(2) Tapping Anywhere: A Position-free Wearable Input Device

"Tapping Anywhere" is a new input device that can control wearables mounted on any position of a human body by tapping actions with foot or hand. A body-mounted sensor detects changes in the body's static charge or static capacity caused by the tapping action. This method can be used not only for controlling wearables with rhythmic commands, but also for monitoring activities in everyday life.

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1. Introduction

There are many "wearables" mounted on our body such as Head Mounted Displays (HMDs), headsets, wrist computers, power generating shoes, and lots of body monitoring sensors. However, it is difficult to control "hard to reach" wearables. Some methods enable touchless control; for example, microphones can detect the human voice (via air), shock sensors can detect tapping vibration (via bone conduction). However, it is difficult to keep sensors away from the position of operation because signals attenuate with distance. Camera-based methods offer longer distances, however, "line-of-sight" condition is required and positions to mount are still restricted.

We propose a new input method that can control wearables in the same manner regardless of attached positions. It detects changes in the human body's static charge or static capacity by the tapping action with foot or hand. By utilizing good conductivity of a human body, wearables can be controlled without touching directly regardless of positions to mount or line-of-sight condition. No device need to be worn on the foot or hand. In addition, operations with foot and hand can be separately detected.

2. Tapping Anywhere

"Tapping Anywhere" is an input method that can control wearables mounted on any position of a human body by the tapping action with foot or hand. Its mechanism is described below.

2.1 Foot Tapping Detection

When a tapping action (e.g., up-down motion of a toe while a heel remains on the floor) is made, static charge is generated by the friction between the foot, sock, shoe and the floor. This charge can be detected as electric potential or electric charge of the human body by the use of an electric charge sensor such as a "charge-amplifier"[*1]. In this case, the human body can be regarded as one electrical conductor, so this detection process can be held on any position of the human body. Therefore, the sensor can be placed anywhere on the human body (**Figure 1** (1)). Moreover, the sensor can be separated from the skin by a thin insulator or layer of clothes.

2.2 Hand Tapping Detection

The fingertip is usually exposed (not covered with clothes), so no static charge is generated when surrounding objects such as desks and walls are tapped. However, tapping changes the static capacitance of the human body because the human body and the

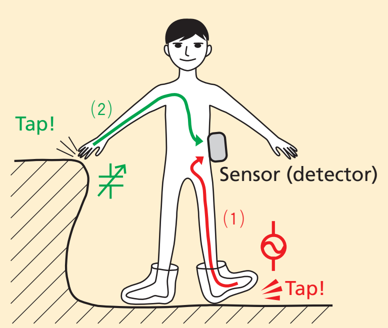

Figure 1 Mechanism of "Tapping Anywhere"

*1 **Charge-amplifier**: A charge/voltage converter circuit used, for example, to detect signals in a piezoelectric accelerometer.

objects can be regarded as small capacitors. A similar effect is used in touch switches and touch pads. However, a more sensitive mechanism is required for hand tapping detection. This approach also allows the sensor to be placed anywhere on the human body (Fig. 1 (2)). There are two types of touch switch sensors; passive type (measuring changes in inductive noise[*2]), and active type (measuring attenuation of imposed signal). Both sensors can be used for tapping detection and neither needs to directly contact the skin. However, the passive type can share the sensor unit with the foot tapping detector. On the other hand, the active type is robust against changes in surrounding environment, such as the presence of AC power lines or changes in electrical field strength.

Figure 2 shows sensor output when tapping with a toe and a finger, and the result of foot and hand tapping detection. These results were gained using a charge-amplifier style electric charge sensor (shared with passive type touch sensor). The sensor, mounted on a 2-mm-thick plastic insulator, was placed on the forehead. Three toe taps on the floor were followed by three finger taps on a desktop. The foot was covered by a sock and shoe; the finger was not covered. The upper part of the graph (raw sensor output) indicates that foot tapping and hand tapping yield waves with different shapes. The two actions can be separated by the use of a simple filter mechanism. (There are some "cross talk"[*3] components such as changes in inductive noise while foot tapping, and discharge when hand tapping.) The middle part of the graph shows the foot tapping detection result, and the lower part shows the hand tapping detection result.

3. Application

3.1 Rhythm Commands

There are some command methods for single bit input devices. Rhythm-based method [1] offers 10 to 30 commands with four to five tapping sequences. **Figure 3** shows the command examples by foot tapping. Two different commands are executed by different tapping rhythms. Rhythm command enables multiple operations for a single wearable device, or selective operation of different wearables.

3.2 Activity Sensor

"Tapping Anywhere" can also be used in activity sensing systems. Ordinary accelerometer-based pedometers and activity sensors have an issue that the output signal changes with the mounted position; for example, a waist-mounted sensor cannot detect hand actions. The proposed method, however, can detect foot and hand action regardless of mounted position.

