Gamification of physical rehabilitation using Kinect and EEG

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Current issues in physical rehabilitation after stroke

Stroke is a medical emergency caused by a blood clot or bleeding in the brain and is a major cause of severe physical disability since motor impairments are present in majority of patients. Rehabilitation usually is a long process and only a small portion of patients are able to quickly recover completely to the state they were prior to stroke. While stroke can occur at any age it is much more common in the elderly. 6 months after surviving an ischemic stroke, hemiparesis (weakness of one side of the body) is present in 50% of patients aged 65 or older, 30% are unable to walk without assistance and 26% are dependant in activities of daily living. Physiotherapy is a large part of every stroke patient's rehabilitation process. Performing exercises designed for stroke patients not only improves their motor abilities but also help reduce some of the cognitive impairments as well as reduces chances of depression and apathy. While the size and location of the lesion are the main determinants of the functional skills that can be regained after onset of stroke, the time and effort spent in rehabilitation also play a significant role. Most of the recovery occurs shortly after the onset of stroke (within the first few weeks or months) but additional functional mobility skills can be gained with repetitive practice being amongst the highest enabling factors. During patient's stay in hospital a physiotherapist oversees the exercise regimen but once at home it is the patient's own responsibility to keep exercising. Post-stroke fatigue and depression are significant obstacles for many and can significatnly reduce the motivation to exercise. It has been shown that regular exercise can reduce both fatigue and depression therefore an attempt should be made to increase the motivation level of the patient.

