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A Review on Haptic Technology: The Future of Touch in Human-Computer Interaction

Prof. Pathak Jayesh Gokul
Lecturer, Department of Electronics and Telecommunication Engineering
Amrutvahini Polytechnic, Sangamner, Maharashtra, India

Abstract: *Haptics is an emerging technology that allows touch-enabled interaction with virtual objects. The word haptic, means pertaining to the sense of touch. Haptic interfaces allow the user to feel and to see virtual objects on a computer, giving illusion of touching surfaces, shaping virtual clay or moving objects. The sensation of touch is the brain's most effective learning mechanism and thus is used in haptic technology —which is why the this new technology holds so much promise as a powerful tool in large number of applications.*

Haptic technology is like exploring the virtual world with a touch. The computer communicates tactile or kinesthetic sensations through a haptic interface –a stick, scalpel, racket or pen that is connected to force-exerting motors. These motors form part of haptic devices --PHANTOM, Cyber Grasp etc.—and operate on principle of force feedback mechanism. With this technology we can now sit down at a computer terminal and touch objects that exist only in the "mind" of the computer. By using special input/output devices (joysticks, data gloves, or other devices), we can receive feedback from computer in the form of felt sensations in the hand or other parts of the body.

In this paper we explicate how sensors and actuators are used for tracking the position and movement of the haptic device moved by the operator. We also cover main building blocks of haptic technology which are force feedback mechanism, tactile and kinesthetic devices, haptic interfaces, haptic devices-PHANTOM and Cyber Grasp, high precision computers, robots. Then, we move on to applications of Haptic Technology in various fields such as medical science (tele-surgery), entertainment, education, and astronomy, social. Haptics has proved its importance in social fields by providing imaginary world (virtual reality) for blind people and for museums. Finally we conclude by mentioning future developments.

Keywords: Haptic, tactile feedback, virtual reality, human-computer interaction, force feedback

I. INTRODUCTION

Haptic technology refers to technology that interfaces to the user via the sense of touch by applying forces, vibrations and/or motions to the user. This mechanical stimulation may be used to assist in the creation of virtual objects (objects existing only in a computer simulation), for control of such virtual objects, and to enhance the remote control of machines and devices (teleoperators). This emerging technology promises to have wide-reaching applications. Haptic technology has made it possible to investigate in detail 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. These new research tools contribute to understanding of how touch and its underlying brain functions work. The word **haptic**, from the Greek (haptikos), means pertaining to the sense of touch, and comes from the Greek verb haptesthai meaning to "contact" or "touch".

Although haptic devices are capable of measuring bulk or reactive forces that are applied by the user, it should not to be confused with touch or tactile sensors that measure the pressure or force exerted by the user to the interface. More generally, **Haptics** is commonly used today to refer to **the science of touch in real and virtual environments**. This would include the study of touch capabilities in different organisms, including humans, and the development of engineering systems to create haptic virtual environments.

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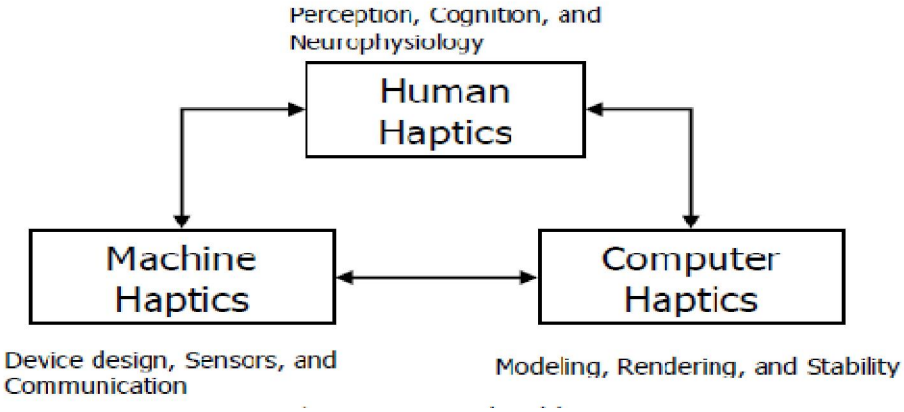
BRANCHES OF HAPTICS

Haptics is commonly divided into following branches:

