Wearable Haptic Feedback System and Interfaces

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Abstract. Haptic devices could be used in a variety of fields. This study depicted the leading design and prototyping steps of some wearable haptic devices and interfaces in different areas. The study first introduced the handed-worn haptic device. Next, the study pointed out the vested worn haptic devices. Finally, it presented the devices by foot wearing. As well as a variety of wearable device application technology, the main design opens new possibilities for future devices. Different materials are used for various types of equipment and principles, which could improve the device's performance. Ideally, wearable haptic devices have a multifunctional impact that can ease the users' body burden and the putting on and taking off process. By analyzing the advantages and disadvantages of various wearable devices, a few points still need to be improved. With the enormous probe of empowerment of wearable technology and interfaces in industries, intelligent wearable haptic will be applied in more fields. And make human life more convenient and efficient.

Keywords: Haptic, Wearable Devices, Feedback System.

1. Introduction

The research used the current popularity of wearable haptic devices in many areas, such as infotainment, medical and health. Most tactile devices sold on the market cannot be considered wearable. Ideally, wearable haptic devices have a multifunctional impact that can ease the users' physical burden and the putting on and taking off process [1]. The current technique of remote operation is very advanced, neither wear-resistant nor portable, and significantly impacts the growth of fields. The Apple Watch, for example, has a linear actuator that can make the watch vibrate. The actuator could provide different amounts and models of vibration of different events; for instance, during the navigation period using a map, different vibrations indicate whether the wearer needs to turn left or right. This device is called "tactics," and is explicitly designed to use wearable haptic devices' capabilities. By making use of skin that is highly sensitive to tangential direction, a single trigger could provide effective direction and twist information with tiny movements, as drivers are safe by giving direction information by using a simple skin elastic touch band connect to the arm or leg [2]. The one application that builds a hand-wearable haptic device. This study described that clutch in wearable systems are essential to holding back or coupling motion. Clutches are made up of between such electrodes separated by a small insulator and an interval of atmosphere. When the difference in voltage between the electrodes is zero, electrodes could slide freely without electrostatic attraction.

The electrostatic clutches could increase comfort and promote integration for wearable applications. Another application is that designed for vested-worn haptic devices. The function of this device is that by giving feedback to correct students' mimicking. The sensitivity of the skin results from a lot of kinds of touch. Skin is susceptible to frequencies around 250Hz. So, this performance could directly transfer the signal about the incorrect angle of the joint. The device caused a statistically meaningful change over time. It reduces real-time errors by up to 27% and increases the learning percentage by up to 23%. Their behavior will become subconscious [3].

Furthermore, the paper presented the integration of haptic vests with the multiple-mode virtual environment. It is composed of videos, audio and haptic feedback. The primary purpose is to determine the users who interact with the virtual environment and benefit from tactile and thermal stimulation by haptic vests. There are also some applications for footed-worn haptic devices. The primary function of the human foot is to direct the body's movement in a preferred manner. The paper described a novel haptic walking interface, which depends on a foundation of the principle of

programmable footplates with constant foot technique contact. It has involved in robot kinematics and is equipped with a highly dynamic driver. It pointed out that the main design target of Haptic Walker is that to have programmable treadmills, foot tracks could be freely programmed and to mimic any required walk trajectory so that patients could train randomly and individually adjusted gait trajectories. So, The Haptic Walker is the only device that can provide infinite instruction paths for completely guided natural or synthetic foot movements. Through the experiment about the practicability of this haptic vest. It concluded this device could enhance the performance of VE [4]. Today's wearable systems include micro-sensors seamlessly integrated into textiles, consumer electronics embedded in fashionable clothing, mechanical watches, and glasses worn on all body parts [5].

2. Wearable Haptic feedback system and Interfaces

2.1. Hand-Worn Haptic Device

The thumb sensor with a hemisphere form is decided to make with Eco flex as the elastic substance, and the metal electrode is encased just on the flat side. The manufactured sensor is bonded to a single-finger enclosure inside via epoxy. The detector distribution is given by the available DOFs of three finger phalanges: distal, middle, and proximal. The proximal and medium phalanx can only fold upward or downward, whereas the proximal phalanx can bend in all directions. Moreover, five Lead zirconate titanate thin chips are placed at the root of each finger to carry out the haptic feedback. It is also common for the phalanx at the front to be bent unintentionally during the bending of the middle or proximal phalanx. These were all also identified by finger-sensing devices, and a minimal outcome was generated as a result. The suggested gloves are made up of just three components: triboelectric finger sensors, palm sensors, and piezoelectric haptic stimulators.

