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Tactile Robot Vibrating Detection Using Haptic Wireless Sensors

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Abstract— Haptic technology, **haptics**, or **kinesthetic communication**, is tactile feedback technology which recreates the sense of touch by applying forces, vibrations, or motions to the user. This mechanical stimulation can be used to assist in the creation of virtual objects in a computer simulation, to control such virtual objects, and to enhance the remote control of machines and devices (telerobotics). It has been described as "doing for the sense of touch what computer graphics does for vision". Haptic devices may incorporate tactile sensors that measure forces exerted by the user on the interface.

***Keywords*—**Tactile;Haptic Sensors;Mobile Device; Touch Synopsis;

INTRODUCTION

Haptic technology has made it possible to investigate how the human sense of touch works by allowing the creation of carefully controlled haptic virtual objects. These objects are used to systematically probe human haptic capabilities, which would otherwise be difficult to achieve. These research tools contribute to the understanding of how touch and its underlying brain functions work.

HISTORY

One of the earliest applications of haptic technology was in large aircraft that use servomechanism systems to operate control surfaces. Such systems tend to be "one-way", meaning external forces applied aerodynamically to the control surfaces are not perceived at the controls. Here, the missing normal forces are simulated with springs and weights. In lighter aircraft without servo systems, as the aircraft approached a stall the aerodynamic buffeting (vibrations) was felt in the pilot's controls. This was a useful warning of a dangerous flight condition. This control shake is not felt when servo control systems are used. To replace this missing sensory cue, the angle of attack is measured and when it approaches the critical stall point, a stick shaker is engaged which simulates the response of a simpler control system. Alternatively, the servo force may be measured and the signal directed to a servo system on the control, known as *force feedback*. Force feedback has been implemented experimentally in some excavators and is useful when excavating mixed material such as large rocks embedded in silt or clay. It allows the operator to "feel" and work around unseen obstacles, enabling significant increases in productivity and less risk of damage to the machine.

The first US patent for a tactile telephone was granted to Thomas D. Shannon in 1973. An early tactile man-machine communication system was constructed by A. Michael Noll at Bell Telephone Laboratories, Inc. in the early 1970s and a patent issued for his invention in 1975.

1994 marked the first use of haptic technology for entertainment when Aura Systems launched the Interactor Vest, a wearable force-feedback device that monitors an audio signal and uses Aura's patented electromagnetic actuator technology to convert bass sound waves into vibrations that can represent such actions as a punch or kick. The Interactor vest plugs into the audio output of a stereo, TV, or VCR and the user is provided with controls that allow for adjusting of the intensity of vibration and filtering out of high frequency sounds. The Interactor Vest is worn over the upper torso and the audio signal is reproduced through a speaker embedded in the vest. After selling 400,000 of its Interactor Vest, Aura began shipping the Interactor Cushion, a device which operates like the Vest but instead of being worn, it's placed against a seat back and the user must lean against it. Both the Vest and the Cushion were launched with a price tag of $99.

Design by Generation

Haptics are enabled by actuators that apply forces to the skin for touch feedback, and controllers. The actuator provides mechanical motion in response to an electrical stimulus.

First

Most early designs of haptic feedback use electromagnetic technologies such as vibratory motors, like a vibrating alert in a cell phone or a voice coil in a speaker, where a central mass is moved by an applied magnetic field. These electromagnetic motors typically operate at resonance and provide strong feedback, but produce a limited range of sensations and typically vibrate the whole device, rather than an individual section.

Second

Second generation haptics offered touch-coordinate specific responses, allowing the haptic effects to be localised to the position on a screen or touch panel, rather than the whole device. Second generation haptic actuator technologies include electroactive,polymers, piezoelectric, electrostatic a ndsubsonic audio wave surface actuation. These actuators allow to not only alert the user like first generation haptics but to enhance the user interface with a larger variety of haptic effects in terms of frequency range, response time and intensity. A typical first generation actuator has a response time of 35-60ms, a second generation actuator has a response time of 5-15ms. User studies also showed that haptic effects with frequencies below 150 Hz are preferred by users. Frequencies of 250–300 Hz, which is the typical range of electromagnetic systems are well suited for alerts but are perceived as annoying over time, which is why first generation haptic systems used to enhance the user interface are often deactivated by the users.