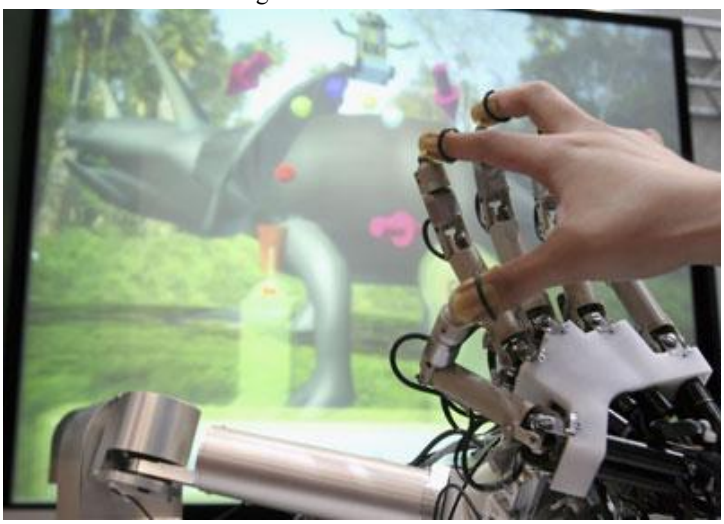


1. Computer haptics:

The latter subfield is commonly known as **computer haptics.** This technology does for touch what computer graphics does for vision. You can see an animation explaining the basics of computer haptics here.

2. Human Haptics:

Human haptics has involved work on biomechanics of skin, tactile neuroscience, haptic and multimodal psychophysics. With 27 bones and 40 muscles, the hand offers tremendous dexterity. Scientists quantify this dexterity using a concept known as **degrees of freedom**. A degree of freedom is movement afforded by a single joint. Because the human hand contains 22 joints, it allows movement with 22 degrees of freedom.



3. Machine Haptics:

Machine haptics includes work on computer haptics -- which, like computer graphics, involves the development of the algorithms and software needed to implement haptic virtual environments -- as well as the development of haptic devices.

The earliest machines that allowed haptic interaction with remote objects were simple lever-and-cable-actuated tongs placed at the end of a pole. By moving, orienting and squeezing a pistol grip, a worker could remotely control tongs, which could be used to grab, move and manipulate an object.

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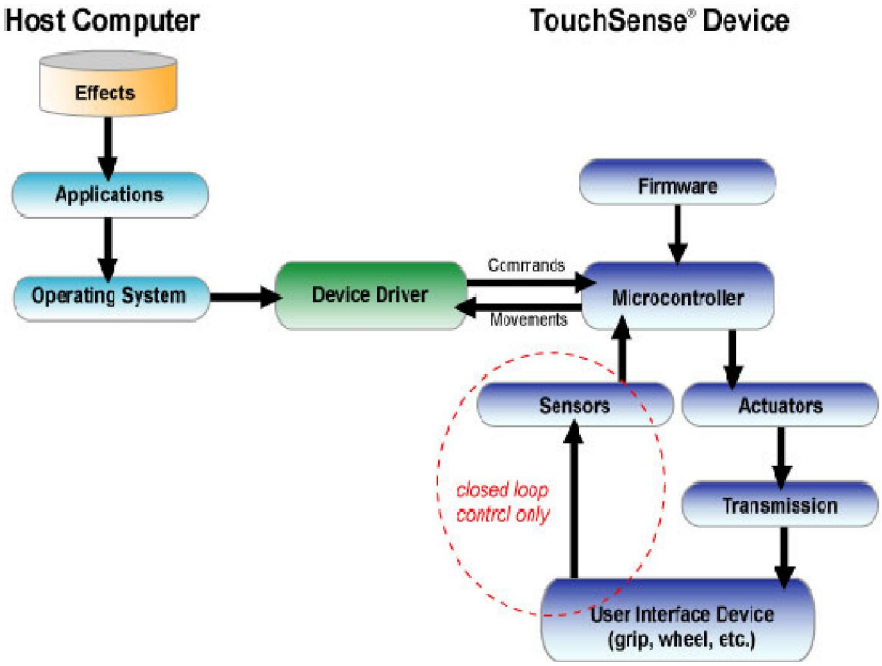
HOW DOES HAPTIC WORK???



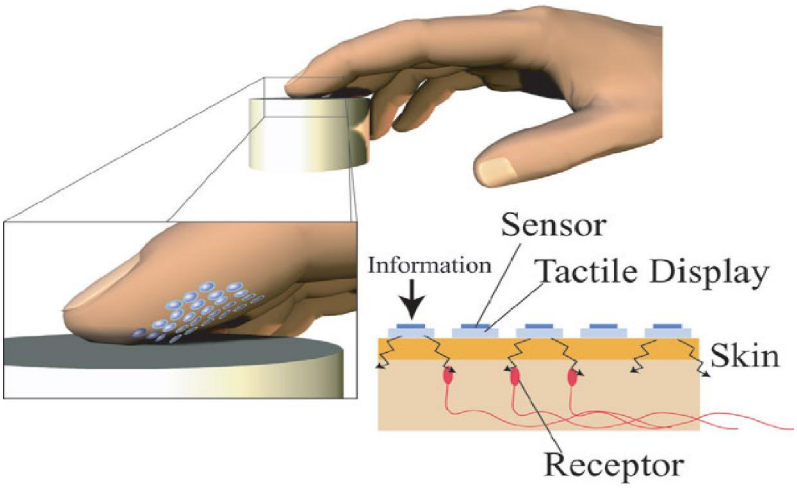
2.1 Haptic Information:

Haptic information is divided into 2 types viz.

