Buru-Navi3: Behavioral Navigations Using Illusory Pulled Sensation Created by Thumb-sized Vibrator

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1 Introduction

Buru-Navi3 is a new force display technology that uses actuators which vibrate asymmetrically to create a continuous pulling force sensation without an external fulcrum. The user does not feel the discrete simple vibrating sensation that is so common in conventional mobile devices today. Instead, the user feels a smooth sensation of being pulled, akin to what we feel when someone leads us by the hand. For all users, the haptic or somatosensory cues created by Buru-Navi3 are, like lead-by-hand navigation or a guide dog for people with visual impairment, intuitive in indicating a certain direction. We have recently succeeded in creating a sensation of being pulled with a *thumb-sized* actuator that asymmetrically oscillates.

At our booth, the user can experience for the first time a novel haptic interaction in mobile devices with our innovative tiny prototype force display. The force display is the smallest and lightest ever with two degrees of freedom (DoF). We also implemented a pedestrian navigation system that tracks the position and orientation of the user, which helps the user walk along a path sequentially from point to point and understand directional cues for navigation by actively moving the hand.

2 Force Feedback Technique

Our approach to creating a sensation of being pulled exploits the characteristics of human perception, using different acceleration patterns for the two directions to create a perceived force imbalance. A brief and strong force is generated in a desired direction (e.g., leftward), while a weaker one is generated over a longer period of time in the reverse direction (e.g., rightward). Although the average magnitudes of the two forces are the same, reducing the magnitude of the longer and weaker force to below a sensory threshold makes the holders feel as if they are being pulled to the desired direction (e.g., leftward). Using two orthogonally placed actuators allows the holders to feel a force sensation in the four or eight principal directions on the azimuth plane.

3 Implementation

We have fabricated two prototypes: a one-DoF force display [Fig. 1(a)] and a two-DoF force display [Fig. 1(b)]. The size and weight of the one-DoF force display are $18\times18\times37$ mm^3 and 19 g, respectively. With this tiny and light force display, the directed force sensation is perceived just as strongly as with the previous larger prototypes.

The system of a pedestrian navigation demo consists of a tablet computer with the two-DoF force display attached, a shoulder bag (containing a battery and control device), a tracking server, and fiducial markers on the ceiling for tracking position. A front camera of the tablet computer faces the ceiling and captures the marker grid there. A server calculates the position and orientation of the user's hand (or force display) after receiving the images and then sends a command to change the force direction. The direction of force is updated and presented so as to help users walk along the path. Figure 2 shows other applications using Buru-Navi3. With a motion capture system, we can track the user's hand with pinching the Buru-Navi3 device. Therefore, the amplitude and direction of force sensation are altered. Multiple users can experience the tug-of-war application together [Fig. 2(a)]. In the angling game, users can feel a nibbling sensation on the hook and being pulled sensation with no fish lines [Fig. 2(b)]. In addition, users can learn calligraphy with the Buru-Navi3 device [Fig. 2(c)].

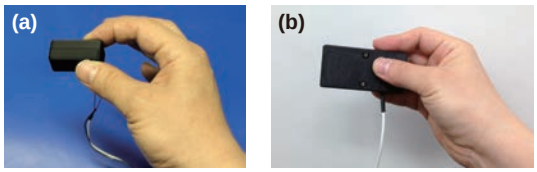

Figure 1: *Proposed novel thumb-sized one-DoF (a) and two-DoF force display (b).*

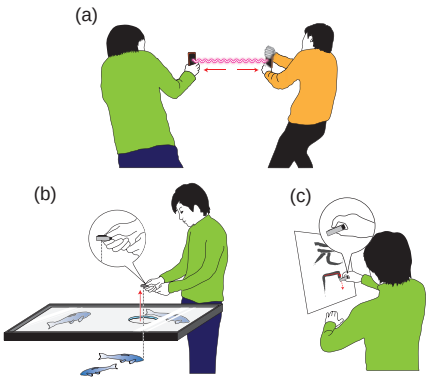

Figure 2: *Buru-Navi3 experience at our booth. (a) Tug-of-war using a pair of Buru-Navi3, (b) angling game and (c) calligraphy guidance using a Buru-Navi3 device.*

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