Third

Third generation haptics deliver both touch-coordinate specific responses and customizable haptic effects. The customizable effects are created using low latency control chips.

To date two technologies have been developed to enable this; audio haptics and electrostatic haptics.

A new technique that does not require actuators is called reverse-electro vibration. A weak current is sent from a device on the user through the object they are touching to the ground. The oscillating electric field around the skin on their finger tips creates a variable sensation of friction depending on the waveform, frequency, and amplitude of the signal.

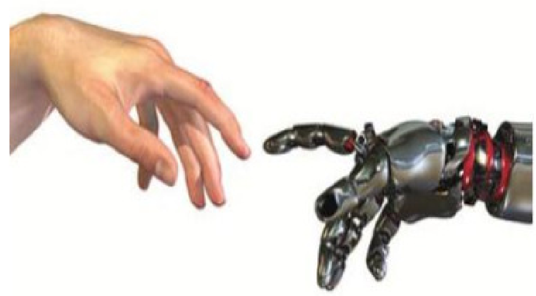
Fourth

Fourth generation haptics deliver pressure sensitivity, enabling how hard you press on a flat surface to affect the response.

There are currently no commercially available (as of May 2013) platforms that use this functionality, but the technology is in development by a number of firms. KDDI and Kyocera jointly announced[9] in 2011 that they were collaborating on research. And, at the Future World Symposium electronics industry conference, 2012, HiWave's (haptics division now spun out to become Redux) CEO stated that the company was also working on pressure-sensitive technology.

In June 2013 a fourth generation haptics demonstration platform, called Bulldog, was announced in the UK electronics publication Electronics Weekly.[10] This took the force exerted by a finger into consideration when delivering the haptic feedback and gave three levels of feedback from a flat panel.

Commercial Applications



Tactile electronic displays

A tactile electronic display is a kind of display device that presents information in tactile form. The two most popular kinds of tactile electronic displays .

Teleoperators and simulators

Teleoperators are remote controlled robotic tools—when contact forces are reproduced to the operator, it is called *haptic teleoperation*. The first electrically actuated teleoperators were built in the 1950s at the Argonne National Laboratory by Raymond Goertz to remotely handle radioactive substances. Since then, the use of force feedback has become more widespread in other kinds of teleoperators such as remote controlled underwater exploration devices.

When such devices are simulated using a computer (as they are in operator training devices) it is useful to provide the force feedback that would be felt in actual operations. Since the objects being manipulated do not exist in a physical sense, the forces are generated using haptic (force generating) operator controls. Data representing touch sensations may be saved or played back using such haptic technologies. Haptic simulators are used in medical simulators and flight simulators for pilot training.

Video games

Haptic feedback is commonly used in arcade games, especially racing video games. In 1976, Sega's motorbike game *Moto-Cross*,[11] also known as *Fonz*, was the first game to use haptic feedback which caused the handlebars to vibrate during a collision with another vehicle. Tatsumi's *TX-1* introduced force feedback to car driving games in 1983. The game *Earth shaker* was the first pinball machine with haptic feedback in 1989.

Simple haptic devices are common in the form of game controllers, joysticks, and steering wheels. Early implementations were provided through optional components, such as the Nintendo 64 controller's *Rumble Pak* in 1997. In the same year, the Microsoft SideWinder Force Feedback Pro with built in feedback was released. Many newer generation console controllers and joysticks feature built in feedback devices too, including Sony's DualShock technology. Some automobile steering wheel controllers, for example, are programmed to provide a "feel" of the road. As the user makes a turn or accelerates, the steering wheel responds by resisting turns or slipping out of control.

In 2007, Novint released the Falcon, the first consumer 3D touch device with high resolution three-dimensional force feedback; this allowed the haptic simulation of objects, textures, recoil, momentum, and the physical presence of objects in games.

In 2013, Valve announced a line of Steam Machines micro consoles, including a new Steam Controller unit that that uses weighted electromagnets capable of delivering a wide range of haptic feedback via the unit's trackpads.