Tactile (Cutaneous) Information which is further divided into spatial tactile information and temporal tactile Information and

Kinesthetic (Proprioceptive) information.

Proprioceptors are receptors carry signals to the brain, where they are processed by the somatosensory region of the cerebral cortex. The **muscle spindle** is one type of proprioceptor that provides information about changes in muscle length. The **Golgi tendon organ** is another type of proprioceptor that provides information about changes in muscle tension. The brain processes this kinesthetic information to provide a sense of the baseball's gross size and shape, as well as its position relative to the hand, arm and body.



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2.2 Force Feedback Mechanism

The two haptic systems used to approximate the human sense of touch are:-

1. Force feedback

F**orce feedback** is a term used to describe tactile and/or kinesthetic feedback. Force feedback is vastly complex. Yet, if a person is to feel a virtual object with any fidelity, force feedback is exactly the kind of information the person must receive. . This is done behaving the user grab a handle connected within the device to motors.Haptic interface devices are being invented that would allow users to feel virtual objects via force feedback .Force feedback means using body as both sensor and actuator – applying a force and knowing how hard body is pushing on something.

2. Tactile Feedback:

Tactile feedback describes the sensation of touch. In the human body, a network of receptors in and underneath the skin connects with the human nervous system, sensing and broadcasting differences in the surfaces of different objects. , **tactile feedback**, uses force that is applied directly to the skin allowing the user to feel sensations such as roughness, or temperature. Sometimes this is done by a small electric current, a moving array of pins or by changing the Temperature of the object.

3. **Proprioception feedback**

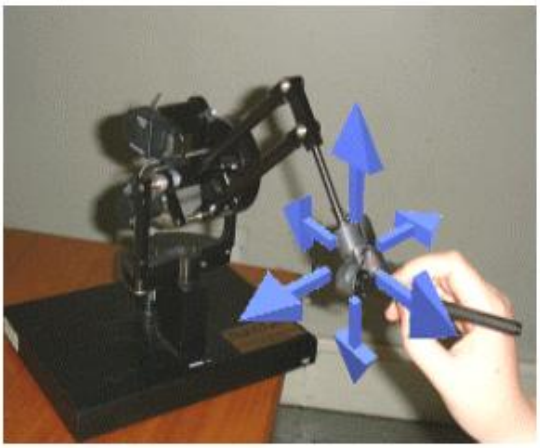
This **i**s the sense of the position of parts of the body, relative to other neighboring parts of the body. This is sometimes integrated with force feedback.

III. HAPTIC SYSTEMS

There are several approaches to creating haptic systems. It requires two important things -- software to determine the forces that result when a user's virtual identity interacts with an object and a device through which those forces can be applied to the user. The actual process used by the software to perform its calculations is called **haptic rendering**. A common rendering method uses polyhedral models to represent objects in the virtual world. These 3-D models can accurately portray a variety of shapes and can calculate touch data by evaluating how force lines interact with the various faces of the object. Such 3-D objects can be made to feel solid and can have surface texture.

The job of conveying haptic images to the user falls to the interface device. In many respects, the interface device is analogous to a mouse, except a mouse is a passive device that cannot communicate any synthesized haptic data to the user. Following are few specific haptic systems.

IV. HAPTIC DEVICES



The main haptic device used in research is the PHANToM from Sensible Technologies .This is a very high resolution, six degrees-of-freedom (DOF) device in which the user holds the end of a motor-controlled, jointed arm (with respect to haptic devices, degrees-of-freedom refers to the number of dimensions of movement. For the PHANToM this is x, y,

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z dimensions plus pitch, roll and yaw). It provides a programmable sense of touch that allows users to feel textures and shapes of virtual objects, modulate and deform objects with a very high degree of realism.

One of the key (and most compelling) features of the PHANToM is that it can model free-floating three-dimensional objects – for example, a user of the PHANToM could feel an object such as a Roman helmet from all sides – front, back, top, bottom – just as if holding it in his/her own hand. It is a force-feedback device as it applies forces to the user and can resist his/her movements or even move the user around.

Cyber Grasp:

The Cyber Grasp system, another commercially available haptic interface from Immersion Corporation, takes a different approach. This device fits over the user's entire hand like an exoskeleton and adds resistive force feedback to each finger. Five actuators produce the forces, which are transmitted along tendons that connect the fingertips to the exoskeleton. With the Cyber Grasp system, users are able to feel the size and shape of virtual objects that only exist in a computer-generated world. To make sure a user's fingers don't penetrate or crush a virtual solid object, the actuators can be individually programmed to match the object's physical properties.