Figure 4 shows sensor output in five common actions. The same sensor-insulator combination was mounted on the waist (over underwear and a dress shirt) and two sensor types were tested. The upper part indicates static charge sensor's output, and the lower part is passive type touch sensor's output. Five actions were performed for 4 seconds each; walking → sitting → filing → keyboard operation (notebook PC) → mouse operation (on the desk). These

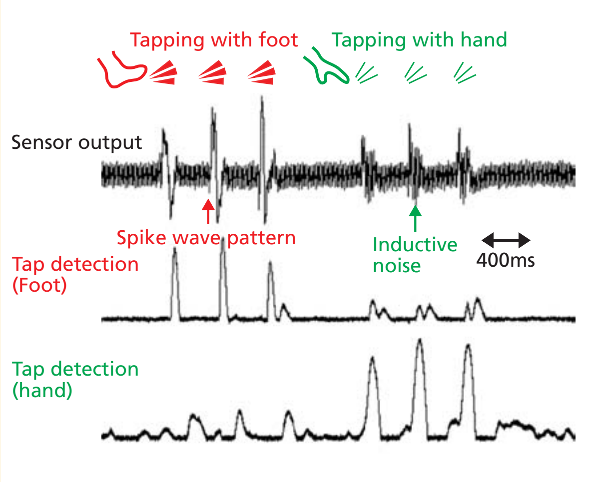

Figure 2 Sensor output and tap detection

*2 **inductive noise:** Noise induced in an object (here, the human body) due to changes in surrounding electromagnetic fields.

*3 **Cross talk**: A "leak" component of a signal to another signal.

graph shows that both sensors can detect not only big motions such as walking and seating, but also small actions such as filing (only the upper half of a body is moving) and mouse operation (only a hand and an arm are moving). The electric charge sensor has difficulty in detecting keyboard operation because only a finger and a hand are moved. The passive type touch sensor, on the other hand, shows some kind of response with keyboard operation; reliable detection may be possible by increasing sensor sensitivity.

4. Related Works

There are some mechanisms that can control wearables without touching directly. For example, [1] uses bone conduction to transfer fingertip tapping shock to the wrist position, however the communication length is under 30cm. [2] uses a small camera mounted on the brim of a cap for capturing hand signs, however it requires "line-of-sight" condition. [3] uses a wearable static charge sensor for detecting walking action. [4] also uses static charge for detecting foot tapping action, however, it requires earth grounding for the sensor device. The good conductivity of the human body can also be utilized for "intrabody communication"[5]. Accelerometer-based wearable activity sensor is used in an emergency report system [6].

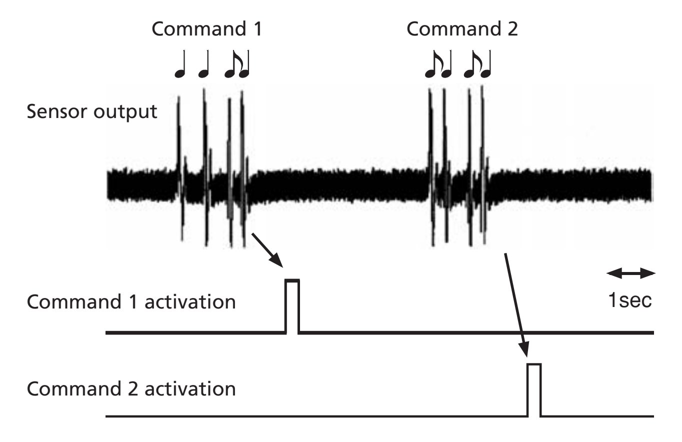

Figure 3 Examples of rhythm commands

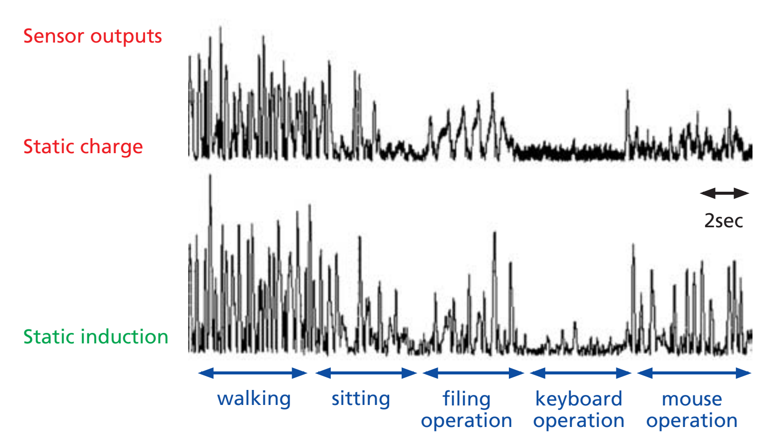

Figure 4 Sensor outputs during various actions

5. Conclusion

"Tapping Anywhere" realizes easy operation of wearables mounted at positions that are difficult to reach. It can also be used for action recognition and emergency detection by monitoring of sensor output continuously. In addition, it can be utilized in industry, such as a sticker type remote "unpowered" vibration sensor by using materials (e.g., wool and acrylate) that generate significant static charges by rubbing.

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