Personal computers

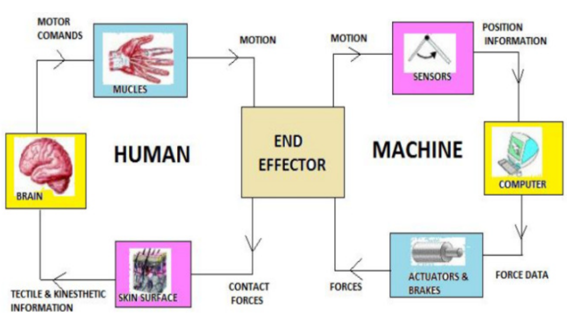


Fig: Basic configuration of Haptics

In 2008, Apple's MacBook and MacBook Pro started incorporating a "Tactile Touchpad" design with button functionality and haptic feedback incorporated into the tracking surface. Products such as the Synaptics Click Pad followed thereafter.

Mobile devices

Tactile haptic feedback is becoming common in cellular devices. Handset manufacturers like Nokia, LG and Motorola are including different types of haptic technologies in their devices; in most cases, this takes the form of vibration response to touch. Alpine Electronics uses a haptic feedback technology named PulseTouch on many of their touch-screen car navigation and stereo units. The Nexus One features haptic feedback, according to their specifications.

In February 2013, Apple Inc. was awarded the patent for a more accurate haptic feedback system that is suitable for multitouch surfaces. Apple's U.S. Patent for a "Method and apparatus for localization of haptic feedback describes a system where at least two actuators are positioned beneath a multitouch input device to provide vibratory feedback when a user makes contact with the unit. More specifically, the patent provides for one actuator to induce a feedback vibration, while at least one other actuator creates a second vibration to suppress the first from propagating to unwanted regions of the device, thereby "localizing" the haptic experience. While the patent gives the example of a "virtual keyboard," the language specifically notes the invention can be applied to any multitouch interface.

Virtual reality

Haptics are gaining widespread acceptance as a key part of virtual reality systems, adding the sense of touch to previously visual-only solutions. Most of these solutions use stylus-based haptic rendering, where the user interfaces to the virtual world via a tool or stylus, giving a form of interaction that is computationally realistic on today's hardware. Systems are being developed to use haptic interfaces for 3D modeling and design that are intended to give artists a virtual experience of real interactive modeling. Researchers from theUniversity of Tokyo have developed 3D holograms that can be "touched" through haptic feedback using "acoustic radiation" to create a pressure sensation on a user's hands (see future section). The researchers, led by Hiroyuki Shinoda, had the technology on display at SIGGRAPH 2009 in New Orleans.

Research

Research has been done to simulate different kinds of taction by means of high-speed vibrations or other stimuli. One device of this type uses a pad array of pins, where the pins vibrate to simulate a surface being touched. While this does not have a realistic feel, it does provide useful feedback, allowing discrimination between various shapes, textures, and resiliencies. Several haptics APIs have been developed for research applications, such as Chai3D, OpenHaptics, and the Open Source H3DAPI.

Medicine

Haptic interfaces for medical simulation may prove especially useful for training in minimally invasive procedures such as laparoscopy and interventional radiology, as well as for performing remote surgery. A particular advantage of this type of work is that surgeons can perform more operations of a similar type with less fatigue. It is well documented that a surgeon who performs more procedures of a given kind will have statistically better outcomes for his patients. Haptic interfaces are also used in rehabilitation robotics.

In ophthalmology, *haptic* refers to supporting springs, two of which hold an artificial lens within the lens capsule after the surgical removal of cataracts.

A Virtual Haptic Back (VHB) was successfully integrated in the curriculum at the Ohio University College of Osteopathic Medicine. Research indicates that VHB is a significant teaching aid in palpatory diagnosis (detection of medical problems via touch). The VHB simulates the contour and stiffness of human backs, which are palpated with two haptic interfaces (SensAble Technologies, PHANToM 3.0). Haptics have also been applied in the field of prosthetics and orthotics. Research has been underway to provide essential feedback from a prosthetic limb to its wearer. Several research projects through the US Department of Education and National Institutes of Health focused on this area. Recent work by Edward Colgate, Pravin Chaubey, and Allison Okamura et al. focused on investigating fundamental issues and determining effectiveness for rehabilitation.