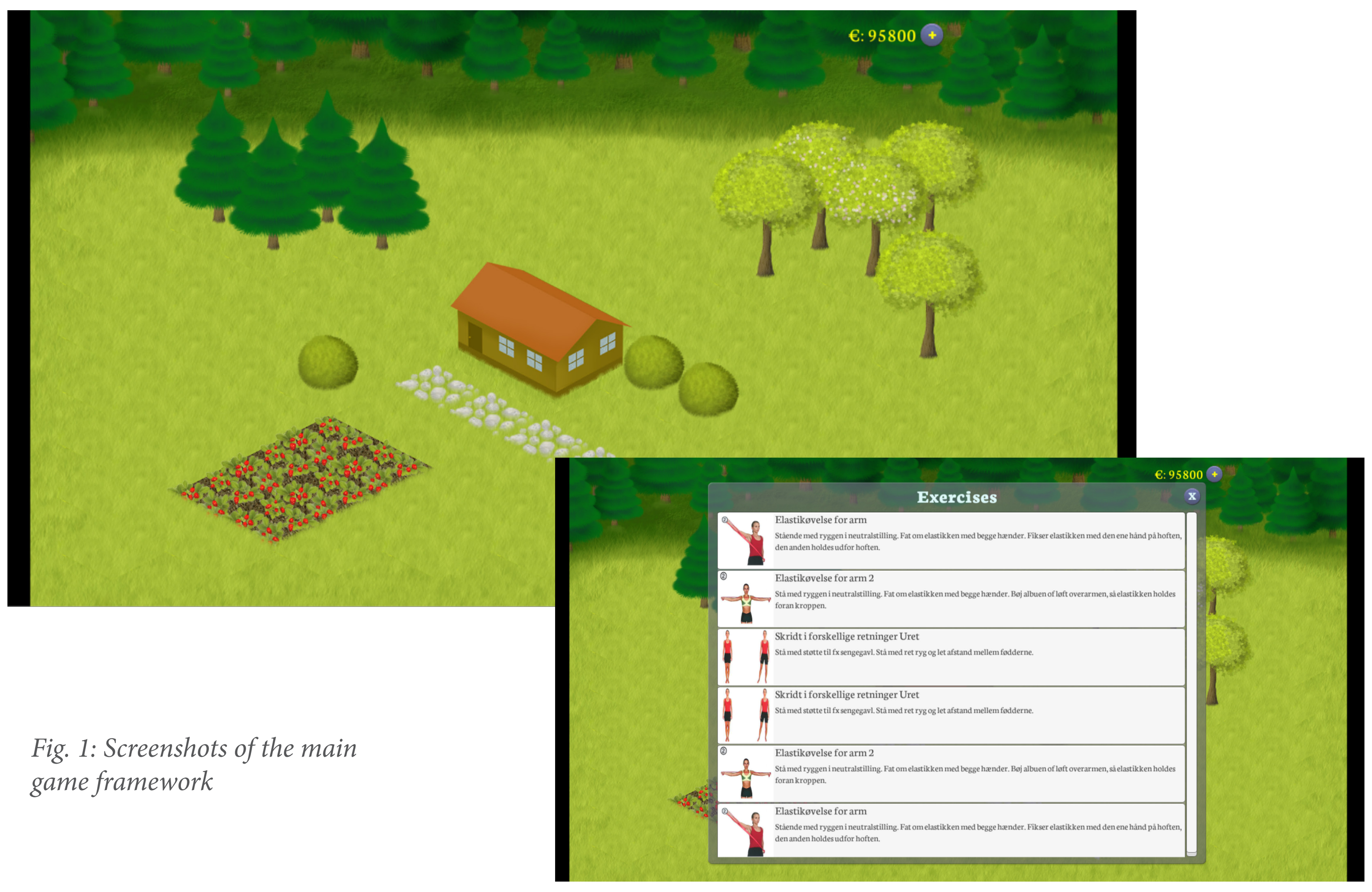

Fig. 1: Screenshots of the main game framework

Proposed solution

A sytem for physiotherapy that would motivate the patient to exercise more while requiring minimal involvement from medical personnel could certainly improve the likelihood of patients' commitment to long-term exercise plans. We therefore propose the development of a system that could be used at the patient's home and use various sensors to monitor the quality of the performed exercises.
Gamification has been proven as an effective way of making many mundane tasks more exciting therefore implementing game mechanics in physiotherapy. When developing a game for stroke patients which mostly are in an older age group there are several aspects that should be taken into account. Due to the fact that most of these people spent the majority of their life without a computer, they require a higher degree of instructional support. A study done on four focus groups of participants aged 66-79 years found that most of them prefer games with familiar content. Almost all participants showed a strong dislike towards violent content, which they assume is present in many modern video games. Casual games like FarmVille however have gained popularity among all age groups. This type of game is therefore very suitable to use as the main framework since it has a relatively familiar setup (resembles real world quite closely) and induces no stress while playing. Ideally the game should provide the player only with positive feedback for using it thus promoting the main goal - regular exercise.
The player will advance through the main game using in-game currency that can be earned by exercising. Exercises used in physiotherapy are versatile therefore the easiest approach is to convert each or several similar exercises in minigames. Depending on the motor abilities of the patient we propose the use of two sensors to monitor how well the person is performing the exercise. For a patient who cannot produce visible movements an intention for a movement can be detected in the EEG readings. If the patient is able to produce voluntary movements a Kinect sensor can be used. Both methods are described more in detail below.

Electroencephalography (EEG)

Fig. 2: EPOC headset

Electroencephalography (EEG) measures voltage fluctuations near the scalp caused by brain activity by using electrodes placed either on or under the scalp. Information in the nervous system is conveyed via ionic current flows which in turn cause electrical activity also at the scalp level. In the recent years more an more consumer grade EEG systems have emerged. Perhaps the most popular one is the Emotiv which has made two types of headsets - EPOC and Insight. Since Insight headset has only 5 sensors, EPOC headset with 14 sensors is more suitable for this project. Compared to clinical EEGs the EPOC is significantly cheaper and relatively easier to set up.

What can be retrieved from the data?

