Integrating Arts and Computation in Mixed Reality Stroke Rehabilitation

Suneth Attygalle
Arizona State University
699 South Mill Ave. Rm 395
Tempe, AZ, 85281
Suneth@asu.edu

Thanassis Rikakis
Arizona State University
699 South Mill Ave. Rm 390
Tempe, AZ, 85281
Thanassis.Rikakis@asu.edu

1. INTRODUCTION

This abstract is a summary of a coordinated submission of posters describing the interdisciplinary Mixed Reality Stroke Rehabilitation project of the Arts, Media, and Engineering department at Arizona State University. Here we describe the background, design, and future of our interactive multimedia stroke rehabilitation system. Specific components of the system are described in the accompanying posters "Interactive Visual Feedback for Mixed Reality Stroke Rehabilitation", "Parametric Musical Sonification for Mixed Reality Stroke Rehabilitation", and "Media Adaptation Framework for Mixed Reality Stroke Rehabilitation". Audio and visual examples are shown on laptops. Positive results from three stroke survivors that took part in our training program are presented in "Improvement in Reach Kinematics from Training in a Mixed Reality Stroke Rehabilitation Environment". Finally, current work in developing a low cost, portable system for the home is presented in "Low cost home system for assessment and rehabilitation of stroke".

2. RECOVERY FROM STROKE

Since brain capacity in humans is determined by the number of connections or synapses made between neurons it is possible for the brain to regain function through the creation of new connections. Clinical studies have shown that the reacquisition of motor skills is related to reorganization of undamaged areas of the brain. Traditional rehabilitation focuses on functional recovery using objects and equipment that the patient is familiar with and has used many times. However, animal studies have shown that stimulating and enriched environments can lead to increased neurogenesis and motor learning. They have also shown that repetitive unskilled movements do not result in motor cortex change. Thus performing challenging tasks that focus on functional recovery, presented in a stimulating and complex environment are likely to be more efficacious than traditional therapy alone.

3. ARTS AND RECOVERY

Arts re-contextualize everyday reality and empower people to discover new approaches for overcoming challenges. A challenge many stroke survivors face is partial paralysis of the arm. It is known that continuing to use the impaired arm can help stroke survivors regain functionality in their arm. However, using the impaired arm can be frustrating with difficulties in performing activities of daily living. If you tried to reach for a glass and then broke it, either by dropping it due to weak grip, or by grasping it too tight due to lack of control, you may subconsciously avoid using that hand. It is crucial to break this negative feedback loop of disuse of the arm. Our environment is immersive, allowing the patient to look beyond reaching as simply reaching, but as a means to compose and interact with an audio-visual scene. This encourages active participation by a stroke survivor in what would otherwise be tedious or uncomfortable. The audiovisual environment becomes a metaphor for the actual reaching task. Meanwhile, the benefits from practice are retained when performed without any feedback.

4. COMPUTATION AND RECOVERY

Traditionally, stroke is treated through exercise with the aid of a physical therapist. While many functional tests have been developed to assess stroke, they are often inconsistent and do not detect small improvements, particularly in quality of movement, some of which may be unobservable by the eye. It is challenging for a therapist to track close to a hundred movement parameters related with multi-joint coordinated arm movement training and their interrelationships. In addition, our training environment adds over 130 virtual and physical parameters that can be adapted. Furthermore, a therapist may have difficulty remembering the full history of the subject's progress across all training parameters. Through the use of real time motion capture and analysis, we can calculate various movement assessment parameters and detect abnormal patterns of movement or compensation measures. Computerized archiving and interactive data visualization offer easy access to all parameters of training and their history. With access to detailed quantitative data, it is easy to track a subject's progress and create individualized therapy. The movement assessment parameters can also drive the generation of customized real-time feedback. The feedback helps the stroke survivors understand how they are moving their arm themselves, through exploration, without someone telling them how to move their arm. In addition, we are currently developing a semi-automated adaptation algorithm that helps the therapist make decisions on how to optimize the interactive therapy based on each subject's actual performance: which movement aspects to focus on and in what order and what feedback structures to use. This algorithm is presented in an accompanying poster.

5. SYSTEM DESCRIPTION

We have developed an interactive multimedia system that integrates physical therapy and cognitive stimuli. The system is an audio-visual environment in which stroke survivors can practice functional, therapeutic reaching and grasping tasks while receiving adaptive, real-time feedback providing measures of performance and results. The system includes training in hybrid (physical-virtual) environments that help connect the subject's learning in virtual environments to execution of daily functional tasks in the physical realm. Movements of the arm are recorded at

100 Hz by a 10 camera infrared motion capture system from Motion Analysis Corporation.

5.1 Reaching Task

A familiar artwork or photograph is shown to the subject. The image then explodes into hundreds of unstable particles. The subject intuitively senses a need to recompose the particles to recreate the image. This is done by completing a reach and grasp to a specific target during which various audio and visual features inform the subject about their movement. The reaching tasks are performed to various locations based on the subjects physiology and include movements forward and across the subjects midline, and against gravity or supported by a table surface. Different aspects of movement are associated with different types of feedback. In particular, temporal features of movement are mapped to audio feedback while spatial features of movement are mapped to visual feedback. Details of the audio and visual mappings are presented on accompanying posters and laptops. The different aspects of feedback comprise a network that is explored so that amplitude of error and direction for improvement are communicated in the most intuitive manner to each subject and that consistent challenge is provided to the subject. Consistent challenge is important to keep subjects engaged in the task.

6. FUTURE WORK

Three small-scale pilot studies have shown very promising results. The system has been accepted by the subjects and all subjects have shown clear trends of relearning pre-morbid movement strategies. Results from the most recent study are presented in an accompanying poster. A large-scale trial commences in 2009 at the Rhodes Rehabilitation Institute at Banner Baywood Medical Center. A scaled version of our system will be installed at the medical center to compare performance of the Mixed Reality Rehabilitation system with conventional therapy. Subjects from this study will have the option of receiving a home system for assessment and rehabilitation that is presented in an accompanying poster. A concurrent study to understand the neural correlates of recovery and the ability of complex, audio-visual environments to promote neural plasticity in the brain is being developed.