A Demonstration of Dynamic Drawing Guidance via Electromagnetic Haptic Feedback

Thomas Langerak
Department of Computer
Science
ETH Zürich
Zürich, Switzerland
thomas.langerak@inf.ethz.ch

Juan Zarate
Department of Computer
Science
ETH Zürich
Zürich, Switzerland
juan.zarate@inf.ethz.ch

Velko Vechev
Department of Computer
Science
ETH Zürich
Zürich, Switzerland
velko.vechev@inf.ethz.ch

Daniele Panozzo
Courant Institute of
Mathematical Sciences
New York University
New York, USA
panozzo@nyu.edu

Otmar Hilliges
Department of Computer
Science
ETH Zürich
Zürich, Switzerland
otmar.hilliges@ethz.ch

Figure 1: Left-to-right: an electromagnet moving on a bi-axial linear stage underneath a high-speed pressure sensitive tablet delivers dynamically adjustable haptic feedback to a minimally instrumented pen. This allows for in-situ haptic feedback aiding users in drawing primitive shapes, or in writing characters, and gives guidance in more complex sketching tasks. We experimentally show that our approach increases accuracy and may help in skill acquisition.

ABSTRACT

We demonstrate a system to deliver dynamic guidance in drawing, sketching and handwriting tasks via an electromagnet moving underneath a high refresh rate pressure sensitive tablet presented in [3]. The system allows the user to move the pen at their own pace and style and does not take away control. Using a closed-loop time-free approach allows for error-correcting behavior. The user will experience to be smoothly and natural pulled back to the desired trajectory rather than pushing or pulling the pen to a continuously advancing setpoint. The optimization of the setpoint with regard to the user is unique in our approach.

Author Keywords

hardware; haptics; magnetism; stylus-based interaction

INTRODUCTION

Sketches and handwritten text have been a primary form of communication for centuries. Given their importance for society at large and the arts and design in particular, it is not surprising that a large number of digital pen interfaces exist that aim to combine the expressiveness and flexibility of pens and pencils with the advantages of digital representations via standalone tablets (e.g., Apple iPad, Microsoft Surface) or specialized digitizers (e.g., Wacom). Several sketch [7, 5, 4, 6] and digital ink [1, 9] beautification approaches exist. However, these typically improve results a-posteriori and hence do not provide real-time feedback. Comparatively little attention has been devoted to improving sketching in-situ.

We demonstrate a haptic feedback system (Fig. 2) to provide variable strength guidance onto the tip of a minimally instrumented ballpoint pen. The feedback is delivered via an electromagnet moving on a bi-axial linear stage below a touch

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Figure 2: Hardware overview.

and pressure sensitive digital tablet, governed by a closed-loop optimal control algorithm. Our approach allows users to perceive different levels of feedback while drawing on the tablet. Importantly, the variable strength of force feedback is crucial in allowing user autonomy, while maintaining the ability to provide guidance.

Previous approaches to pen-based haptic feedback rely on permanent Neodymium magnets (e.g., [8]). However, due to the steep increase in magnetic force as the pen approaches the magnet, this fully controls the pen, removing agency of the user. In contrast we propose a novel optimization scheme, inspired by model predictive contour control (MPCC) [2], to position and regulate an electromagnet such that it provides dynamically adjustable in-plane magnetic forces to the pen tip. Using this optimization scheme allows for a large degree of user autonomy, which is in sharp contrast with DePEND [8] (in which the system does not react to user input). This autonomy enables, for instance, creative freedom (Figure 3). More technical details on the implementation of the control method can be found in [3].

SYSTEM

MagPen (Figure 2) is a compact, non-invasive tabletop haptic feedback system in which users draw on normal paper with a minimally modified ballpoint pen. The strokes are recorded by a Sensel Morph (<https://sensel.com/>) pressure sensitive touch pad. We chose the Sensel board for its high spatial resolution (6502 DPI), high speed (500 Hz) and low latency (2 ms). Since the board is pressure sensitive, the sketching surface does not interfere with the input recognition. Users draw with a 3D printed ballpoint pen with a permanent ring magnet mounted in the shaft.

To deliver haptic feedback to the pen, we move a programmatically controlled electromagnet (Intertec ITS-MS-5030-12VDC, diameter = 5 cm, height=3 cm, 12 V 11 W) on a bi-axial linear stage directly underneath the input sensor. Our implementation consists of a the bi-axial system and high-torque stepper motors.

APPLICATIONS

Calligraphy:

Figure 1 illustrate writing of flourished characters, with only minimal visual guidance (single starting point).

Figure 3: Different variants of the same dragon, drawn with identical system settings. Each pair of drawings used with different tools.

Drawing teaching aid:

Connect-the-dots exercises are often used to teach children motor skills as well as stroke ordering. Our original paper [3] shows results from a similar exercise performed with our system.

Outlining & inking:

Figure 3 illustrates the effect of two core capabilities of the proposed approach. Here we first outline the proportions of the dragon head and then use different pens to ink-in the details. Note that the system provides haptic guidance but allows the user to draw the shape in different styles and with varying high-frequency detail, while maintaining similarity to the reference shape.

DEMONSTRATION

In our demonstration visitors will be able to draw a pre-determined shape. During the drawing they will be encouraged to make mistakes on purpose to fully explore the hardware capabilities. To understand the system only takes 30 seconds, a simple drawing can take up to 3 minutes. Visitors can take the drawings home as souvenir. During the demo they will notice how the feedback increases with the error they are making. Next to this they will notice the smooth correction.

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