Computer Supported Non-Visual Signature Training

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Abstract
In this paper we describe a system designed to facilitate learning of handwriting. The goal of this research is to teach visually impaired users to sign their name. Handwriting is a complex fine motor task that is best learned through doing with immediate feedback. The system described combines pen-input models with haptic trajectory playback and passive guidance through a force feedback device combined with non-speech and speech-based auditory cues to provide an accessible non-visual teaching environment. A user can therefore feel and hear the shape of letters and is guided to recreate their shape. By combining these techniques with a pattern recognition algorithm feedback on performance is provided to the user.

Keywords
Haptic, non-speech audio, sketch based interfaces, trajectory playback, accessible interfaces

Introduction
Development of handwriting skills is a complex fine motor task that is best learned through practice and refinement. Continuous visual feedback is an integral part of the learning process for sighted people. Visually impaired people (VIP), however have little chance to practice their handwriting skills. While handwriting is a skill that VIP do not generally require in everyday life, there are some occasions when being able to sign is important. One instance is when producing letters or completing forms where it is often necessary to sign the document. This can be a major challenge for VIP, particularly if the visual impairment occurred from birth or before

handwriting skills are developed. VIP are acutely aware of the importance of a 'normal' looking signature. One highly achieving VIP described her signature to us as 'resembling the meanderings of an inebriated fly'. Another suggested that being able to sign a job application letter appropriately might be the difference between getting a job interview or not. The goal of this research is to develop a system that will help support blind or visually impaired users to learn to write their signatures.

For sighted people handwriting and signatures develop from early drawing experiences with continuous visual feedback supporting the development of fine motor skills and consistent formation of letters and words. A particular feature of handwriting and signatures is that they are unique to each individual and each instance, while conforming to a pattern that in itself is unique.

For VIP to have a consistent and visually appealing signature they must first learn appropriate fine motor skills and basic letter shapes. From this they can join the letters into signature words and refine a signature. This system supports VIP working collaboratively with a trainer. The trainer can create model shapes on a tablet PC which are then transformed to a haptic device. The haptic interface includes both active playback and constrained guidance with associated audio also available. Visual feedback is given to the trainer by echoing the haptic input onto a monitor, while pattern matching algorithms are used to beautify model shapes and computationally evaluate progress.

Background & Related Work

Accessible Writing Aids and Drawing Interfaces

Traditional methods of VIP learning the shapes of letters and numbers involve exploration of the characters presented in relief (eg. raised paper). By exploring the shape of the characters with their hands, VIP can build up a mental representation of each shape. Signature aids are commonly used by VIP when a signature is required. These take the form of a palpable sheet of card with a rectangular area cut from the middle. This rectangular area is placed over the signature area giving the signer a better idea of the size and orientation of the signature area as well as the current pen position within the box. While this is a useful aid when writing a signature, it is still necessary to learn the shapes of the letters and, just as importantly, to develop the fine motor skill required to draw them. One potential solution to help transfer these skills is to use haptic trajectory playback and passive guidance combined with audio positional feedback.

Accessible computer interfaces have previously been studied for browsing or creating drawings, charts and diagrams. Previous work by Kurze [5] examined developing an accessible interface for drawing. Kurze describes a drawing environment that combines swell paper – to create a physical line based representation of the drawing – with a stylus and digitiser to provide positional information to a computer within an image. Verbal cues are used to label different lines on the image which can subsequently be read back by the computer as the user explores the drawing. The TEDUB system [4] allows VIP to browse technical diagrams using a range of input devices. A technical drawing from a source (eg. A bitmap) can be read in and parsed into a structured form and made accessible through haptic and audio feedback.

Trajectory Playback Training Systems

Trajectory playback has previously been studied as a method of transferring trajectory information to sighted users. Feygin *et al.* [3] conducted a study into the possibility of providing gesture training using either visual, haptic, or visual-haptic guidance. Participants were asked to repeatedly recall each gesture. Results showed significant improvement in recreating the gesture in all conditions between the first and the last gesture suggesting learning was taking place. However, the haptic only training mode performed significantly worse than the haptic-visual training mode, but not significantly worse than the visual training mode. Oakley [7] studied the effect of gesturing on transmission of shape information but through a collaborative computer system. The results suggested that trajectory playback could be used to transfer shape information to a user. In the visual only and visual/haptic conditions significantly better drawings were produced than in the haptic only condition. Oakley's results suggest that additional information to the haptic trajectory playback is important to understanding the image. Audio is a potential replacement for visual cues when supporting VIP.

