Stylus Assistant: Designing Dynamic Constraints for Facilitating Stylus Inputs on Portable Displays

Long-Fei Lin Shan-Yuan Teng Rong-Hao Liang Bing-Yu Chen
National Taiwan University

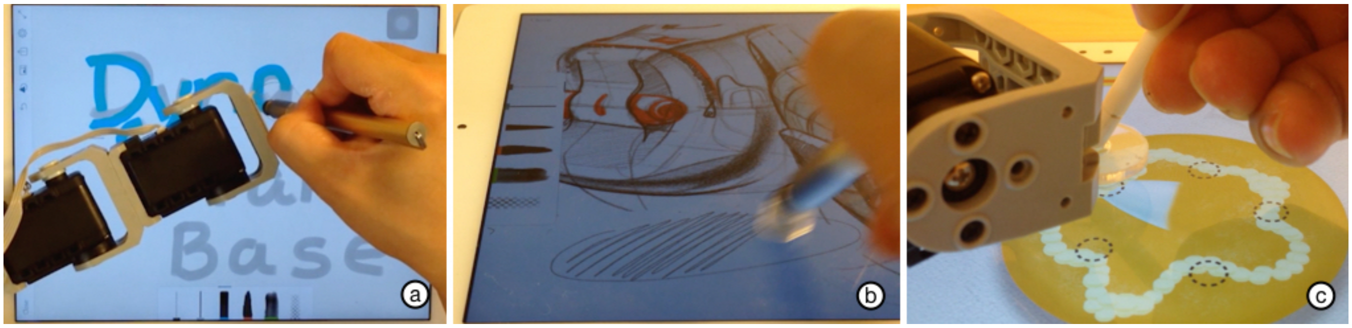

Figure 1: *This work proposed two types of actuator arrays to realize dynamic physical constraints on portable displays for facilitating stylus input, such as (a) writing, (b) sketching, and (c) gaming.*

1 Introduction

Accurate stylus tracking has been integrated in a highly portable form, drawing and writing applications are realized on the portable displays, which have numerous users nowadays. Nonetheless, when it comes to learning how to perform handwriting or drawing applications, the users still heavily rely on the on-screen visual guidance, which would be easily occluded when a user's hand is resting on the screen while performing stylus input.

Several previous works using actuation mechanisms to provide haptic guidance to decrease the demands of visual engagement during the stylus interactions. LineFORM [Nakagaki et al. 2015] proposed using a serpentine robot, allowing users holding in the non-dominant hand to guide stylus drawing on paper. DePENd [Yamaoka and Kakehi 2013] also actuate stylus using a strong magnet mounted on an x-y actuation platform, attracting the tip of a ferrite ball pen to guide stylus drawing on paper that is placed on the platform. However, these devices as a mean of computer input, they are still lacking a mechanism to maintain the correspondence between the device and the display; also, since these mechanisms are not suitable for portable displays, such as tablets, the form factors need to be reconsidered.

This work proposes two types of actuator arrays, *DynaFrame* and *DynaBase*, to realize dynamic physical constraints on portable displays for facilitating stylus input, such as writing, sketching, and playing (Figure 1). Both of the devices are designed for portability, and introduce as little occlusion to the pixels as possible.

2 DynaFrame: Around-Display Constraint

DynaFrame (Figure 2) is a frame consists of a robot arm surrounding the display, allowing the users fixing a portable display device to the center of it. The robot arm consists of four Dynamixel AX-18A servo motors (torque of 18.3 kg/cm and a speed of 0.103 sec/60). The size of each motor is 32 x 50 x 40mm. The connectors of each joint are 3D printed, and a ring-shape transparent acrylic stylus holder is attached to the end.

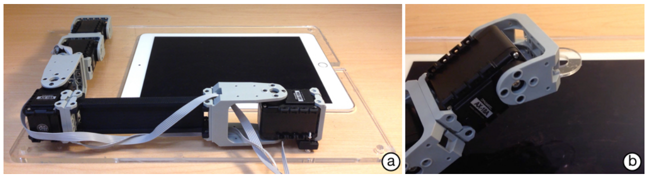

Figure 2: *DynaFrame. (a) Overview. (b) Stylus holder.*

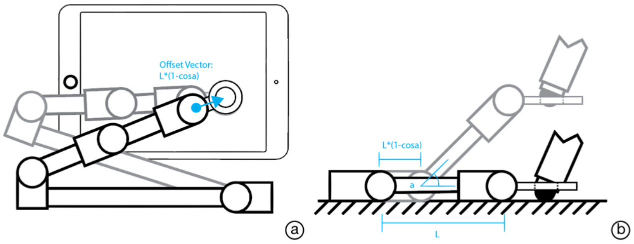

Figure 3: *Inverse kinematic with (a) orientation and (b) hover height correction.*

Several additional physical and mechanical designs are made to minimize the occlusion. In normal situations, the arms masquerade itself as the frame of the display, so that the device would not occlude the display area. Only if the force guidances or haptic assistances are needed, the arms move to the desired location to facilitate user interactions. Based on implmemented inverse-kinematic (IK) mechanisms with orientation and hover height correction, as shown in Figure 3, DynaFrame can move a stylus tip to any position on or above a display within 2cm hover height, thus can guide users manipulating the stylus.

