International Conference on Virtual Rehabilitation 2011
Rehab Week Zurich, ETH Zurich Science City, Switzerland, June 27 - 29, 2011

# Development of a Haptic Keypad for Training Finger Individuation after Stroke

Thomas J. Lord
Dept. of Biomedical Engineering
Illinois Institute of Technology
Chicago, IL USA
thomasjlord@gmail.com

Yu Li
School of Art and Design
University of Illinois at Chicago
Chicago, IL USA

Diana M. Keefe
Department of Biomedical Engineering
University of Rhode Island
Kingston, RI USA

Nikolay Stoykov & Derek Kamper
Sensory Motor Performance Program
Rehabilitation Institute of Chicago
Chicago, IL USA

***Abstract*—This paper presents a low-cost virtual-reality environment for training finger individuation in stroke survivors with chronic hand impairment. Users play an ergonomic 5-key virtual piano while receiving either assistance or resistance from a pneumatically actuated glove. The level of assistance and the difficulty of the task can be modulated by a therapist.**

***Keywords-stroke; hand; training environment***

## I. INTRODUCTION

Increasingly, we are reliant upon manual dexterity not only for controlling objects but also for communication, such as through typing and texting. Diminished ability to perform individuated finger movements, such as often occurs following stroke [1], can thus impact quality of life in many ways. Recent studies suggest that repetitive practice is fundamental to rehabilitation following stroke, whether for the lower [2] or upper [3] extremities.

The amount of time available to work one-on-one with a therapist, however, is limited. Thus, therapy paradigms which can be performed without constant supervision from a therapist may increase the opportunity for targeted practice. One therapy technique for retraining finger individuation is to play piano. Unfortunately, the limited coordination often present in stroke survivors may render playing of an actual piano extremely frustrating. A virtual piano, in which success or failure of pressing a key can be modified to accommodate the player, may provide greater incentive for therapy. Indeed, one group has developed a virtual piano for use in stroke therapy [4]. That system, however, uses rather expensive equipment to provide assistance and haptic feedback. We sought to develop a less expensive, lighter system, with a greater emphasis on therapist control of the level of challenge for the user.

## II. VIRTUAL KEYPAD DESIGN

### A. Hardware

The virtual scene, consisting of a keypad and virtual hand, is projected onto a computer monitor. To focus on finger control, the virtual hand remains stationary above the keys; thus, no stereovision o tracking of the head or arm is required. Joint angles in the hand are measured with bend sensors using a custom sensor glove termed the Shadow Monitor [5]. Data from the 10 bend sensors, (two for each digit), covering the joints are sampled by a microcontroller which wirelessly transmits this information to a computer (Figure 1).

Extension assistance and/or resistance to finger flexion is provided by the PneuGlove, a pneumatic bladder attached to the palmar side of the sensor glove [6]. The bladder contains 5 independent air channels, (one for each digit), each controlled by an electropneumatic servo valve (QB02005, Proportion-Air, McCordsville, IN).

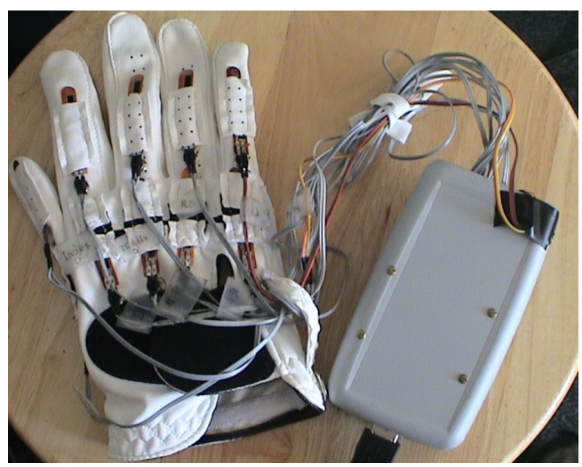

Fig. 1. Shadow Monitor. Ten bend sensors (two for each digit) measure joint angles which are transmitted to a computer for controlling the virtual hand.

