Physiosoft – A Fun Low-Cost Auto Feedback Tool for Physiotherapy

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Abstract—Physiotherapy uses repetitive movements to restore, maintain or develop full body movement and motor function. Physiosoft is a low cost visual based goal oriented auto feedback mechanism that complements the work of a therapist. The system simulates motor and cognitive therapeutic exercises in the treatment of specific injuries by using physical visual markers which are attached to the location area to be treated of the patient and are tracked with a webcam and image processing. Specifically the patient needs to center the visual marker which he/she sees in the webcam image with planned circle positions that are overlayed in sequence on the webcam image. By centering all planned circle positions, the patient completes the intended prescribed movement by the physiotherapist.

Physiosoft enables the physiotherapist to time and set performance objectives and at any time review the status/outcome of any session from a particular patient. We believe that visually engaging a patient and providing auto-feedback of movement and results in realtime alike in a computer game, helps achieving the objective of the therapy. We present initial results and lessons learnt from using Physiosoft with real patients that we believe can be useful for similar approaches in the future.

Index Terms—physiotherapy, OpenCV , serious game

I. INTRODUCTION

The goal of this project was to develop a system that would support and simulate physiotherapy sessions by means of an interactive environment. A WebCam allows the user to interact with the application through the interpretation/recognition of visual markers placed to his/her body. The motivation of this work was the realization that many physiotherapy exercises for some kinds of lesions could be designed with a computer system and catered at home rather than at an extra cost in travelling long distances to a clinic, and with potential long daily waiting times.

At an initial stage, a therapist is essential to assess a patient, design exercises and set objectives. Each exercise consists of a series planned circle positions that make up a movement path. Each planned circle position is displayed overlayed in turn on the webcam image that the user sees on a screen or projection wall. The user needs to center the visual marker on each circle of the planned movement path in turn (Figure 1). When one set position is reached, the next position circle is displayed thus re-creating the complete intended body movement.

Figure 1. Physiosoft system set-up. The patient’s pose is captured by the WebCam and is either displayed on a computer screen or projected on a wall. The patient wears a highly reflective circular marker attached to his body by means of an elastic band. The system recognizes circles and plots a green circle on the screen where the detected circular marker is. The user must move his body part so as to center the green circle in a target outlined yellow circle to complete part of a designed motion path.

The main objective of this work thus was to design a system that a therapist would deem useful in treatment, allowing the design of exercises for a variety of lesions, the log of patient sessions at the comfort of their home and the ability to review their performance.

The structure of this paper is as follows. In Section II we review related work, in Section III we describe Physiosoft and the designed exercises. In Section IV we present results. Finally, in section V future work is outlined, followed by conclusions.

II. RELATED WORK

The field of physiotherapy is extensive, in this paper we highlight the main approaches that use computers to help assess and rehabilitate a patient.

Computerized dynamic posturography evaluates oscillations of the body by registering the pressure exerted by the feet on a platform that measures force. These systems also allow one to analyze shifts in the center of gravity of a patient and muscle activation by using filming facilities, pressure plates and electromyographs that measure the electrical activity produced by skeletal muscles. A study using this system is described in [9]. Moving platforms are essential to the study of balance and posture, the STATITEST™ [5] is a multisegment posturography system that is composed of a platform with an area of approximately 1m², 2 sensors (e.g one attached to the head of the patient, and the other to the hip), by two screens (one positioned in front of the patient,
and the other positioned in front of the therapist) and an antenna that can be positioned on the floor near the feet of the patient. This antenna produces a magnetic field, and the changes to this field during the exercises are captured by the two sensors. Stabilograms are then presented on the screens, and the strategies a patient uses to retain balance can be pinpointed and corrected if necessary. An example study that uses the STATITEST is described in [2]. One very interesting interactive application that is used with the STATITEST is a game called the apple game, where the patient is represented as a snake on the screen, and has to move his center of gravity in order to position himself on top of apples, nests or balloons to destroy them, the game ends when all objects have been destroyed or when a maximum time specified by the therapist has expired.

The Balance Rehabilitation Unit (BRU™) is a Virtual Reality System and force measuring platform that was developed specifically for the treatment of patients with balance disorders. Developed by Medicaa® [5], the system has three modules: posturography, rehabilitation and posture training. BRU creates virtual 3D images that recreate real world situations that induce dizziness, it is possible to train the reflexes that are present in balance, by using visual stimuli such as changes in depth perception and movement velocity.

The posturography module assesses balance in ten sensorial conditions; the rehabilitation module allows one to practice different movements and oculomotor reflexes using a variety of visual stimuli (foveal, retinal and sensory integration); the posture training module uses interactive games that allow one to increase the stability limit of the patient and train posture strategies. An example study that uses BRU is presented in [3].

In the systems reviewed here, auto-feedback appears to be a common element that is important in rehabilitation. In the past, several accessories have been developed that enable one to interact with computer games by using our body. Nintendo created the wii-remote [6], Sony created the Playstation eye [7] and move [8] and Microsoft created the Kinect [4]. Although these accessories have not targeted Physiotherapy directly, as more control is available with this type of devices, one can expect developers to create Physiotherapy applications for home use.

