A Therapeutic Robotic System for the Upper Body Based on the Proficio Robotic Arm

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***Abstract*— Robotic-assisted technology has given the researchers new opportunities to augment traditional physical rehabilitation with technologically advanced devices. The goal is to leverage robotic technology to improve the efficacy of physical therapy and expedite the recovery period of patients. Robotic systems can take on an important role in physical therapy – assisting, guiding, and motivating patients to do their prescribed physical exercises correctly. In this work, we present a comprehensive physical therapy system using the *Proficio* robotic arm. Our system interprets the 3D kinetic and kinematic properties of a person's movement with the *Proficio* arm, evaluates the performance of the person, and recommends adjustment to the difficulty level of the exercise. The Proficio can be also used to enhance user training by moving their arm according to the required exercise. Our system has a graphical interface so that users can view their own task performance during the exercise. In addition, we propose a Microsoft Kinect-based system to complement our design. This system analyzes the trajectory of the user during an exercise, and perform evaluations regarding the posture and movement of the body. The proposed system also enables the therapist to remotely monitor the daily exercise of a person in real time so that he or she can give feedback and motivation.**

***Index Terms*— Robotic Assisted Technology, Proficio Robotic Arm , Microsoft Kinect**

I. INTRODUCTION

Physical therapy promotes motor learning and is an essential part of recovery from a surgery, physical disability or any temporary physical problem. Physical therapy is often so challenging that patients need help from the therapist in their training sessions as well as their daily exercise at home. Robotic assisted technology can respond to a variety of challenges. It has been shown that patients who have been provided with robot-aided rehabilitation have gained more from their therapy sessions than those who were using only standard plans [8], [5]. A systematic review of studies regarding the effect of robots in rehabilitation was given by Kwakkek et al. [4] who found that a positive trend exists toward robot-assisted therapy with regards to motor recovery measured by common assessment scales.

Furthermore, the robots can be used to teach a person the expected exercise by moving their arm. In this "passive mode", the person is simply following along. In the "active mode", the person moves the robotic arm, and the robot gives feedback to the patient (the patient may simply feel the weight of the arm or a resistant force). The use of robots for physical therapy makes it possible for the therapist to have a quantitative evaluation of a patient's performance. Therapists usually use observational checklists to assess the progress made by the patient. Followed by quantitative measurements obtained from an assistive robot, they can evaluate the process more precisely.

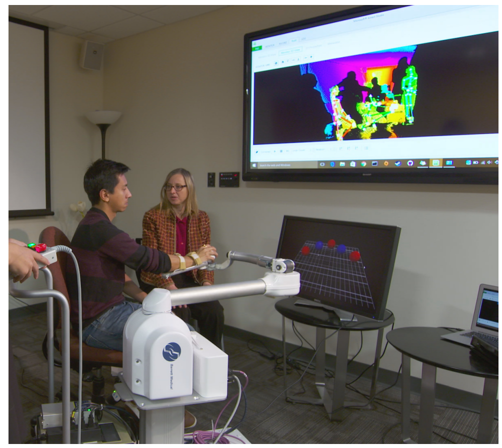

Fig. 1: Exercise setup: The user's arm is strapped to the Proficio robot arm and the robot is moving the arm in the designed trajectory. The exercise is also monitored by the Kinect.

This paper summarizes past and ongoing work in developing our therapeutic system, called *DyAd* [6]. We use the *Proficio* robotic arm [1], see Figure 1. It is a commercially-available 3-degrees-of-freedom robotic arm. It is a backdrivable manipulator that allows the user to move the robot in addition to the robot moving the arm of the user strapped to it. *DyAd*, uses the *Proficio* to obtain measurements so it can quantitatively measure the performance of the user with Dynamic Time Warping [3] and a variation of the Spectral Arc Length method [2]. Based on the user's performance, *DyAd* makes a recommendation on how to adjust the difficulty level of an exercise dynamically. Since the robotic solution is not affordable to be used daily at the patients' home, we have proposed *ExerciseCheck*, a Kinect-based system to complement our design. The patient performs the exercise in front of the Kinect and *ExerciseCheck* provides the patients with informative evaluations and enables an interactive remote communication between the patient at home and the therapist at clinic.