Haptic playback techniques have been studied as a method of teaching surgical procedures. Dang *et al.* [2] discusses a constraint-based training system for surgery training that provides guidance to users by restricting their movements from deviating from a predefined path. This method allows a user to follow the path taken for a procedure by an experienced surgeon, but allows the user to apply the forces to perform the surgery on the virtual patient. Similar techniques have also been applied to teaching Chinese handwriting. Teo *et al.* [8] demonstrate a system where the actions of a teacher can be recorded and played back to a student to aid forming characters.

Pen-based Input

Handwriting recognition is freely available on computers that support stylus (pen) input. This has lead to computer supported learning tools for handwriting on Tablet PCs [6]. However VIP need to start with larger, more simple shapes. Inkkit [1] is an extensible diagram recognition toolkit for the tablet PC. Its primary focus is to support the definition and recognition of diagram components by example and an api for plug-ins to convert recognized diagrams into other data formats. The pertinent parts of InkKit for this project are the drawing spaces, recognition and beautification. On a sketch-page the user can write, draw and undertake usual editing functions such as resize. The recognition engine is fully trainable from user examples. To create a new diagram type the user simply draws three to four examples of each valid diagram component. The recognition uses these examples to recognize components on a sketch. Beautification is the process of transforming a hand-drawn diagram to a formal diagram where all the components are aligned, regular and of standard sizes. InkKit includes beautification that progressively smoothes the lines of hand-drawn shapes until they are completely regular.

Proposal

A scenario of use for this system is that VIP and teachers sit together with a shared tablet and Phantom. They start with the trainer drawing a simple straight line on the tablet. The software converts this line into a flat plane with a straight groove on it on the Phantom and takes the Phantom pen to the starting position. Initially the haptic device guides the user through the ink stroke, this is progressively replaced by the user tracing along the stroke. As the user becomes more confident the guiding groove becomes softer until there is no guidance from the Phantom. Audio feedback may also be useful as a replacement for visual feedback. Audio can be used to indicate relative x, y and z position and to reinforce correct position or alert the user when the pen deviates from the desired path. VIP users' input is echoed onto the tablet screen so that the trainer can note progress. To provide self-feedback VIP can draw on the tablet and then check their drawing on the Phantom. Depending on individual confidence and ability, the size of the haptic image can be reduced and more complex shapes can be introduced such as boxes and circles and alphabet shapes. Finally the required alphabet shapes can be put together to form a signature. While ultimately the user needs to develop hand-writing which includes natural variation it may be better to initially present VIP with a partially or fully beautified version of the trainers ink strokes.

This environment joins together a force feedback device, stylus input and audio output; hence the system then provides a multimodal, collaborative learning environment for VIP users. To achieve this we use a tablet pc with stylus input for the trainer to create example drawings and words. This input is fully supported with recognition and beautification. The Phantom is used as both an output and input device. Active playback drags the user through a trajectory and this is combined with a passive constraint based system that restricts the user to a path around the trajectory. The active playback system will allow the teacher to interact with the learner in real time. The user will be able to feel the shape and timing of the movements of the teacher, with the teacher being able to speed up or slow down their movements for expert or novice learners. The guidance provided by these systems can be dynamically changed. As the user becomes more skilled at creating the shape, the gain of one or both active and passive systems can be reduced such that the user receives less guidance until they can eventually draw the shape unaided. Audio feedback provides shape information about the trajectory being played back. The pitch of a sinusoidal tone is mapped to vertical position on a page with horizontal position being mapped to audio pan. The user can combine the information from the haptics and audio to build a mental representation of the trajectory.

Future work

This paper describes work in progress. We plan progressive evaluation of each aspect of the system. Particular areas of interest are the combination of audio and haptic feedback, the effectiveness of dragging versus guiding the user in the virtual space, collaborative aspects of trainers and VIP working closely together, usefulness of beautification of the trainer's examples and overall effectiveness.

- Previous studies have shown that haptic visual playback is more successful when learning shapes than haptic alone. We intend to investigate the effectiveness of replacing the unavailable visual modality with audio cues. The hypothesis is that quicker and more effective learning will take place with audio support.
- Most haptic training systems either use active playback where there user is dragged through the trajectory or passive guidance in the form of a relief graph. This work will combine these two methods to allow flexibility. The system can be adapted to provide varying levels of guidance for novice or expert users. The effectiveness of each alone and combined will be evaluated.
- Many computer based training systems are controlled by the system. However a collaborative environment where the trainer and trainee work closely together has potential benefits. Future studies will examine the effectiveness of close collaboration in the learning process.
- Beautification of the trainer's example drawing has the potential to significantly simplify the trajectory that is rendered on the Phantom. However it is unclear whether this will improve the performance of VIP using the system. Performance with and without beautified trajectories will be compared.

Finally the overall effectiveness of the system as a training environment will be compared against traditional techniques for teaching signature creation.

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