### B. Software

A 5-key piano model, with each key controlled by its respective digit, was created in Maya (Autodesk, San Rafael, CA, Fig. 2). The five key model, with an ergonomically positioned thumb key, was used rather than a full piano in order to emphasize training of finger individuation without the need for arm movement. The model was then imported into the software package Virtools (Dassault Systèmes, Vélizy-Villacoublay, France) to provide animation. A virtual hand,

This work was supported by a grant from the National Institute on Disability and Rehabilitation Research (H133E070013 – Rehabilitation Research Center).

controlled by the data from the Shadow Monitor, is present in the scene along with the virtual keypad (Figure 2). One PC, running Virtools, is responsible for rendering and updating the virtual scene.

Another PC controls the system through a Visual Basic (VB) program which communicates with the Shadow Monitor, drives the PneuGlove, and communicates with the Virtools computer through a Transmission Control Protocol (TCP).

## III. PROTOCOL


Fig. 2. Picture of the virtual keypad and hand, with the PneuGlove in the foreground.

The virtual keypad can be run in one of three modes: Train, Learn, and Play. In the Train mode, it creates a sequence of key combinations which the user must play by properly moving the digits. The desired keys to be played are indicated by a color change to green (Figure 3). The user then flexes the corresponding digits while keeping the others extended. If the joint angles for a digit exceed flexion threshold values, the key is considered pressed and an audio tone corresponding to the pitch of that key is evoked. After pressing the keys, the user is then instructed to release the keys. If desired, assistance can be provided by the PneuGlove to resist flexion of the digits which are supposed to remain extended while permitting flexion of the digits which should be pressing the keys. The PneuGlove can also assist extension during key release. A therapist can set the level of assistance, along with thresholds for the joint angles for successful key press, from a custom graphical user interface. In addition, the software keeps track of performance and adjusts the difficulty of presented key combinations accordingly.

In the Learn mode, the user attempts to learn a song by following the prompts on the virtual keypad. The PneuGlove can again provide assistance. Finally, in the Play mode, the user can play anything he or she wants.

## IV. DISCUSSION

A virtual keypad has been developed to facilitate training of finger individuation after stroke. The virtual scene consists of a 5-key ergonomic piano and a virtual hand, controlled by the user through the Shadow Monitor which monitors 10 joint angles on the hand. Haptic resistance to a keystroke or assistance to keep specified digits extended can be applied with a low-weight pneumatic glove, the PneuGlove. A therapist can control the difficulty of the training to keep it challenging without becoming overly frustrating. A pilot study examining the efficacy of the system will soon be initiated, targeting subjects at Stage of Hand level 5-6 on the 7-point Chedoke-McMaster Stroke Assessment scale [7]. The Train, Learn, and Play modes will all be incorporated into each training session.


Fig. 3. Example of the Train mode. Keys to be pressed are indicated in green (top). A successful keystroke changes the color of the key, and the player is prompted to release the key (bottom).

## V. REFERENCES


[1] P. Raghavan, E. Petra, J.W. Krakauer, A.M. Gordon, "Patterns of impairment in digit independence after subcortical stroke," J Neurophysiol, pp. 369-78, Jan 2006.

[2] K.P. Westlake and C. Patten, "Pilot study of Lokomat versur manual-assisted treadmill training for locomotor recovery post-stroke," J Neuroeng Rehabil, pp. 6-18, Jun 2009.

[3] S.L. Wolf, C. J. Winstein, et al., "Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial," JAMA, pp. 2095-104, Nov 2006.

[4] Adamovich SV, Fluet GG, …. "Design of a complex virtual reality simulation to train finger motion for personss with hemiparesis: a proof of concept, " J Neuroeng Rehabil, pp 6-28, Jul 2009.

[5] L.K. Simone, N. Sundarrajan, X Luo, Y. Jia, D. Kamper, "A low cost instrumented glove for extended monitoring and functional hand assessment," J Neurosci Methods, pp. 445-48, Mar 2007.

[6] Connelly L, Y. Jia, M.L. Toro, M.E. Stoykov, R.V. Kenyon, D. Kamper, "A pneumatic glove and immersive virtual reality environment for hand rehabilitative training after stroke," IEEE Trans Neural Syst Rehabil Eng, pp. 551-9,Oct 2010.

[7] Gowland C, Stratford P, Ward M, et al., "Measuring physiocal impairment and disability with the Chedoke-McMaster Stroke Assessment," Stroke, pp. 58-63, Jan 1993.