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REVIEW OF HAPTIC TECHNOLOGY IN BIOMEDICAL ENGINEERING

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INTRODUCTION

Haptics or kinesthetic communication is the science of applying touch (tactile) sensation by applying forces, vibrations, etc. and control to interaction with computer applications. The word "Haptics"derives from the Greek haptein meaning "to fasten." Haptics offers an additional dimension to a virtual reality or 3-D environment and is essential to the immersiveness of those environments. By using various special input/output devices (joysticks, data gloves or other medical devices), users can receive immediate feedback from computer applications in the form of either felt sensations in the hand or other parts of the body. 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.[1]

In combination with a visual display, haptics technology can be used to train people for tasks requiring hand-eye coordination, such as surgeries and space ship manoeuvres. It can also be used for games in which we feel as well as see our interactions with images. Reverse electrovibration, also known as virtual touch, is one area of haptics used with VR and augmented reality (AR) technology. Virtual touch facilitates electronic transmission of human tactile stimuli, allowing end users to perceive the textures and contours of remote objects. Besides conveying the feel of everyday objects, the technology can also be used to enhance accessibility, for example through the transmission of Braille characters.

Haptic Technology has come into existence in the medical industry recently, but it's foundation has been laid since the late 1950's, with the birth of nuclear industry, Goertz and his colleagues at Argonne National Lab in the US developed the first force-reflecting robotic manipulators, a master-slave telemanipulation system in which actuators, receiving feedback signals from slave sensors, applied forces to a master arm controlled by the user. Haptic technology was used in the 1960s for applications such as military flight simulators, on which combat pilots honed their skills. Motors and actuators pushed, pulled, and shook the flight yoke, throttle, rudder pedals, and cockpit shell, reproducing many of the tactile and kinesthetic cues of real flight. By the late 1970s and early 1980s, computing power reached the point where rich colour graphics and high-quality audio were possible. This multimedia revolution spawned entirely new businesses in the late 1980s and early 1990s and opened new possibilities for the consumer. Flight simulations moved from a professional pilot-only activity to a PC-based hobby, with graphics and sound far superior to what the combat pilots in the 1960s had. The multimedia revolution thus also gave rise to the medical simulation industry. By the 1990s, high-end workstations displayed highly realistic renderings of human anatomy. [1]

By the mid 1990s, shortcomings in simulation products were identified. Even though graphics and animations looked incredibly realistic, they could not possibly convey what it actually feels like to break through a venal wall with a needle or fight the flight yoke out of a steep dive. New industrial and consumer products were in need of enhanced programmable haptic technology that could provide sensations similar to an actual hands-on experience. Then, in 1993, the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology (MIT) constructed a device that delivered haptic stimulation, finally making it possible to touch and feel a computer generated object. The scientists working on the project began to describe their research area as computer haptics to differentiate it from machine and human haptics. Today, computer haptics is defined as the systems required -- both hardware and software -- to render the touch and feel of virtual objects. Computer haptics uses a display technology through which objects can be physically palpated. It is a rapidly growing field that is yielding a number of promising haptic technologies. A haptic interface consists mainly in three components: actuators, sensors and the computational system.[2]

Actuators are used to apply mechanical signals to distinct areas of the user's body. Sensors are used to measure mechanical signals from the user. Another important part of the device is the computational system. The function of this system is to provide haptic rendering, which makes the bidirectional exchange of information between the interface and the user.[3],[4]

Applications of Haptics

It is difficult to imagine life without haptics, in part because it is such a natural and integral part of our lives. Without haptics, we would have great difficulty grasping and manipulating objects, be unable to determine many material or surface properties, and miss feeling the warmth of a loved one's hand. Thus, many of the applications of artificial haptics address scenarios where the sense of touch is lost or greatly diminished compared with the experience of a healthy person in the real world.

