Gamifying motion control assessments using leap motion controller

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Abstract. In rehabilitation, exergames and serious games are widely used in order to motivate patients in the therapeutic procedure. Patients are asked to modify their incorrect motor patterns or reinforce the proper ones through activity rather than exercise. Interactive applications as such, can have a huge impact on a patient's motivation making repetitive physical exercises into pleasant experiences, thus maximizing the gains of therapy. In this paper we present the design and implementation of a serious game platform based on virtual 3D game environment and leap motion controller for interaction. For each session, achieved goals and response to stimuli is recorded and analyzed. Preliminary analysis results from evaluating the game with healthy subjects are encouraging.

Keywords. Serious games, motion assessment, rehabilitation, leap motion

Introduction

In the field of neurorehabilitation, serious games and exergames are becoming popular. These are games of serious purpose that combine virtual reality with physical exercise [1]. They are widely employed as tools for the treatment of patients with motion difficulties, of neurological or myoskeletal cause [2], offering the possibility to execute a series of repetitive and functional movements efficiently [3], in a less monotonous and boring way [4]. Implementing the therapeutic exercise in a game environment, following an interactive scenario with goals, results in attracting the patient's interest and increases the adherence in the therapeutic procedure while at home. This is feasible with a prior learning process, along with the guidance of the therapist.

These serious games applications include the use of biosensors (accelerometry, ECG) and cameras (e.g. Microsoft Kinect, Leap Motion Controller), via dedicated APIs. They also include immersive interfaces, and user-computer interaction means, beyond the classical mouse, keyboard, and screen, which give the impression that the user acts inside the game environment, and translate the actual movements into actions in the virtual world.

Within this context, we present a novel serious gaming platform for motion rehabilitation. The proposed gaming approach addresses the need for alternative rehabilitation solutions that can be delivered anywhere with the use of modern exergaming technologies. An important aspect is the ability to use the platform at home, in unsupervised environment, while the progress and adherence can be monitored remotely via objective measures. Potential end-users of the system are a) individuals with motion disorders, b) physiotherapists and rehabilitation experts, rehab labs or institutions , who wish to add this service in their infrastructure.

1. Methods and Tools

In order to properly design and develop the serious gaming platform for motion rehabilitation the following requirements were defined.

- *Interaction through physical movement detected with biosensors*. The core interaction with the system must be performed using modern and intuitive HCI interfaces to allow replication of the actual physical movements that we need to restore/improve.
- *Movement associated with therapeutic - rehabilitation process and entertainment*. The games of the platform must be entertaining by using 3D virtual environment and by providing real-time feedback and goals that the user must achieve.
- *Support of both supervised use and unsupervised use.* The overall setup must be non-complicated to allow the use not only in a controlled environment but also in the users' home after a few demonstrating minutes at the lab/clinic.
- *Low cost infrastructure*. The platform must rely on low cost consumer based hardware. The use of medical specialized devices and high-end hardware must be avoided.
- *Monitoring of response via stored activity data.* The platform must store acquired data in a format that can be analyzed. While analysis and visualization tools can be performed out of the game using proper analysis tools.

Based on the above requirements we have chosen Leap Motion controller as the interface to use for the interaction between the user and the games. Leap Motion Controller is a motion sensor based on IR cameras with high accuracy in a bounded scope, it tracks with high detail the hand and individual finger movement. Also is a consumer device available at low cost and it is easy to install and setup.

The software development was based on Unity3D. Unity3D is a popular game development platform, a powerful platform with numerous options and embedded functionalities and it also offers an easy learning curve and fast prototyping.

1.1. Description of Functionality and Implementation Details

The motion. The game metaphor is based on the metaphor of a virtual object, the motion of which follows the actual motion of the user's hand. An airplane was selected as the virtual object - avatar. The goal was to repeat specific movements as many times as possible, without any confusion for the patient, which lead to the selection of an infinite-length path as the avatar field of action. Actually, the avatar is static in Z axis (back-front), and the impression of movement is given by the relative movement of the background towards the avatar. This offers better control over the medically defined movements.

The targets and the scores. While static on the Z axis, the avatar must move and rotate in the XY plane, in order to pass through 'gates' appearing in steady rate at different parts of the screen. This guides the hand motion and rotation, and generally the motion control of the hand. This control is assessed by a game score, based on the gates that were successfully passed.

Customization. The game is extensible and customizable. The system parameters are: a)window size: depends on the hardware, b)gate appearance rate: defined by the clinical expert, c)Gate appearance position: currently positioned on a 3x3 grid and d)rotation angle sensitivity: tailored to the patient and expected results

In Unity 3d the whole implementation is organized in *scenes*, viewed by the user. The basic components are the *Game Objects* (GOs). The *prefabs* are predefined GOs with known characteristics (rotation, scale, meshes), that build a scene. In the specific game, these are a) Airplane avatar whose motion reflects the actual hand motion, b) the gates - waypoints, and c) the terrain that makes the infinite path.

