Innovative Mobile Force Display: Buru-Navi

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ABSTRACT

Humans capture the environmental world not only by vision but also by somatosensory information. Here we introduce several types of mobile force-display gadgets 'Buru-Navi' recently developed, and showcase some application trials for pedestrian navigation and for enhancing immersive sensation along a video scene.

1 INTRODUCTION

In last several decades, numerous studies have been conducted in telecommunication, tele-robotics, and virtual reality fields for developing haptic/force display as human interfaces [1-5]. Recently, there are increasing number of devices that actively provide tactile/somatosensory information to a person by vibration, force-application, or changing contact condition, such as smartphones, game controller, touch panels, and robotic manipulators etc. While great advancements to give a realistic sensation have been achieved by using robots whose bases were fixed on the ground or support, ungrounded force-display device was difficult to be developed because of inherent physics problem: action-reaction principle. In spite of this difficulty, ground-free force-display would be desirable to give a sensation in various mobile scenes, and several studies [6,7,8] attempted to use an illusory force sensation which is elicited by an asymmetric vibration without any external force application. Additionally, remarkable advancements in reducing size and weight of devices [9,10] have been reported. Here we introduce several types of mobile force display we developed recently [11,12], and demonstrate some trials of tactile pedestrian navigation, and haptic enhancement of immersive sensation along a video scene [13].

2 DEVELOPMENT OF DEVICES

Figure 1 shows two types of force displays we developed. Buru-Navi4 Shell Force type-P (left photo, B4SF-P) can produce the force sensation in two degree-of-freedom (2DoF) of forward/backward and rightward/leftward rotations by holding it bimanually. The type-T (right photo, B4SF-T) can produce the force sensation in 2DoF of orthogonal translational directions by holding it with one hand as shown in the figure. A smartphone can be mounted on both types of B4, which send driving commands to produce asymmetric vibration by B4 using Bluetooth connection. Each B4 contains a custom made controller board, two linear actuators (9x9x36 mm, NIDEC seimitsu, custom-made), and battery so as to be used in mobile applications.

Fig. 1 Mobile force display: Buru-Navi4 Shell Force (B4SF)

The Buru-Navi4 Finger Force (B4FF) shown in Fig. 2 was designed to be separated from a smartphone in order to reduce size, weight, and energy consumption. When a person pinches a gripper of this gadget with thumb and index fingers, this gadget can create a sensation of being pulled in any radial directions by various combinations of asymmetric vibrations in the orthogonal directions generated by linear actuators. In addition, several types of sensor-ICs have been installed in this device for various possible applications.

Fig. 2 Finger Force (B4FF)

3 TACTLE PEDESTRIAN NAVIGATION

Tactile pedestrian navigation is one of attractive applications of mobile force display as tried previously [8,14,15] because directional force sensation is more intuitive for navigation than simple vibration patterns [16]. This section will briefly introduce an experiment of pedestrian navigation using location information measured by smartphone GPS (Global Positioning System) (Fig.3 left photo) and a current examination of obstacle avoidance by creating force sensation (Fig.3 right photo).

Fig. 3 Pedestrian navigation trial images using B4SF-P with GPS location signal (left) and using B4FF with a laser distance sensor for obstacle avoidance (right).

3.1 Method

This navigation experiment was done in an outside flat ground (60x80 m) which was partly covered by short grasses. Locations of waypoints were specified with 20 m intervals in a matrix form, and no visible marker was placed at those waypoints. Current location of the participant was measured by the GPS on an Android smartphone (SONY Experia) and used in the real time navigation.

Four peoples were participated in this experiment, who did not know locations of target and via-points, but could see the surrounding environment to avoid accidental fall over. They were instructed to hold the device (Buru-Navi 4SF-P) bimanually as shown in Fig 3, and then to start to walk from the start position in a comfortable walking speed according to the sensation of being pulled by the device. Instruction direction of force sensation (forward/backward translation, rightward/leftward rotation) induced by asymmetric vibration was selected based on the difference between the heading direction and the direction toward the current waypoint from the current location, and that direction was updated in real-time during walking. Owing to this algorithm, the participants could correct the walking direction even though the participants moved in a wrong direction. The waypoint was updated according the planned path (randomly selected) when the participant came into the tolerance circle (r = 10m indicated by dashed curve in Fig. 4) of the current waypoint.

3.2 Results

Figure 4 shows three examples of walking paths. Small red and green sticks respectively indicate the desired direction to the next waypoint and the heading direction at each location. Letters of R/F/L indicate the instructed commands of the force sensation (rightward / forward / leftward). According to the command, the device produced an appropriate asymmetric vibration to induce the sensation of being pulled. Thick arrows denote the directions of walking. Participants started from the center of the most right dashed-circle, and moved to the first waypoint in each navigation. When the participant went into the tolerance area (dashed circle) of each waypoint, instructed command changed according to the direction of the next waypoint. Because of (1) the system latency including measurement of GPS, (2) the delay of human reaction, and (3) limited accuracy of position measurement, we needed to use sufficient size of tolerance area. In spite of these problems, participants were successfully guided by the force sensation produced by asymmetric vibration in many trials as seen in the figure.

As a quantitative measure of navigation, we calculated total path ratio (actual path – length / sum of planned straight paths between via-points) and averaged walking speed of each navigation. The medians of the ratio and speed of 45 navigation trials were 1.4 (ranged 1.0 – 2.2) and 1.33 m/s (ranged 0.7 – 1.8) respectively.