Robotics

The Shadow Hand uses the sense of touch, pressure, and position to reproduce the strength, delicacy, and complexity of the human grip. The SDRH was developed by Richard Greenhill and his team of engineers in London as part of The Shadow Project, now known as the Shadow Robot Company, an ongoing research and development program whose goal is to complete the first convincing artificial humanoid. An early prototype can be seen in NASA's collection of humanoid robots, or robonauts. The Shadow Hand has haptic sensors embedded in every joint and finger pad, which relay information to a central computer for processing and analysis. Carnegie Mellon University in Pennsylvania and Bielefeld University in Germany found The Shadow Hand to be an invaluable tool in advancing the understanding of haptic awareness, and in 2006 they were involved in related research. The first PHANTOM, which allows one to interact with objects in virtual reality through touch, was developed by Thomas Massie while a student of Ken Salisbury at MIT.

Arts and design

Touching is not limited to feeling, but allows interactivity in real-time with virtual objects. Thus, haptics are used in virtual arts, such as sound synthesis or graphic design andanimation. The haptic device allows the artist to have direct contact with a virtual instrument that produces real-time sound or images. For instance, the simulation of a violin string produces real-time vibrations of this string under the pressure and expressiveness of the bow (haptic device) held by the artist. This can be done with physical modeling synthesis.

Designers and modellers may use high-degree-of-freedom input devices that give touch feedback relating to the "surface" they are sculpting or creating, allowing faster and more natural workflow than traditional methods.

Artists working with haptic technology such as vibrotactile effectors are Christa Sommerer, Laurent Mignonneau, and Stahl Stenslie.

Future Applications

Future applications of haptic technology cover a wide spectrum of human interaction with technology. Current research focuses on the mastery of tactile interaction with holograms and distant objects, which if successful may result in applications and advancements in gaming, movies, manufacturing, medical, and other industries The medical industry stands to gain from virtual and telepresence surgeries, which provide new options for medical care. The clothing retail industry could gain from haptic technology by allowing users to "feel" the texture of clothes for sale on the internet Future advancements in haptic technology may create new industries that were previously not feasible nor realistic.

Holographic interaction

Researchers at the University of Tokyo are working on adding haptic feedback to holographic projections. The feedback allows the user to interact with a hologram and receive tactile responses as if the holographic object were real. The research uses ultrasound waves to create acoustic radiation pressure, which provides tactile feedback as users interact with the holographic object. The haptic technology does not affect the hologram, or the interaction with it, only the tactile response that the user perceives. The researchers posted a video displaying what they call the Airborne Ultrasound Tactile Display. As of 2008 the technology was not ready for mass production or mainstream application in industry, but was quickly progressing, and industrial companies showed a positive response to the technology. This example of possible future application is the first in which the user does not have to be outfitted with a special glove or use a special control—they can "just walk up and use [it]".

Future Medical Applications

One currently developing medical innovation is a central workstation used by surgeons to perform operations remotely. Local nursing staff set up the machine and prepare the patient, and rather than travel to an operating room, the surgeon becomes a telepresence. This allows expert surgeons to operate from across the country, increasing availability of expert medical care. Haptic technology provides tactile and resistance feedback to surgeons as they operate the robotic device. As the surgeon makes an incision, they feel ligaments as if working directly on the patient.

As of 2003, researchers at Stanford University were developing technology to simulate surgery for training purposes. Simulated operations allow surgeons and surgical students to practice and train more. Haptic technology aids in the simulation by creating a realistic environment of touch. Much like telepresence surgery, surgeons feel simulated ligaments, or the pressure of a virtual incision as if it were real. The researchers, led by J. Kenneth Salisbury Jr., professor of computer science and surgery, hope to be able to create realistic internal organs for the simulated surgeries, but Salisbury stated that the task will be difficult. The idea behind the research is that "just as commercial pilots train in flight simulators before they're unleashed on real passengers, surgeons will be able to practice their first incisions without actually cutting anyone".

According to a Boston University paper published in *The Lancet*, "Noise-based devices, such as randomly vibrating insoles, could also ameliorate age-related impairments in balance control." If effective, affordable haptic insoles were available, perhaps many injuries from falls in old age or due to illness-related balance-impairment could be avoided.

In February 2013 an inventor in the United States built a "spider-sense" bodysuit, equipped with ultrasonic sensors and haptic feedback systems, which alerts the wearer of incoming threats; allowing them to respond to attackers even when blindfolded.

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