II. METHODOLOGY

A. Performance Evaluation and adjusting the proper Difficulty level of Exercise

The *Proficio* provides kinematic and kinetic information to *DyAd* regarding the movement of its end-effector that the subject controls while doing an exercise. We have designed *DyAd* to capture the trajectory of the movement and evaluate the performance of the subject in the following way:

- Using Dynamic Time Warping, *DyAd* compares the *measured trajectory* obtained from the subject with the *designed trajectory,* which the subject is supposed to follow, and computes a score for the dissimilarity of these two trajectories.
- *DyAd* measures the smoothness of the movement along the measured trajectory using a variation of the Spectral Arc Length method. Smoothness is a critical metric to evaluate the continuity and the intermittency of the movement in patients [2].
- *DyAd* captures the average speed of the movement.

Using these three parameters, *DyAd* can help the physical therapist to evaluate the performance of the patient. *DyAd* also recommends an adjustment of the level of difficulty of the exercise using reinforcement learning.

B. Assistance in teaching the exercise to the patient

One of the challenges people who need physical therapy typically face is to understand an exercise and follow it exactly as they are supposed to. Parkinson's patients, for example, may think that they are stretching their arm sufficiently, but their motion actually falls short. The *Proficio* robotic arm can help them with this challenge in two ways:

- The *Proficio* can be accompanied by a simple user interface that shows users the current position of the end-effector in 3D space and the target position, so that they can visualize the task and see a representation of their movement. This visual interface can be incorporated in training sessions, to make sure that users learn to perform their exercises precisely.
- The haptic feedback of the *Proficio* can be utilized to help the users move their arm when they have difficulty moving the arm by themselves. We can restrict the movement of the arm to avoid any deviation from the designed trajectory.

DyAd-guided physical therapy with the *Proficio* robotic arm is currently too costly as a tool to support the daily exercises of patients at home. The Microsoft Kinect interface has been recently suggested to be used for physical therapy at home. We can use the *Proficio* to examine the accuracy and reliability of the Microsoft Kinect for this purpose.

C. The Proficio and the Microsoft Kinect

To evaluate the accuracy of the Microsoft Kinect in detecting the skeleton of a user's upper body, we have designed an experiment to compare the result of the Kinect with the *Proficio* robotic arm. The *Proficio* can measure the trajectory of its end-effector at high accuracy and thus can be used as a reference to evaluate the performance of the Kinect. Our experiments, [7] revealed that the accuracy of the Kinect depends on the exercise type, the background that the Kinect senses, and the orientation of the user with respect to the Kinect sensor. We found that, with an appropriate direction and no major occlusion, the Microsoft Kinect can be effectively utilized for physical therapy at home.

We thus complement our design by proposing *ExerciseCheck*, a Microsoft Kinect based system that addresses some of the problems patients usually report at home. It captures the skeleton or some predefined anatomical landmarks of the upper body, evaluates the performance of the subject doing an exercise in front of camera.

One of the important capabilities of *ExerciseCheck* is that it can simultaneously send information to the physical therapist. Thus, the therapist can monitor the patient's daily exercise and send immediate feedback. This mutual interaction between the therapist and the patient, while the patient is at home, promises to make the therapy period more effective, increase the patients motivation and eventually lead to optimal recovery.

III. CONCLUSIONS AND FUTURE WORK

Robot-assisted physical therapy needs both accurate hardware like the *Proficio* robot arm and a software system that manages the interaction between robot and patient, i.e., provides incentives and measures performance. So far, we have designed *DyAd*, a system that quantitatively evaluates the performance of the user and recommends adjustments to the level of the difficulty of the exercise. *DyAd* can help a therapist to design a proper exercise for a patient. In addition, a user interface connected to the *Proficio* can help the patient to visualize the movement and enhance the training process. The Microsoft Kinect can then be utilized besides the Proficio – the patient uses *DyAd* at therapy sessions with their therapist and interacts with *ExerciseCheck* at home. In the future, we will combine these systems and conduct an extensive rehabilitation study with individuals who have temporary or permanent physical disabilities.

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