Certain highly specialized professions can use augmented haptic feedback, such as an astronaut teleoperating a robot outside the International Space Station to enable repair tasks while avoiding a dangerous human space walk, or a surgeon using a robot to perform a delicate procedure at a scale not achievable with the human hand. In such teleoperation scenarios, we often aim to give human operators a sense of "telepresence" such that they feel they are directly manipulating the environment with their own hands, rather than having their actions mediated by a robot and communication/control system.

In some cases, we seek to replace a sense of touch that was lost owing to disease or accident. An upper-limb amputee has completely lost the sense of touch through the loss of a hand; ideally, a prosthetic hand would sense haptic interactions between itself and the environment and relay that information back to the amputee, so that the amputee does not need to rely entirely on sight in order to manipulate objects.

A more universally experienced lack of haptics is in interactive computing. Computers, tablets, and smartphones have sensors to measure human inputs, but their outputs (displays) are limited primarily to the visual and auditory channels. As discussed below, vibration feedback has made inroads as a haptic display for human–computer interaction, but the quality of this interaction leaves much room for improvement, and many other promising haptic feedback modalities have yet to be implemented in commercial systems.

Human Haptic Perception

Unlike the four other senses (sight, hearing, taste, and smell), the sense of touch is not localized to a specific region of the body; instead, it is distributed across the entire body through the touch sensory organ, our skin, and in our joints, muscles, and tendons. The sense of touch is typically described as being divided into two modalities: kinesthetic and tactile. Kinesthetic sensations, such as forces and torques, are sensed in the muscles, tendons, and joints. Tactile sensations, such as pressure, shear, and vibration, are sensed by specialized sensory end organs known as mechanoreceptors that are embedded in the skin. Each type of mechanoreceptor senses and responds to a specific type of haptic stimulus.

The mechanoreceptors are characterized by their temporal resolution and the size of their receptive fields. Fast-adapting mechanoreceptors capture transient signals, and slow-adapting mechanoreceptors capture mostly static stimuli. For example, Meissner corpuscles are fast-adapting mechanoreceptors that respond to low-frequency vibrations and sense the rate of skin deformation. Pacinian corpuscles respond to a wider range of high-frequency vibrations and provide information about transient contacts. Merkel disks are slow-adapting mechanoreceptors that detect edges and spatial features. Ruffini endings sense skin stretch and allow for the perception of the direction of object motion or force.

The density of mechanoreceptors differs with the location on the body. Mechanoreceptors are more dense in the glabrous skin of the hands and feet than in hairy skin, which makes touch easier to localize on the glabrous skin. To create a truly effective haptic interaction, designers must account for the location dependency and specialization of the mechanoreceptors in creating both the device and the signals to drive it.

Haptic Devices

To introduce the breadth of haptic device design and control, we consider three major categories of haptic systems: graspable, wearable, and touchable.

Graspable systems are typically kinesthetic (force-feedback) devices that are grounded (e.g., to a table) and allow the user to push on them (and be pushed back) through a held tool. Graspable devices can also be ungrounded (e.g., using flywheels to provide inertial forces) or can be tactile devices that are held in the hand.

Wearable systems are typically tactile (cutaneous) devices that are mounted to the hands or other parts of the body and display sensations directly to the skin. They can provide cues such as vibration, lateral skin stretch, and normal skin deformation. They may also be body-grounded devices, such as an exoskeleton, that provide a kinesthetic cue to the user by creating a reaction force on a less sensitive part of the body. The wearability of the devices makes them attractive for use in mobile applications where users should be free and unencumbered to move about their environment.

Touchable systems are encountered-type displays that allow the user to actively explore the entire surface. They can be purely cutaneous devices that change their tactile properties based on location, such as a surface with variable friction. Touchable devices can also be hybrid cutaneous and kinesthetic devices that change their shape, mechanical properties, and surface properties.For each of these categories, the mechanism of haptic feedback can vary.[5]

CONCLUSION

After reviewing different papers on the use of haptic devices in medical industry, it provides enough evidence that it is the new, efficient method of dealing with various medical problems. This system represents the bright future of haptic application. Haptic technology can be very daunting in the beginning as they are very complex and expensive but once we are familiar with it's concept and application , it is not so trivial.

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