An Immersive Physical Therapy Game for Stroke Survivors

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ABSTRACT
We report a system for gamifying physical therapy for stroke survivors that provides a fully immersive 3D environment. The system consists of a Kinect, an Oculus Rift immersive goggle and a pair of haptic gloves. The Kinect is used to provide bodily gesture for the game as well as to record data to allow assessment of therapy progress regarding body postures. The haptic gloves operate as a controller for the player's in-game hands as well as to record data that provides therapy progress regarding finger flexibility.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation: Miscellaneous.

Keywords
Kinect, stroke, physical therapy, virtual reality

1. INTRODUCTION
Stroke is the number one cause of adult disability. In 2013 there was over 750,000 stroke incidents [4]. For those who survive stroke, long-term disabilities can occur, varying from physical to cognitive disabilities depending on the affected areas of the brain. These disabilities are usually compounded with aging-related disabilities (a majority of stroke survivors are 60-80 years old [2]. Successful physical therapies for stroke survivors have one common characteristic: they are time intensive (they range between 5-10 hours a week for 12 weeks [1] and they start as soon as the medical condition has been stabilized (often within 24 to 48 hours after the stroke) [3]. The intensity and duration of rehabilitation makes it difficult for patients receiving outpatient therapy to follow the schedule, especially when long travel is involved, opening opportunities for remote therapy systems. In addition, because of the intense duration, abandonment due to boredom often occurs, also opening opportunities for finding more enjoyable ways for stroke rehabilitation.

We report an immersive 3D game for independent use at patient homes that present exercises in more fun way while at the same time allows recording of therapy progress.

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2. SIMILAR SYSTEMS
There are a few recently developed systems that aim at providing remote physical therapy that are similar to our system. A project sponsored by Microsoft Research and Seoul National University called "Stroke Recovery with Kinect[1]" is an interactive rehabilitation system prototype that helps stroke patients improve their upper-limb motor functioning in the comfort of their own home. This system tracks user gestures and adjusts the difficulty of rehabilitation sessions based on their progress. They also have future plans of stroke patient interaction through social networking and also large scale data analysis of rehabilitation data trends.

One reason behind the increased interest is the prospect that therapy may be cost effectively administered in patient's own homes as an alternative to what is accepted by most professionals as the most effective treatment, Constraint-Induced Movement Therapy (CI). Ohio State University's Wexner Medical Center research team have built a model for exactly this purpose. Their prototype comes in the form of a boat rowing game that utilizes a Kinect and two gloves; one to weigh down a patients unaffected side, and the other to track movement by their affected side[2].

3. OUR SYSTEM
At the highest level our system consists of two main components; the external devices (glove, Kinect, Oculus Rift) and the game. The Kinect tracks the movement of the user's body. This allows users and stroke therapists to assess how well stroke patients can move their outer extremities. We incorporated gloves for finger motion capture and pressure sensing. Most existing systems are limited to simply tracking the entire hand as one point. Collecting detailed data on user's fingers allows us to create scenes that focus on the rehabilitation of hand motion and strength.

The gloves use bend sensors to capture the motion of the glove wearer's fingers and send a corresponding linearized value for each bend sensor to the computer using Bluetooth. The software takes this data along with Kinect and Oculus Rift input and uses these devices to power a game in the Unity3D engine that has the player do exercises and games that are inspired by physical therapy techniques. The movements to be implemented were provided to us by the physical therapist of the Cabrillo College Stroke and Disability Learning Center. The software records data regarding the users' movements from the Kinect and the gloves into a database so that it can be read and graphed using a utility

[1] http://research.microsoft.com/en-us/projects/stroke-recovery-with-kinect/

[2] http://www.themarysue.com/stroke-rehab-game/

developed in Python that make it easy to see and manipulate the data. Figure 1 depicts the relationship of the different components.

