

Low-cost Home System for Assessment and Rehabilitation of Stroke

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1. INTRODUCTION

This abstract is part of a coordinated submission to the Workshop on Media Arts, Science, and Technology of complementary posters on mixed reality stroke rehabilitation. We will discuss the Home System, an interactive tabletop device that may be used as a tool to assess a stroke patient's functional recovery over time or monitor retention of motor learning from previous rehabilitation programs. It does this by engaging the stroke patient in a reach-and-grasp exercise while measuring reach times and hand trajectory.

2. MOTIVATION

Stroke is the number one cause of disabilities among American adults. Improvements in health care have resulted in more people surviving stroke but with some degree of impairment of their upper limbs that affect their activities of daily living (ADL) [2]. A stroke survivor then enters a rehabilitation program with the goal to relearn how to use their impaired limb or at least recover some of the functional abilities of that limb. The Home System aims to be an unobtrusive method for stroke survivors and physical therapists to assess and track the functional recovery and retention of motor skills learned during the rehabilitation program.

There are many advantages to having a low-cost assessment tool in the stroke patient's home. First, upper limb use is critical in evaluating rehabilitation progress, but on a long-term scale, the cost of such assessments in a physical therapy clinic can be prohibitive. Furthermore, most insurance does not cover such long-term care. Second, stroke survivors with more severe disabilities may not be able to travel on their own to a rehabilitation clinic, thus the travel becomes an additional burden on the spouse or caretaker. Our system addresses these two issues in that it is low-cost (about \$1200) and can be conveniently placed in the patient's home where they can use it according to their own schedule. A further advantage of such a setup is that a physical therapist can monitor more patients remotely than they can see in their clinic.

3. SYSTEM DESIGN

3.1 Game Design

At the core of the home system is a game interface used to facilitate practice of reaching and grasping motions. There are two main systems the user interacts with: target cones and a rest position. The target cones feature light emitting diodes (LEDs) to visually prompt the user when to reach for the target. Embedded within the cones are capacitive touch sensors and force sensing resistors to detect both a complete grasp as well as a touch of the cone. A table-mounted foam pad with embedded switches is used

as a physical start, or rest position, such that the user rests their wrist and forearm on the pad prior to and after each reach. Two conductive cloth contacts, one in the pad and one in a wristband worn by the user, ensure proper wrist position. Also, a tact switch within the rest pad ensures the arm is relaxed before reaching and that their posture is balanced. The positions of the cones and rest position are based upon measurements and desired ranges of motion determined during previous therapy sessions.

The game begins when the user presses a start button. Two different sounds are played as feedback for improper wrist and forearm placement. Once the user has properly positioned and relaxed their wrist and forearm, a red LED lights on one of the cones, chosen pseudo-randomly, for a short amount of time. The light then turns green which prompts the user to reach for and grasp the cone. The short amount of time between when the LED turns red and green allows the patient to create a plan of action before the reach actually begins. If the user cannot reach the cone after six seconds, the reach is considered a miss and another cone will be chosen. Also, the cone lighting procedure will reset if the user leaves the rest position to reach for a cone too early, when the light on the cone is still red.

The cones and switches are connected to a Wiring [3] prototyping board which controls the progress of the game and monitors when the hand is in the correct rest positions. It also takes two important time measurements. It first measures the patient's reaction time, which is defined as the time it takes for the patient to initiate a reach after the green light comes on. Second, it measures the time it takes to complete each reach. These measurements are used as indicators of functional recovery and retention. The goal is to see reaction and reach times become more consistent and decrease with time.

3.2 Motion Tracking

One of the factors of interest in the rehabilitation process is endpoint trajectory, which we define as the trajectory of the wrist. This is tracked using two Nintendo Wii game controllers, or Wii Remotes. Similar to higher end motion capture cameras, the Wii Remotes have a built-in infrared camera and can be used to track the position of a reflective marker worn on a wristband by the user. Each Wii Remote is configured with an added infrared LED array that illuminates the area the patient will perform the exercise. The remotes have a built-in image processor that can identify up to four markers at a time. Using two Wii Remotes allows for the reconstruction of a 3D trajectory of the hand as it reaches and grasps each target.

Data from the Wii Remotes and the Wiring board is collected and logged in software running on a Mac Mini. This software's primary purpose is to establish connections with the Wii Remotes

and the Wiring board, and save the collected data to disk. It also performs some simple handshaking with the Wiring board (just to ensure that the Wii Remotes are connected before starting a session) and produces the audio feedback for improper wrist and forearm placement.

The results of the Wii Remote motion tracking system have been cross validated with a 10 camera Eagle RealTime motion capture configuration with EvaRT software. Displacement and velocity were tested in each principle direction with absolute maximum and root mean squared error utilized. Some error was found with motion in two directions: as the marker moved further off the table and closer to the cameras. However the velocities reported by both systems were nearly identical. Displacement errors could be minimized by staying within the usable space of the home system game [1].

There are two important features of end point trajectory. The first is “bellness,” a measure of how close the velocity profile resembles a normal Gaussian distribution. An unimpaired subject would have a velocity profile that looks like a bell—an increase in velocity to some peak and then a decrease as the hand approaches the target. An impaired subject usually has two or more peaks in their velocity profile, indicating they slow down, or hesitate, mid-reach. Bellness is measured as the area under the first local minimum to the end of the reach divided by the area from the first local maximum to the end of the reach. For an unimpaired subject, this area would be zero. The number of local minimums from the first peak to the end of the reach is also measured. The second feature considered is the jerkiness of the reach, which is a measure of the smoothness. It is desired to see jerkiness decrease and the velocity profile follow more of a bell curve over time.

The end goal of this system is to have the user play the game for ten minutes at least three times a week over a month. During each session, the user would reach towards each of the three cones eighteen times.

4. CONCLUSION

The home system for stroke rehabilitation is a low cost (approximately \$1200), minimally invasive system that can provide a simple and reliable way to track reaching motions at home. It takes the core ideas developed and practiced during therapy sessions and makes them more accessible to the user.

In the future the system will be validated with stroke patients. The knowledge gained will provide a foundation for further development of the home system to include more functionality in order to enhance the training and assessment capabilities of the device.

5. REFERENCES

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