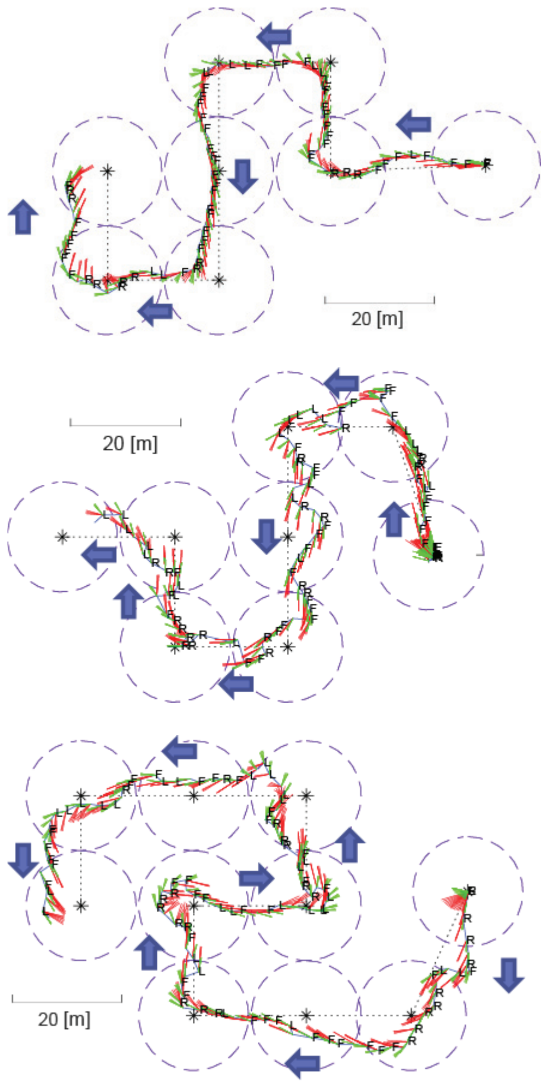

Fig. 4 Walk trajectories, heading and desired directions, in several pattern of planned paths

3.3 Future direction

As shown above, a route instruction by pulling force is useful for navigation, but it would be insufficient to navigate especially blind people because of possible obstacles on roads, such as parking and moving bicycles and even walking peoples. Right photo in Fig. 3 shows an examination of force sensation guidance of an obstacle during walking. Using a distance from the device to an obstacle detected by a built-in laser sensor, its temporal change, and human arm movement detected by the motion sensor, we have developed a method to create a force sensation so that the shape of object can be perceived. This method can be further extended by using a recent depth camera system.

4 ENHANCEMENT OF IMMERSIVE SENSATION

The mobile force display introduced above can be used another applications. Nowadays various video and movie images extend our visual experiences, especially with a head-mount display, but it is difficult to feel bodily sensations only from viewing those scenes. Multi-sensory integration techniques have been actively developed in various applications, including amusement parks, teleoperation, and virtual reality. However, a motion chair or moving plate for giving a bodily sensation would not be convenient when you want to see an image clip on your smartphone or tablet-PC. Even in such cases, directional force sensation at fingers, in addition to a simple vibration, would be expected to assist to give an immersive sensation into the video or game scenes. This intuitional expectation would be endorsed by neuroscience and psychophysics studies which showed that visual information affects tactile information processing, and tactile information also affects visual information processing [17-21].

4.1 How to create time-varying commands for force sensation along a video scene

In using a pulling force sensation, temporal synchronization between visual and tactile information is important [22,23], in addition to the direction itself. To easily create complex commands for time-varying pulling force sensation synchronized to the video scene, we dynamically rotated the B4 device in the direction of desired force sensation with watching video scenes, and then transformed the recorded motion signals into the commands. The commands can be also created from the image motion analysis techniques, such as global and/or local optical flow extractions.

Fig. 4a shows an example of giving a car-driving sensation with a video of first-person view in a car by using B4SF-P. By giving asymmetric vibrations in opposing directions at the right and left sides, the holder can feel the rightward or leftward car-handling sensation. Accelerating and decelerating sensations can be also created by applying asymmetric vibrations in the same direction.

Fig. 4b shows another example of reinforcing a sensation of offload-bicycle driving in a forest by using B4FF which can give a dynamically changing force sensation synchronized with video scene. Since this kind of application can be simultaneously experienced with multiple persons as shown in Fig. 4c, it would be useful for sharing a sensation of experiencing in theaters and in public viewing.

(a)

(b)

(c)

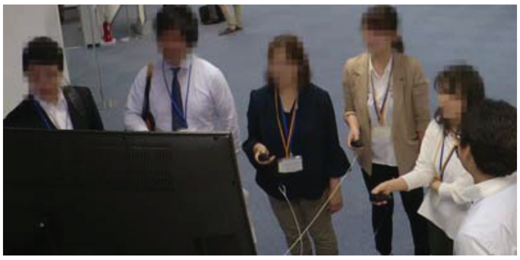

Fig. 4 (a) Car-driving sensation with a video clip of first-person view in a car by using B4SF-P. (b) Offload-bicycle driving sensation by using B4FF. (c) Sharing experiences of video and force-sensation with multiple persons.

5 CONCLUSIONS

Mobile force display gadgets we developed recently and the application trials were introduced here. In contrast to conventional force displays, such as robot manipulators, our force displays are not necessary to be supported by a fulcrum because asymmetric vibration, rather than constant force application, is used to induce the force sensation. By introducing a new mechanism for improving a directional force sensation, we have succeeded to develop new force displays which are able to be combined with smartphone or tablet. Due to these advancements, we will be able to extend application of force display in various scenarios of mobile scenes.

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