment. Through our serious game, working with the robotic device and the tracking network, it is possible to monitor the clinical evolution of the volunteers, by evaluating compensations in the affected upper limb compared to the healthy one.

We aim to use this system as a method of future stroke rehabilitation, since more efficient exercises can be offered to a larger set of engaged individuals.

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