Figure 1(a) shows how DynaFrame can provide procedural guidance in stylus interactions. DynaFrame first places the ring constraint on the starting point, waiting for the user to place the stylus tip in it. After the user placed the stylus tip in the ring, the robot arm moves the stylus along the path to the end point, then lifts the stylus tip toward the next starting point. For tablet computers that can sense the hover of the stylus, such as Samsung Galaxy Tab [1], the

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[1] http://www.samsung.com/

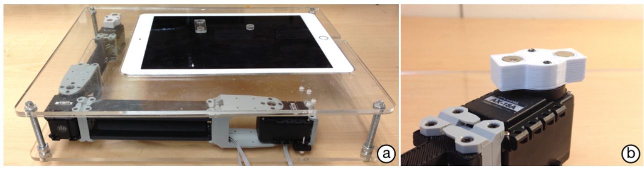

Figure 4: *DynaBase. (a) Overview. (b) Magnetic shaft.*

system can further guide the hover position and in-air movement of a stylus as shown in Figure 1(c). Perceiving these procedures by experiencing it would help them to know what and how to perform these actions.

Discussion: The around-device constraint, *DynaFrame*, provides good visibility. The exposed robotic arm mechanism clearly guides users what and how to perform desired actions. The rich haptic feedback provided to the users is also useful to guide the movements of the stylus, effectively extends the affordance of the passive stylus. However, during guidance, the mechanical arm still introduced some occlusions to the screen, which sometimes occlude the user's area of interests. To reduce occlusion, placing the robot arm to the *back* of display can be helpful.

3 DynaBase: Back-of-Display Constraint

Placing the actuation mechanism behind the device effectively eliminates the occlusion introduced by the hardware. Hence, we proposed another back-of-device constraint design, DynaBase (Figure 4), based on magnetism. DynaBase is a base station consists of a robot arm under the platform, which allows users docking a portable display device on its surface. The robot arm consists of three Dynamixel AX-18A servo motors with a magnetic shaft mounted on the servo on the end, is steadily fixed into the base station. A pair of magnets, One is with north-pole facing upward, and another one is with south-pole facing upward, are mounted on the shaft to the end of a robot arm, thus the magnetic shaft is able to rotate the magnetic piece with similar placement of magnets to any integer angles in wide range of speeds. Two analog Hall sensors are attached to the back of the magnets to recognize which pieces are snapped to the shaft based on the change of magnetic-field intensities. To sum up, this system can detect the presence of transparent magnetic physical constraint, and utilizes the invisible magnetic attraction to manipulate the position and orientation using the underlying magnetic handle as a dynamic physical constraint for stylus input.

Figure 1(b) shows the interaction techniques of DynaBase. DynaBase first moves the magnetic shaft to the default position, and show visual hint about the position and orientation of the back-of-device shaft to request users placing a magnetic *Point* constraint on the display. The magnet inside the *Point* constraint conducts the stylus tip to the touchscreen, so the system is aware of the presence of a stylus. Once the desired magnetic constraint is snapped to the correct position, the system detects it based on the change of magnetic fields. Then, DynaBase freely moves the constraints on the display surface, such as filling a region. Then, the user has to lift the stylus tip from the *Point* constraint to make the point constraint moved to the next starting point. Although the DynaBase can only guide user interactions per stroke, it did reduce the occlusions into a negligible size.

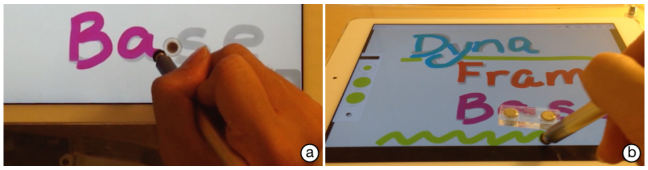

Figure 5: *Soft constraints. (a) Point constraint. (b) Ruler-shape constraints.*

DynaBase also provides soft constraints to provide haptic assistances such as overshooting prevention or alignment. As shown in Figure 5, DynaBase indicates the users where to start by moving the *Point* constraint nearby the end point of a stroke, and wait there until the stylus hit it. Once hit, it moves the *Point* constraint to the next endpoint, and so on. By perceiving the haptic feedback, the users prevent themselves from overshooting. Users can easily Different types of constraints, such as the *Ruler-shape* constraints, to draw linear or curvature strokes with physical constraint.

Discussion: Although not supporting the haptic guidance in three dimensions, DynaBase introduces less occlusions to the screen, occlude less users' area of interests in the application. The magnetic physical constraint can also nimbly move on the screen surface, easily avoid colliding user's hand, even when multiple users are performing collaborative work.

4 Conclusion

This work proposes two types of actuator arrays, DynaFrame and DynaBase, to realize dynamic physical constraints on portable displays for facilitating stylus input. Both of the dynamic constraint systems not only provide effective and expressive ways to facilitate users performing stylus interactions without introducing significant occlusions on the portable display, but also keep the display platform portable.

Since the technique demonstrated here using capacitive touchscreen and capacitive stylus, it works with finger touch as well — future work can consider using this technique to provide haptic guidance [Weiss et al. 2011] on touchscreen interaction. Future work can also consider using this platform to extend the expressivity of tangible interaction [Ishii and Ullmer 1997] and applications for portable displays.

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