In the EEG recordings certain rhythmic activities can be noted. Alpha rhythm is defined at 8-13 Hz frequency with maximal amplitude in the occipital regions of the brain, best seen when the person is relaxed or drowsy. Beta activity is defined at a frequency 14 Hz and above. It is present in the background of most subjects and is normally symmetrical, however in case of a remote infarct inter-hemispheric asymmetry may be present. Theta activity is defined at 4-7 Hz frequency and is usually present in waking adult EEG. These rhytmhs are to some extent present all the time but Mu rhythm is only present when the person is still and is attenuated with movement (either real or imaginary) of a limb on the contralateral side of the body and thus is useful in this project. It is a rhythmic frequency at 7-11 Hz and is found in the central derivations of the motor strip and is usually detected in the C3 and C4 sensor locations. In the figure to the right the original placements of the electrodes for the EPOC headset can be seen. In this project the electrode placements are slightly adjusted, tilting the headset slightly back and thus positioning the F3 electrode closer to the motor strip.

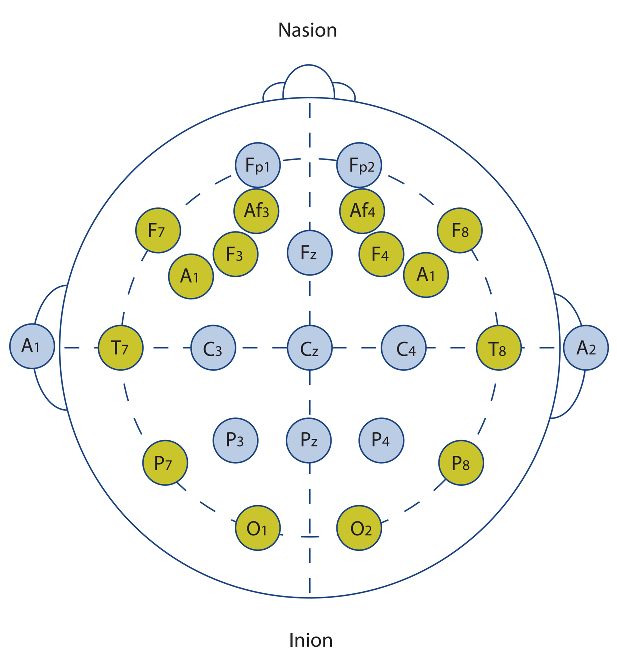

Fig. 3: 10-20 electrode placements , EPOC electrode placements marked in green

After recording the readings from each of the sensors a Fourier transform can be applied to analyze which frequencies are more common in the signals. In figures 4 and 5 you can see the frequencies for 25s long recordings.