About the fingers and palm sensor, the triboelectric output is produced by friction contact with charged to interact between the surface of two different kinds of material. The sensor is in a neutral state when it is first turned on. The fingers sensor relies on that through the contacting interaction between the elastomer and the fingers' skin. Positive charges from the skin surface will cancel out the negative electric potential from the sensor's surface, and the electrode's charges mat is repelled down to the ground. The glove's 16 sensors were monitored simultaneously as a preliminary test on machine learning-based object recognition using triboelectric outputs. As a result, raw data containing various essential information in a dynamic grabbing process, such as finger bending speed, contacting force between fingers and sensor arrays, sensor triggering sequence, and operation manners for a specific user, can be fed directly into the training model without the need for preprocessing, i.e., normalization and segmentation [6]. This ability of wearable devices could stimulate different senses of touch depending on their active ingredients. Compared with traditional bulky tactile feedback devices, lightweight, minified tactile feedback interfaces have a portable wearable and even skin-integrated format, which is more suitable for next-generation electric devices [7]. Clutches are critical components in wearable systems such as soft exoskeletons, haptic clothing, and rehabilitation equipment for blocking or coupling motion. Electrostatic clutches can be tiny and light, low profile and flexible, so they are better wearable applications. Electrostatic clutches are made up of two flexible and partially overlapping electrodes separated by a thin insulator and, in some cases, an air gap. They are variable capacitors with electrodes that can slide relative to one another while maintaining roughly out-of-plane spacing.

The high density of forces associated with the textile-based materials of Electrostatic allowed them to place just on hand and finger bones to prevent them from moving. It is a very effective device. For example, it could block a load of several kilograms, although only a few square centimeters overlap among the bands. In addition, textile integration permits ultralight and its high flexibility of Electrostatic clutches, which could enhance comfort and promote wearable integration device applications. Exactly, The Electrostatic could be washable. Washing with soapy water could clean the surface of Electrostatic and restore most of its performance, and remove the particles from finger

oil and wear. In the future, Kinesthetic haptic feedback will be a rapidly expanding field. The thickness of devices was required to be very thin [8].

2.2. Vest-Worn Haptic Device

This study shows how users can use a haptic vest to perceive a virtual environment by using two types of stimuli: tactile and thermal. As a result, the vest contains two types of actuators: (I) vibrotactile actuators, which generate tactile stimuli via vibration patterns, simulating virtual interactions such as contact with people or objects within the VE; (ii) thermoelectric actuators, which generate hot and cold sensations, so that users detect a temperature change whenever they approach a thermal focus. The ultimate goal of haptic perception is to improve reality and immersion or presence.

Three parameters influence the temperature achieved by the edge of the Peltier battery stick on the skin surface. They are the amounts of pressure, the variable velocity and the position relative to the fire. The temperature is going to change. For example, when the velocity of the users increases dramatically, the user's body temperature will rise as a result of physical activity. As a result, a temperature change caused by pressure or exercise is irreversible. The vest must be tightly in contact with users' bodies, allowing the user to perceive tactile patterns better. They tested whether a vest equipped with tactile and heat actuators could improve serious game performance. The result is that, in most cases, the participants could correctly and precisely connect events with tactile patterns. The researchers claim that the vest could improve the sense of reality and the presence of a virtual environment (Figure 1) [4].

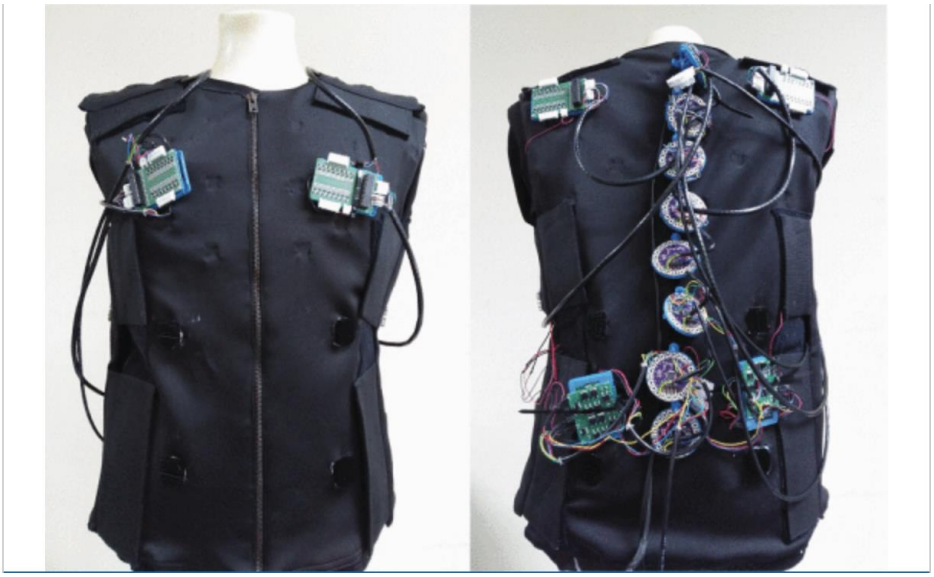


Figure 1. Evaluation in digital realities: haptic jacket and user sensorial abilities [4].

