

Tele-Rehabilitation Serious Game

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Abstract – The musculoskeletal system is a complex arrangement of muscles, tendons and bones. This system is affected by many factors, and presents unique features for each individual. There is constant risk that the normal behavior of this system might be altered due to transport accidents or aging effects. Usually, physical therapy sessions are practiced at the clinics to recover the patient’s functionalities. Recently, tele-rehabilitation has been investigated to improve the clinical outcomes. In this paper, we introduced a novel tele-rehabilitation solution based on serious gaming technologies. Different components of the system were designed and described. Two serious game scenarios were created. A multi-sensor fusion approach was developed to improve the kinematic accuracy of the rehabilitation movement. A preliminary evaluation showed great potential for our system to be applied in a home-based rehabilitation setting.

Keywords: *Serious Games, Musculoskeletal Rehabilitation, Multisensory Fusion*

I. INTRODUCTION

Serious games have been deployed recently as a potential solution in many medical, educational and cultural fields. This new concept allows the user to register and monitor their progress during gaming sessions. In medical applications, it can also allow medical experts to monitor their patients that perform exercises at home through these systems. This can also benefit patients by minimizing their clinical sessions, unless the experts see it necessary. This can solve the current problem of the lack of physical therapists with respect to the population. In France, there is 104 physical therapists for every 100,000 habitant [1], while 1 stroke case occurs in France every 4 minutes [2]. Our work concentrates on musculoskeletal rehabilitation, which can happen due to age or health accidents (e.g. stroke). Serious games can be very beneficial in this field for both experts and patients.

In this paper, we introduced a novel tele-rehabilitation solution based on the serious game technology. Different components of the system were designed and described. Two serious game scenarios were created. A multi-sensor fusion

approach was developed to improve the kinematic accuracy of the rehabilitation movement.

II. PROPOSED SYSTEM

A. *Serious Games*

Based on expert recommendations following our previous works [3-5], serious games need to integrate multiple gestures in order to be more motivational and realistic. Furthermore, the games need to incorporate daily scenarios, which could allow patients to know the real life application of their rehabilitation program. For these reasons, we have developed two scenarios with multiple gestures. The first scenario is a football scene (Figure 1). The patient plays the scenario as an avatar whose objective is to hit either one of two cones using a football. Patients start with pivoting their body to target one of the cones (rotating the body changes the aim’s position). Next, the patient needs to check the bottom right pointer and verify that it is on the green section. Finally, the patient hits the ball. When a cone falls, patients get one point, and they are requested to move to the middle again to start again. Patients are required to repeat these actions until the time, chosen by their therapist, expires. This game targets lower limb rehabilitation, balance rehabilitation as well as some cognitive rehabilitation. There are three levels of difficulties for the therapists to choose from.



Figure 1. Football Scene

The second scenario is an object manipulation scene (Figure 2). An avatar also mimics the patient. The objective is to move a flower from one vase to another. The patient must take the flower, change it from one hand to another, and then pose it in

the other vase. This game has also three levels of difficulties. The patient gets 4 points when executing the three actions successively. This game targets higher limb and cognitive rehabilitation.



Figure 2. Object Manipulation Scene

Finally, after each trial, the expert will be able to check the results of their patients. The results are presented in three different types: 1) Joint position videos, which present the motion of the patient during the exercise from 3 different planes (Frontal, Sagittal and Top planes); 2) Joint angle graphs, which detail the angle variations of the important joints and 3) Exercise statistics which show the evolution of the patient through several exercise trials.

These games were tested on healthy and pathological subjects, to determine the response of these two groups after playing serious games.

B. Data Fusion for Serious Games

A previous study we conducted concluded that a fusion between Inertial Motion Units (IMU) and Kinect cameras could lead to better joint angle estimation [6]. This new technique has been applied to our serious games. Such technologies, depending on two separate types of sensors, need to take into consideration the absence of either one of the two sensors. Therefore, we deployed this technology for our serious games using a system of systems technique. This means that the absence of either type of sensor will not affect the games, and the presence of both sensors will lead to a better angle estimation through data fusion. This helps limit the number of IMU sensors needed on the patient's body, and limits them to joints for which experts need more accuracy.

C. Graphical user Interface

The rehabilitation application is part of the patient/expert interface. The expert has the possibility to add exercises and rehabilitation programs, monitor patients' exercise trials (joint position and angles) and change the assigned rehabilitation program. The patients has to play the games assigned by their experts and assign sensors to joints that require more accuracy (indicated by the expert). All data are encrypted and saved in a local database.

III. PRELIMINARY EVALUATION

The preliminary evaluation of the proposed system was performed. Note that this evaluation focused only on the two designed serious games without multi-sensor fusion. Thus, only Kinect camera was used for acquiring kinematics data of the rehabilitation movements. This evaluation was performed at the "Centre Hospitalier Universitaire de Limoges". 20 patients (13 males and 7 females with a mean age of 49.75 ± 18.68) participated in this evaluation. Finally, the patients were asked to answer some questions through a questionnaire to evaluate the usefulness of the proposed solution.

The results of our questionnaires show that the patients accepted this new technology and felt safe while executing the exercises. Some patients were able to get a higher score with increasing levels of difficulty. This can be explained by the patient's motivation, to perform in a better way, once they assimilate the concept. Hemiplegic patients were among the top testers of our system.

IV. CONCLUSION AND PERSPECTIVES

This paper presented a tele-rehabilitation serious game with two scenarios. These games require motion capture sensing technology, using visual or inertial sensors. Our solution presents a flexibility to use visual and/or inertial sensors. Preliminary evaluation outcomes showed great potential application of our new technology for a home-based rehabilitation setting. In future works, a new evaluation campaign, with multi-sensor fusion solution, will be performed to confirm the improvement of joint kinematics for rehabilitation movements.

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