Guiding Hand:
A Teaching Tool for Handwriting

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ABSTRACT

The goal of our demonstration is to illustrate how the haptic, force feedback device, can be used to assist people with disabilities in learning fine motor tasks, such as writing. We will be demonstrating this idea by the simulation of several letters and symbols. We use electromagnetic sensors (MotionStar Wireless® 2) to capture unencumbered movements performed by a 'normal' individual. The captured movement is translated to the haptic coordinate system with the use of a table-top centered frame as an intermediate frame. The translated movement is then fed into our haptic system, which varies the exerted force as a function of trainee performance. Our demonstration will use the Phantom® Omni™ for the simulation of these writing tasks, and it will also provide visual feedback of the desired and user trajectories.

Categories and Subject Descriptors: Information Interfaces And Presentation [User Interfaces]: Haptic I/O, Graphical User Interfaces

General Terms: Algorithms, Design

1. INTRODUCTION AND PROBLEM DEFINITION

Haptic devices have been used to train people who experience difficulties performing fine motor tasks [2, 4, 3]. These devices provide a proprioceptive input allowing the user to perceive movement and location of a limb in 3-dimensional space through force feedback. Haptics can record and report 3D spatial positions, velocity vectors as well as the forces applied in three dimensions x, y and z at the gimbal. These features make them highly useful for training and learning purposes. In [2, 4, 3] several different approaches for teaching handwriting have been proposed.

We have gathered data to be used for haptic training with the 'free form' movement of a 'normal' person recorded by a motion tracker. The free form movement was used to release the trainer from the need to hold the robotic arm of haptic which might influence the normal functioning of different motor tasks. This data was then translated to the haptic workspace. Using haptics for training is a three step process. The first requires the ability to simulate the writing motion with the haptic. The second requires programming the force control to permit a smooth 'natural' trajectory, with minimal jerking and transition points experienced by the user. And the third is to use them as intervention tools to improve people's capability who suffer from writing disabilities.

We aim to simulate writing activity in a fashion that seems natural to the user. It requires obtaining positional data in 3D. The first objective has been accomplished by using a 3D motion tracker called Motionstar Wireless®2 Electromagnetic Sensor (EMS) system. It reports 3D spatial location of the sensors. Next, the limb movement must be guided by sufficient force to accomplish the functional task. The force should be smooth, i.e. the derivatives (velocities and accelerations) should not change sharply. Objective two is accomplished by translating EMS data into the workspace of the haptic. We have used the Phantom®Omni™ (Fig. 1(a)) as the guiding interface which involves three degrees of freedom. We have applied this method to laboratory experiments to assess the ability of the programs to accomplish writing letters and shapes.

The EMS system captures 3D position and orientation of the EMS sensors with respect to the EMS transmitter. The movement is translated to a haptic device, which typically has fewer degrees of freedom than a human arm. For translating the free form movement from the EMS to the haptic, we need an intermediate coordinate system that represents a moving frame. Our method assumes that we use a single EMS sensor that is usually placed on the end effector that is manipulated by a person while writing. We have used the *plane of the paper* as the intermediate frame between the EMS and the haptic where three points were captured to calibrate the intermediate frame against the EMS and the haptic coordinate systems. The whole movement trajectory is usually made up of a number of strokes. For example, writing a dollar sign consists of 3 strokes: an S, a lift, then a straight line (see Fig. 2). The trajectory needs to be broken down into these separate strokes to facilitate the understanding of motor learning. We manually segment the movement into simple strokes and then 'smooth' the strokes using polynomial curve fitting. The captured motion is then transformed to the haptic coordinate system so that it can be used to guide a subject′s hand through a desired movement (Fig. 1).

In our experiments we have computed the guiding force based on the subject's deviation from the current position to the next estimated position. The force **F** is:

$$\mathbf{F} = \kappa \cdot \mathbf{dr}$$

where κ is the spring constant of the haptic. **dr** denotes the distance from the current point to the next point in space. If

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(a) (b)

Figure 1: Haptics used: (a) Learning using Omni™. (b) Learning using Premium™.

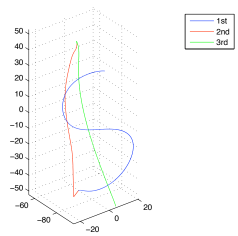

Figure 2: Strokes involved in making a $-symbol.

the subject is going farther away from the desired trajectory, the haptic will increase the force in order to ensure that it guides the hand along the right trajectory. This type of control can be thought of as a spring, which is tied to the trajectory and keeps on pulling the stylus of the haptics towards the trajectory. As a person is being guided by the haptic repetitively to perform a functional task, the force can gradually be dialed down to allow him/her to drive the stylus of the haptic, based on his memory and learning.

2. DEMO DECRIPTION

We have used MathWorks MATLAB for processing the data and OpenHaptics™ toolkit from SensAble Technologies [1] for programming the haptics. We have used the Phantom® Omni™ to guide a subject′s hand in writing. It has a small workspace of 160×120×70 mm, and it can apply upto 3.3 N of force on its gimbal. It reports the position, velocity and force applied in 3D coordinates. The reason for using the Omni™ is that it is more restrictive in terms of workspace and gives greater control needed to tune fine motor skills. It can apply high force in a smaller work area. We have used $\kappa = 0.15\, N/mm$ for all our experiments.

The translated and smoothed movement trajectory is loaded into the haptic′s training program. The program displays the desired trajectory, including lifts, in a specified color (default is green). As the user manipulates the haptic-pen, a cursor is drawn on screen reflecting the user′s movement (currently a cone). Fig. 3 shows an example of the graphical user interface used. In our demo we will use the Omni to guide the hand of a person to trace different letters and shapes. These letters and shapes have been recorded with the EMS earlier and the trajectories already translated to the haptic.

The user can perform the trajectory matching tasks with either guidance or freeform settings. In guidance mode, the haptic applies a force, as previously described, to move the user to the desired position at a specific time. The user begins the matching task by clicking a button on the haptic.

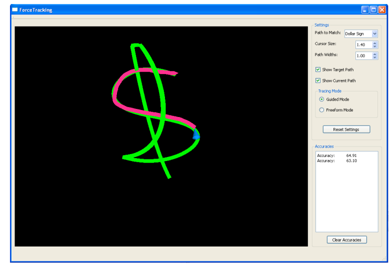

Figure 3: Graphical User Interface.

Force is then applied by the haptic to move the pen to the starting position; the task will not begin until the cursor is within bounds (2 mm) of the starting position. As the user moves the cursor during the tracking task, another path is drawn marking where the cursor has been over time (default is pink). Once all points in the desired trajectory have been used for the force calculations, a performance measure is calculated. This measure is based on the proximity of points in the drawn path compared to the desired path. If the point is within 4 mm it is considered a hit, if not, a miss. The ratio of hits to total points is relayed back to the user as their accuracy.

In freeform mode, the user is in the tracking task as they hold down a button on the haptic device. As they continue to hold down the button their path is drawn in the same manner as is done in guidance mode. There is no force applied by the haptic in this mode. When the user releases the button their accuracy is computed as described above. The accuracy measure is dependent on time, so even if the user matches the overall trajectory in space, but perform the task slower or faster than desired, their accuracy would be low.

Movement trajectories can also be mapped into the program for teaching gross motor skills; such as eating, combing hair, brushing teeth, etc. The unencumbered movement of these functional activities was recorded using EMS and then these trajectories were translated to the Phantom® Premium™ 3.0/6 DoF (see Fig. 1(b)). This haptic device has a larger work- space and provides six degrees of freedom.

3. ACKNOWLEDGEMENT

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