Through the wearable robotic system, students simultaneously receive real-time tactile feedback from all joints. The tactile feedback can supplement the teacher's visual or auditory feedback. The goal is for students to use this novel high bandwidth vibrotactile information to learn new motor skills more quickly and deeply. It would also be designed to be used in various applications, such as sports training and nerve damage recovery, and would employ one of the most precise motion capture systems. Using a dozen high-speed infrared cameras, synchronized strobes, and custom hardware. Choosing five known joint positions to calculate joint angle data. The Vicon system, on the other hand, is costly and bulky. As a result, it is impractical for some people. This system enabled people to train themselves to sit and stand for a short period without the supervision of others. The system could provide a constant sports movements system to give feedback to students when they try to learn new skills in sports. Students will train the users to accept the feedback to learn sports skills unconsciously. Correcting probably became an automatic muscle reflex rather than a conscious mediation. It is similar to letting other people view your shoulder and timely correct your posture.

There is a lot of application in future research; this feedback will probably have some applications in our daily life. The efficiency of steady-state learning improves by up to 23%. The studying errors are enhanced by up to 27% over flexion joints. It will become an unconscious action [3].

2.3. Foot-Worn Haptic Device

Gilded Gait was an innovative tactile sensory interface system that mechanically simulated perception with specific vibrotactile feedback implemented to the user's outsoles. Admittedly, the interaction between this system is passive. As the vibration is only triggered when the user is accurate, ensure this system can present information unnoticed at the periphery of the user's attention. It is suitable for urban and outdoor use because of its properties. Frey has designed shoes that could only tilt to guide the wearer to either right or left automatically. Several electronic components are fixed onto an external circuit board connected to the insole. The insole comprises six vibration panels that display response patterns, a push-down switch, and an accelerometer that can detect users' footsteps. When they chose the gel, using a gel allows the user to feel much stronger vibrations and safely protects the internal structure by avoiding the impact caused by the footsteps. When the step is detected, the microcontroller immediately orders the vibration panels to vibrate in the designed pattern, and the user will receive an illusion of a virtual ground texture. It has three kinds of patterns of vibrational feedback. Applying haptic feedback to only one foot, for example, enables the app to offer simple turn-by-turn navigation, removing the need to refer to maps for all, but it needs some complex intersections. By experimenting, the result means that the feelings brought to the participants are realistic. When the user wearing the shoes takes a step, the soles get in touch with the ground, the push-down switch is pressed, and the accelerometer marks a sudden enhancement in the direction of upward acceleration. The accurate timing of the users' steps without apparent delay. The paper is convinced that this system is practical and will explore further in the future (Figure 2) [9].



Figure 2. Gilded gait: augmented footsteps reshaping the urban experience [9].

This innovative haptic motion control interface features two configurable foot systems with long-term walking device interaction. The machine is based on the kinematic structure of rigid hybrid parallel series robots. It is equipped with an electric direct drive motor that enables highly dynamic pedal motion for contact force measurement, with six degrees of freedom force or torque sensors installed under each foot platform. To continuously detect the contact force between the foot and the

footplate. The primary function of foot movements is to transform the biological species in an intended way. Therefore, in the virtual environment, the users can navigate in the environment by using a tactile foot device. The researchers developed the system for the essential applications of gait recovery as a result of acquiring a place of importance consisting of maximum passive and active safety measurements of the machine's users and medical operators. Using intelligent robot devices to guide paralyzed patients and their walking track, physical therapists, can be freed from the hard work. In the later training periods, the behaviors of compliant machines play a valuable role, in which machines could simulate physical therapists, just as an intelligent tactile foot device. Designing a tactile foot device that is much more portable is unnecessary. This device needs to hold onto the whole human body weight. So, relatively larger, and stronger manipulators are essential. It will add manual and automatic emergency switches to guarantee the user's safety. They will all link to the central emergency switches circuit. At any time, the physiotherapist can issue a "stumble" command to one of the footplates, which instantaneously prevents the footplate. The motor device belongs to the group "programmable pedals." which provide the user with tactile foot sensations, similar to hand sensations, to present an interface with tactile sensation to the hand [10].