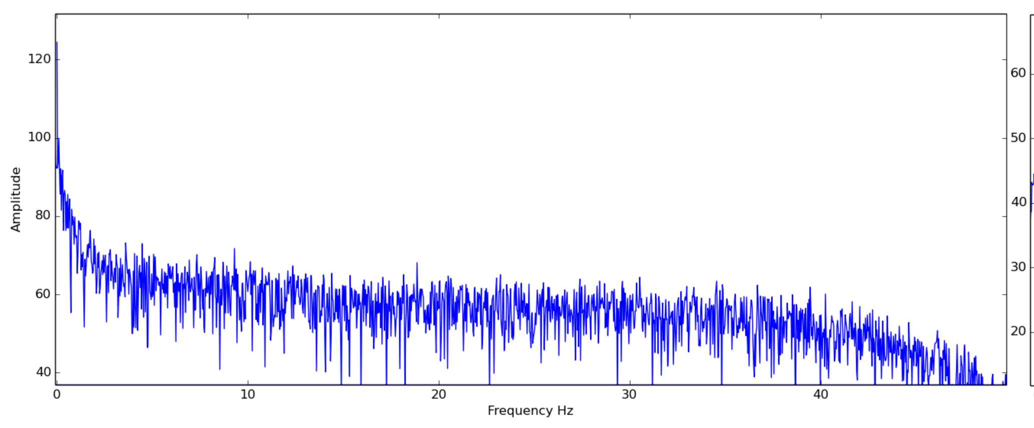

Fig. 4: frequencies for F3 electrode while moving arm

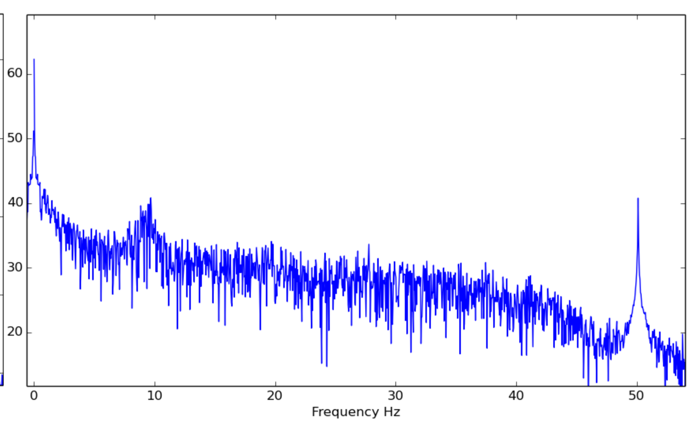

Fig. 5: frequencies for F3 electrode while resting

While moving, the frequencies are distributed rather uniformly but in the resting state a peak at around 9 Hz can be seen. It should be noted that the peak at 50 Hz is a common noise artifact and should be disregarded. The peak at the lower frequencies suggest presence of Mu rhytm.

How can this be implemented in games?

Currently using this analysis it is possible ot detect if a limb is being moved on either side of the body. Since Mu rhythm is localized to the body part map on the motor strip, placing more electrodes along the sagital axis could provide more detailed information for the body part being moved. A realtime analysis for the presence of Mu rhytm can be used as input for controling simple games substituting for example a press of a button.

Kinect

The use of Kinect on clinical applications, specifically on physical rehabilitation, is not a new concept. There are several studies on this area and there seems to be an increasing interest on this topic. Motion-capturing systems using traditional RGB cameras have to deal with two main limitations, namely perceiving the human body when the background is cluttered or has a similar color and the use of additional clothing or markers to guarantee the motion tracking. Despite these limitations, the results of the studies prior Kinect were shown to be at least as effective as conventional treatment.

Fig. 6: Microsoft Kinect sensor

What is Kinect and why use it?

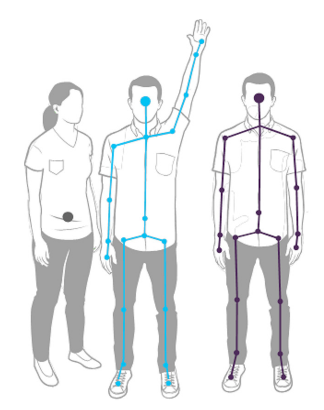

Fig. 7: Kinect skeletal tracking

Kinect is a motion sensing device from Microsoft. It consists of an infrared camera and sensor, a color camera, a microphone array and an accelerometer. By using the Kinect sensor, users can interact with a console or computer using body gestures and spoken commands, known as Natural User Interface (NUI). Kinect comes with a software pipeline that converts information coming from the infrared depth camera into the skeleton joints in the human body on real time and therefore is able to recognize and track a human body. Figure 7 shows the joints that can be tracked with the Kinect, giving developers enough information and flexibility to create new applications using NUI.

How to use it in physiotherapy?

The Kinect and its skeleton tracking capabilities will be used to recognize different gestures, such as raise a hand, do a squat or move a leg to the side. These gestures correspond to the different exercises the patients could do. Gestures consist of three states, namely, detected, in progress and completed. Another relevant concept is the patient's profile which defines the exercise routine for a patient. It includes information such as what kind of exercises, how many repetitions, for how long or what should be the amplitude of the movement. Using the information from the patient's profile when performing simple calculations on the position of the joints of interest, will enable the transition between the gestures states for a particular patient. The gestures, its states and the patient's profile will define the interface for controlling the different minigames the patient will play in order to perform his/her exercise routine.
Patients will receive visual feedback while performing the exercises. This will give them the possibility to correct their body postures, know what is the goal (duration or repetitions) for each exercise and, hopefully, prevent injuries due to badly performed exercises or over exercising. Below you can see a one of the mini-games for training arm inspired from an old arcade game where raising an arm is used for controling gun on the spaceship.