III. PHYSIOSOFT

In this section we first present the general set up of Physiosoft, describe the markers used and the Physiosoft application components before describing the exercises that were designed with our system.

A. System set-up

The system is comprised of a desktop computer, a computer screen or projector, a WebCam, a highly reflective marker attached to the part of the patient and the Physiosoft application (Figure 1).

B. Markers

In order to help the system detect markers, we used a highly reflective tape to make circular markers. This material alike highly visible strips worn by night joggers provides high contrast with the rest of the scene. The markers are attached to a particular limb or head by means of an elastic band.

In order to make a particular session more difficult for the patient, rather than for the system, the marker’s physical size was not changed, and instead the radius of the system response circle when the marker was detected could be changed (Figure 2).

C. Physiosoft Application Components

The Physiosoft Application has three main components:

- The main user interface
- The system administration interface
- Image processing and circle detection

The main user interface is shown in Figure 3. It has three areas, user login on the right, exercise category information, difficulty level and change level option on the bottom area, finally the background area where the WebCam image is shown with the target positions of the exercise plotted in turn with yellow outlined circles. The logical sequence of target positions form the intended movement for the patient to follow. The reflective marker is placed on a specific location of the body according to the area or function being treated.

In the background area of the main interface, the system response, the marker’s circular shape is detected and is also plotted with a green full circle. Finally, the moment a user starts a session the time required to center the marker on the position of each target circle is logged to a file and is plotted on the background image when the task is completed (top right of the background image of Figure 5).
The system administration interface is accessible when the user with administration rights logs in (Figure 4). In this interface the therapist can register or delete a patient, register the type of ailment(s), assign one of four categories of exercise, and access user performance logs.

The third component of Physiosoft is its real-time circle detection capability in the WebCam image. This is achieved with the Emgu CV [1].Net wrapper to the well established OpenCV image processing library. Specifically we use camera Capture, convert image frames to greyscale, and use the HoughCircles routine to retrieve a circle if present. We then calculate the distance of the center of the target circle’s (yellow) to the center of the detected circle (green) to trivially reject the position of the user’s marker. If the distance of the marker’s center to the goal target center is smaller than the radius of the goal target, the outlined target yellow circle is plotted as a full yellow circle and a message acknowledging the success of the task is shown to the user (lower right of Figure 5).

D. Exercise Design

The input of a professional therapist is always necessary when designing exercises, to define distances on the screen and define postures. Each of the developed exercises can be performed in a variety of ways in the application of everyday tasks, for example placing a glass of water near the mouth following a given pattern and coordination of correct movements.

D1. Exercise – spinal column

In order to interact with the geometric shapes on the screen, one needs to lean forward, flex and stretch the neck. The goal of this exercise is to improve the amplitude of movement of the neck and strengthen the associated neck muscles, thus relearning of how the movement is performed. This exercise is performed from the seated position (Figure 5).

D2. Exercise – Reach and object manipulation (drinking glass of water)

The main movement required for this task is made by the shoulder joint; hence the sequence of target position follows an arc configuration (Figure 6).

The goal of this exercise is to facilitate the movement of the arm in a coordinated manner and to increase the amplitude of the movement.

The marker is placed on the glass of water.
D3. Exercise – Rehabilitation of the movement pattern of clenching the fist

This movement pattern is characterized by victims of stroke, where in most cases tasks involving the affected segment are impossible, for instance opening and stretching the hand. The movement with which the marker interacts with the figure on the screen forces the extension of the fist (Figure 7).

The goal of this exercise is to rehabilitate the movement pattern and reposition the affected structure (fist).

D4. Exercise – lower body (hip and knee)

In the same way that it is possible to perform a variety of exercises for the upper body, it is possible to do so with the lower body. Specifically for the segments that perform the main movements: hip and knee.

The goal of this exercise is mostly to rehabilitate the flexion of the knee at half amplitude, and full amplitude of the hip, along with the capacity of the individual to remain standing on one foot whilst bending the support leg. This exercise allows the patient to improve their balance (Figure 8).

IV. RESULTS

The designed exercises were intended to be accessed mainly by health professionals or autonomously only by patients in an advanced stage of recovery. At this pilot stage, testing with patients at earlier stages of recovery was not allowed.

When testing Physiosoft with four patients in advanced stages of recovery the following system points were identified:
- Establishing the distances between targets on the screen when designing an exercise can be challenging. In most cases, much smaller distances were required.
- The room used in the therapy requires a strong ambient light, and should have a plain background without circles to prevent erroneous marker responses.
- The patient should also have plain clothing to avoid erroneous marker responses.

V. FUTURE WORK

We would like to extend the System Administration interface to allow the therapist to create new exercises, assign more specific goals and more exercises.

CONCLUSIONS

Physiosoft proved to be more complete than previous work in terms rehabilitation as it was easier to use and allows one not only to treat balance and posture control, but it can be used to fortify and increase amplitude of movement of each segment.

Whilst Physiosoft does not provide the interactivity provided by BRU and STATITEST, it gives visual feedback that appears to be as effective as the mentioned software systems.

We received positive feedback from health care professionals involved in the project. Approval from Hospital officials to be used at a larger scale is pending.
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