A certain number of prefabs is constructed that alternate each other and give the impression of the infinite spanning path. Certain scripts handle filtering and storing the output of each session. In the prototype as session output is defined the trajectory of a patient's hand movement throughout a session, saved as a signal and a list with all the gates and their corresponding attributes. The objective of saving these data is to monitor a patient's condition and derive information regarding his performance and his overall improvement after a set of therapeutic sessions. The aforementioned design and development has taken place in an agile manner, in short design-develop-test iterations, and in a multidisciplinary collaboration. In each cycle there was a series of tests with experts and healthy individuals that gave us insights and feedback as what were major drawbacks that they detected though the game sessions

2. Results

The platform was designed to be simple and intuitive in use, yet not lacking in functionality. As the loading of the game completes, a "Menu" scene follows that gives the candidate user three options: start the game, change the parameters or quit.

The airplane can be moved across x and y axis and rotate around z axis (optional). The gates, move towards the avatar of the player and the game’s objective is to guide the airplane inside these rectangular objects. The user or his appointed clinician can adjust the speed of the gates and their distance between them. This determines how fast the user will need to react in the game. There is also the parameter for ending one session, that may be a time limit or a specific score to reach. (Figure. 1)

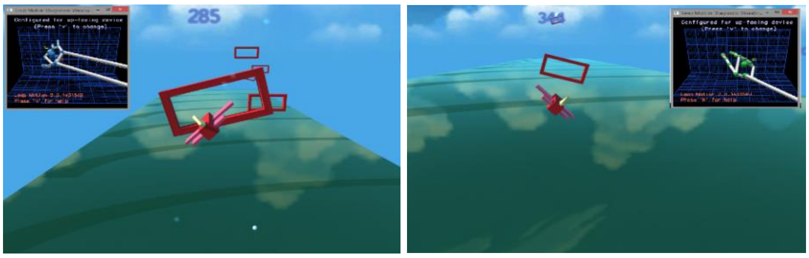

Figure 1. Hand’s movement (visualizer) translation into game movement

The graph below is an attempt to visualize how the patient’s hand moved during one game session in accordance with the waypoints. It may be presented as a line plot, but in reality it is a consolidated figure of the (x, y) positions of the airplane avatar in chronological order. This sequence of motion points and gate-objects is available in each session for further analysis, and actually constitutes the basis for the creation of quantitative metrics for comparisons, of rehabilitation progress among others.

The platform has been tested so far on healthy individuals, whose data were used to produce the above figures. They provided positive feedback and a number of detailed observations about motion handling of the avatar and the general functionality of the serious game. There was also a successful test with one patient for feasibility purposes, but the results were premature to be interpreted as an actual evaluation of the system.

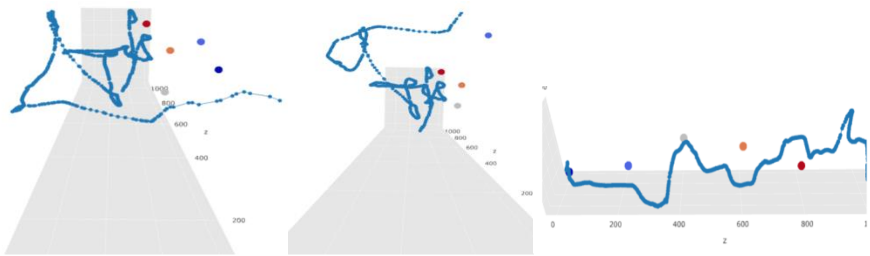

Figure 2. Reconstructed visualization of the actual hand movement and the position of the presented waypoints. Z-axis corresponds to game time.

3. Future Steps and conclusion

In the previous sections we presented the rationale and the implementation of a serious gaming platform for motion rehabilitation. The implemented prototype game developed on Unity3D gaming platform leverages Leap Motion controller to interact with the user's hand and proposes how to organize the goal setting, customization and scoring for the serious gaming purposes. At the moment, this framework is limited to a specific range of motions and game paradigms. Since initial results seem promising, future steps include a small-scale study involving patients with problems on the motion control of upper limbs, that will possibly reveal any limitations. Also, further analysis of the recorded data will provide additional insights on the game's effects on the disease and the analysis modules. Processing data from each session, will be performed in almost real-time conditions to provide detailed feedback to the patient as fast as possible. Another scenario that must be investigated is the synchronous acquisition of additional signals (e.g Electromyography, EMG) to examine the correlation between stimulus and actual motion in patients and in healthy subjects, and extend accuracy to a wider range of movements.

4. References

[1] Nunzio Alberto Borghese, Michele Pirovano, Pier Luca Lanzi, Seline Wüest, and Eling D. de Bruin. Games for Health Journal, 2013

[2] Barry G, Galna B, Rochester L. The role of exergaming in Parkinson's disease rehabilitation: a systematic review of the evidence. *Journal of NeuroEngineering and Rehabilitation*, 2014

[3] S. Ens, R. Pelletier, T. Jarus, D. Rand A. Neil, "Sony PlayStation EyeToy elicits higher levels of movement than the Nintendo Wii: implications for stroke rehabilitation," European Journal of Physical and Rehabilitation Medicine, 2013,13-21

[4] Laver KE, George S, Thomas S, Deutsch JE, Crotty M. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev, 2015