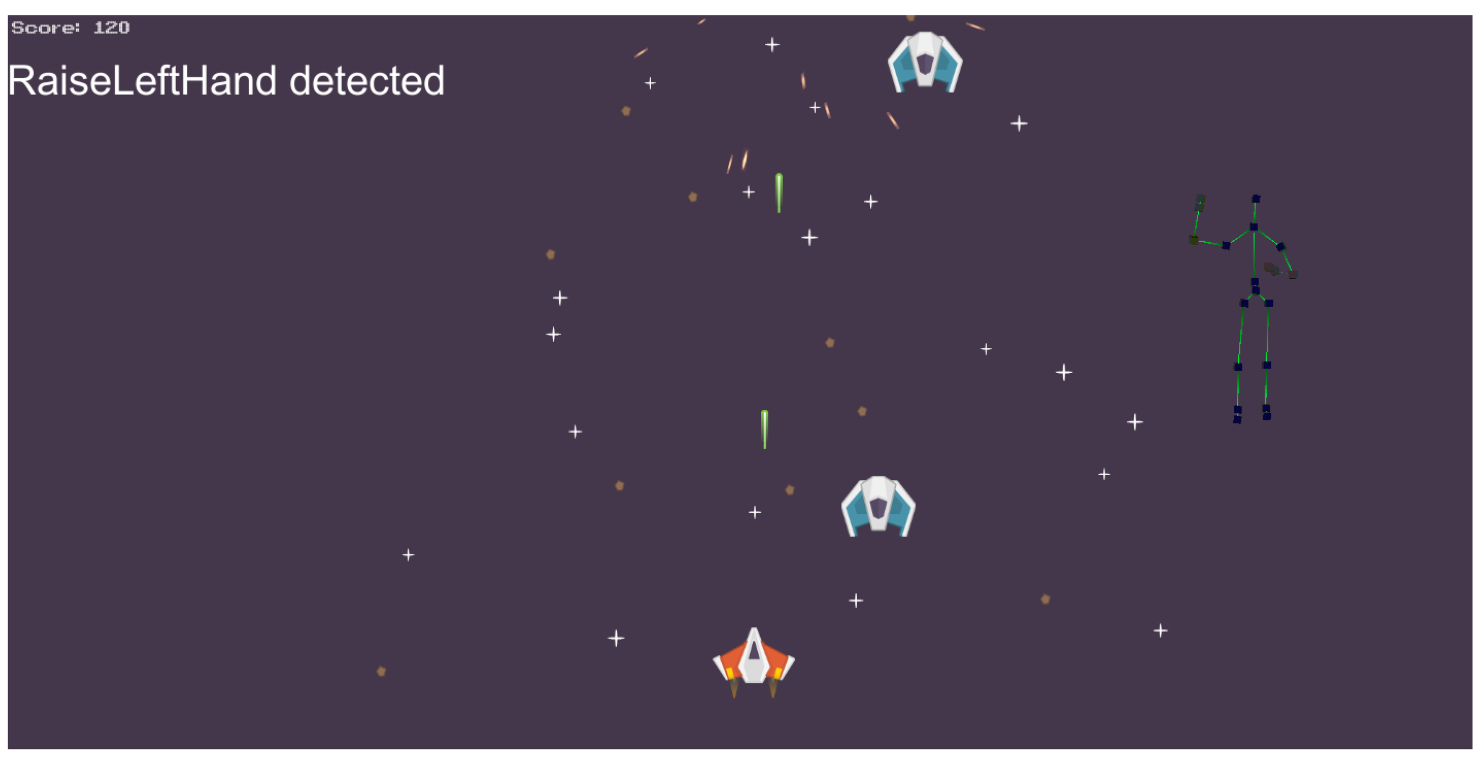

Fig. 8: Screenshot of a minigame using Microsoft Kinct sensor