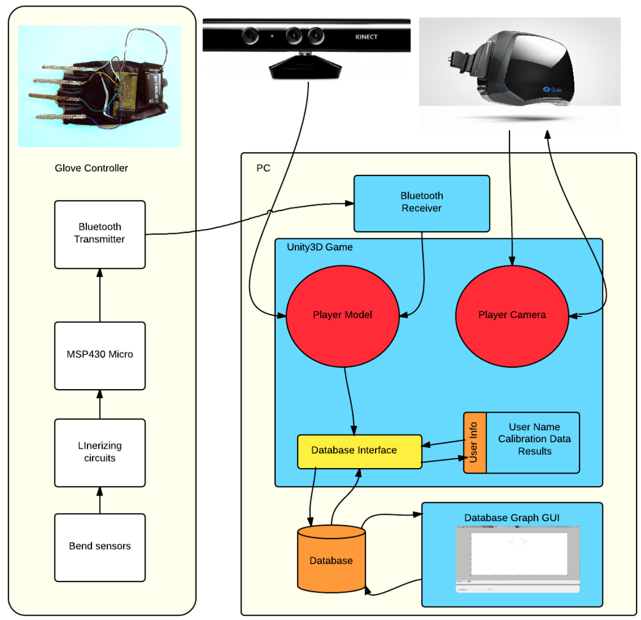

Figure 1. The components of our system

3.1 The Game

Our first exercise scene tasks the user with moving four cylinders placed around him/her into a box in front of the user. Two of the cylinders are on a shelf above the user and the other two are on a counter behind the user, providing users with a variety of reaching and grabbing activities. The scene records user position data continuously and the time it takes the user to place the objects in the box. The user is represented in-game is a virtual character who mimic's the user's movements.

Along with this scene, we have a scene which acts more as an exercise then a game. The screen gives the player instructions like "Raise right arm as high as you can" and records relevant data. In this case it would be the maximum angle of the arm from the shoulder. The idea is to show that our system can make taking goniometric measurements much easier.

To integrate the Kinect into our Unity project we are using a middleware created by the San Francisco startup, Zigfu. The Zigfu Development Kit (ZDK) for Unity3D is a wrapper that provides numerous tools for establishing communication between Microsoft's Kinect for Windows and the Unity3D game engine.
The game works by leveraging the Kinect to control the in game character model's movements, the Oculus Rift as the screen as well as control the camera orientation, and the GloveReader to control the finger animations as well as the hand gestures. A script on the hand checks for collisions with cylinders and if the player is grabbing at the time of collision the cylinder's position is attached to the hand's position until the "grab" gesture is false. When this happens the cylinder falls from whatever position the hand is in at the time of the gesture change.

3.2 The Gloves

To gather data from the user's hand, we used the 2.2" flex sensor, SEN - 10264. This flex sensor behaves like a variable resistor. As the sensor is bent, the resistance across the sensor increases. We tested these sensors to observe if the resistance and angle of bend had a linear relationship. Using a goniometric protractor and a multi-meter we were able to measure the resistance of these bend sensors in 15 degree increments.

3.3 Data/Analysis

This system gathers a lot of data during the exercise. Inside Unity3D, the Kinect gives us X, Y, Z coordinates and angles of each joint on the user's body. We record these locations/angles 10 times a second to give us snapshots of the user's movement at any given time. This allows us to reconstruct the user's actions in a graphing tool that shows a skeletal outline of the user at any given time through the exercise with a slider that allows a user or therapist to move through the exercise virtually.

4. PRELIMINARY USER EVALUATION

This system had only been tested by one stroke survivor. He had stroke 4 years ago and was a musician and a music store owner prior to stroke (he still runs a music store). In general, the user was quite happy with the system and would recommend it to others but were concerned about the geekiness of the system. Some of his actual comments were: "I can see this system to be useful for those who cannot travel to Cabrillo College all the time" and "I would definitely recommend this system to the more geeky friends. I am not sure how others would react though."

5. CONCLUSION

At ASSETS we will be demonstrating the system. Our very preliminary user study shows promise and we would like to receive feedback from ASSETS attendees to improve the next generation of our system.

6. ACKNOWLEDGMENT

We thank Cabrillo College Stroke and Disability Learning Center for allowing us to demonstrate our system, Lenny Norton who provided us with the movements that needed to be implemented, and the anonymous participant for testing our system and providing us feedback for improvement.

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