3. Discussion

The handed tactile devices, such as human-machine interface (HMI). Only three units are included in the gloves: a triboelectric finger sensor, a palm sensor, and piezoelectric sensation sensitizers. These detectors can be capable of all kinds of work; they don't need to take integration of traditional inertia or resistance transducers. It became more convenient. Except for use in the training process, these gloves ultimately can be the triggers of the virtual social network. More interaction between the elderly and their families could improve emotional comfort. Strength their relationship. On balance, the smart gloves with a simple design triboelectric sensor and piezoelectric tactile mechanical stimulator demonstrated that the possibility of low construction costs, as well as low power dissipation of Hirsch devices, could enhance analysis based on a large amount of data acquired through artificial intelligence technology. Overall, these gloves revealed a new possibility for a new HMI way to solve. Compare favorably to current inertia and resistance training shoe covers used in VR applications, entertainment, social networks, and robot control. Another hand-worn haptic device is the Textile Electrostatic Clutch.

Due to the 3D braided structure, the textile electrodes always produce low capacitance, generating high roughness and holes in the braided structure. The lower capacitance also causes low electrostatic forces and, as a result, low friction shear forces. Making matters more complex, it is also tricky to coat the fabric electrodes equitably. To resolve the problem, they used 31.7μm thick conductive tape to cover this textile to flatten it first. They then attached to 25μm dielectric film. Ultimately, an Electrostatic clutch can be the Ultimate, Electrostatic configuration file and is very flexible. It was more suitable to be designed with wearable applications. I thought the finger roots were equipped with five lead zirconate titanates, which could enhance the sensitivity to touch.

The sensor is divided into three phalanges, which makes the received tactile feedback more accurate. The vested-worn haptic device is a haptic vest. They experimented with whether the vest using haptic and thermal actuators could improve games' performance by analyzing the data of an experiment. According to the evaluation of haptic patterns, just five participants did not associate with an event in VE and stimulus. It is probably due to desynchrony among the event-tactile patterns or short of stimulus realism, relatively to be contacted. However, most participants could connect to events and tactile responses together. To reiterate, these five HE groups participants did not appropriately correlate events, and these differences could be attributed to the need for perfect stimulus for these participants to recognize and positively estimate haptic patterns.

Meanwhile, two participants could not be sensitive to the thermal stimulus; they did not perceive these well, and others who participated in the experiment could not connect to the stimulus and some virtual events. So, they were included in the HE groups. These participants need a higher sense of

reality to correlate correctly to the events and VE. The paper pointed out that they could be designed to act as footed-worn haptic devices. Using Gilded gait to make a discussion. They conducted a GPS receiver, "Application Module," which could periodically detect the user's position. The module has a microcontroller, which includes mapping data among the geographic position and feedback patterns. The first experience with this application has been positive, it is easy for them to notice the simulated textures, but it is not very abrupt. Giving the feeling to the user is like walking on the bumpy tiles of a Japanese sidewalk. They expected the Gilded Gait would trigger a new and exciting action. They found that the gel sheet did well in protecting the internal electrodes and improving the ergonomics technique, which inhibits the "mechanical" feeling of soles. They also created a music player "application module "to explore the possibility of inputting data using Gilt Gait. The numbers of input errors are strangely low. This device could be suitable for multiple other uses. When comparing prediction data to actual data, the BP neural network has better prediction performance and comparatively small error, which can meet the demand, as well as fast prediction speed and simple handling.

4. Conclusion

This paper introduces the three kinds of wearable haptic devices. Such as handed-worn devices, vested-worn devices, and footed-worn devices. The users can use the device of Gilded Gait in various fields. The system not only helps visually disabled people navigate sidewalks but is also already being used by young people as a walking guide on their mobile phones. The gel sheets also protect the internal electrode devices and improve human engineering. To make the soles more comfortable, inhibit the feel of "mechanical". The users will use this system in a lot of areas. Likewise, the hand-worn device is the clutches. These devices are central parts of many robotic systems, which enormously prevent or coupling many robotic patterns. This system is mainly designed for gait recovery because of occupying an important place in identifying with maximum passive and the measurements of the active safety of users as machine and medical operators. It will guide paralyzed patients to go along with the walking pathway correctly, which can replace the physical therapists, just as an intelligent tactile foot device. To protect the user's safety, it will append some necessary switches. Another type of wearable haptic device is the vested-worn technique, the haptic vest. In the field of VE, vests unquestionably have a significant impact and boost productivity. The vest included two kinds of vibrotactile actuators and thermoelectric actuators. The users can perceive stimulation more sensitively. Such as thermal stimulus and vibrate stimulus. About Wearable Vibrotactile Feedback Suit, this system could promptly mediate action when students learn new sports skills. As time passes, the users' muscles will subconsciously and automatically accept feedback. Necessarily, the research will apply this artificial intelligence in more areas. Improving the users' experience and performance of these devices.

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