The principle of a force feedback glove is simple. It consists of opposing the movement of the hand in the same way that an object squeezed between the fingers resists the movement of the latter. The glove must therefore be capable, in the absence of a real object, of recreating the forces applied by the object on the human hand with (1) the same intensity and (2) the same direction. These two conditions can be simplified by requiring the glove to apply a torque equal to the interphalangian joint.

V. HAPTIC INTERFACE

Haptic interfaces enable person-machine communication through touch, and most commonly, in response to user movements. Haptic interfaces enable people to communicate with a computer by using their hands to manipulate as well as feel virtual objects, which can be:

- Representations of remote objects (tele-manipulation)
- Computer-generated objects (**virtual reality**)
- Haptic interfaces provide an additional channel for human-computer interaction

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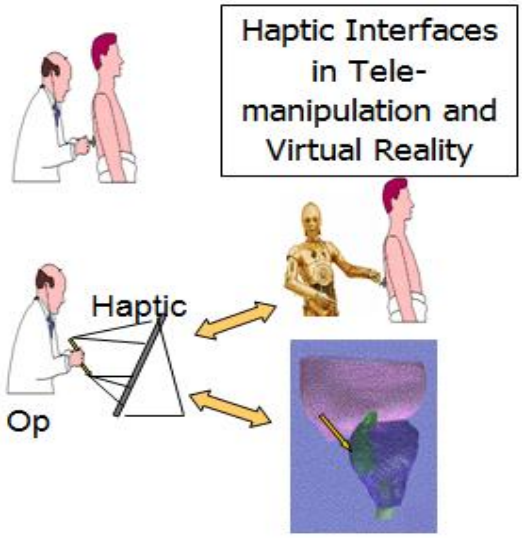

5.1 Working of haptic interface:

Haptic interfaces define a user reference point located within a volume of a user connection element such as a finger thimble or stylus configured grasped by a user. Are a series of mechanical transmission elements such as gimbals, linkages, and frames configured between the user connection element and reference ground to permit substantially unrestricted movement of the connection element?

Based on the configuration and orientation of the transmission elements, multiple independent degrees of freedom may be provided. Depending on the particular application for the interface, each degree of freedom may be powered and/or tracked, or free, being neither powered nor tracked. The powered axis may be active, with force being varied as a function of system conditions, or passive, such as when a constant resistance or drag force is applied.

A degree of freedom can be tracked using an **encoder, potentiometer, or other measurement device** so that, in combination with other tracked degrees of freedom, the spatial location of the reference point within the work volume can be determined relative to ground. The interface, in combination with appropriate computer hardware and software, can be used to provide haptic feedback in a virtual reality environment or link a user to an actual manipulator located, for example, in a remote or hazardous environment.

Haptic interface should have low friction and weight balance such that a user's movements will not be unduly resisted and the user will not become fatigued merely by moving the connection element within the work volume. Even while using an imperfect haptic device, a user quickly adapts to its interference, ignores its imperfections, and naturally associates the device's mechanical stimulation to everyday experiences such as perceiving surface texture and shape of the objects through touch.

5.2 Components

A complete haptic interface usually includes one or several electromechanical transducers (**Sensors and actuators**) in contact with a user in order to apply mechanical signals to distinct areas of the body, and to measure other mechanical signals at the same distinct areas of the body. The function of this computational system (**Transducers**) is to provide haptic rendering capabilities, which are analogous to the visual rendering functions of common graphic systems. Haptic rendering stresses the bidirectional exchange of information between the interface and the user. The computational task in haptic rendering is to generate signals that are relevant to a particular application. Several approaches exist for

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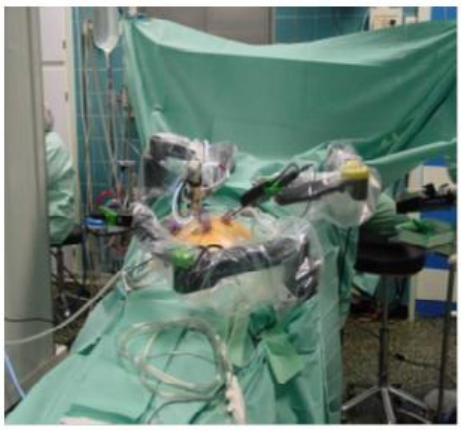
creating such haptic feedback. For example, a model may be used to represent an environment and forces as a function of displacements and their derivatives.

VI. APPLICATION OF HAPTICS

Medical Science

Applications in this area mainly are simulators that recreate realistic medical procedures. These simulators allow healthcare providers to practice procedures in an environment that poses no immediate risks to patients. Such applications are provided by Virtual Reality Dental System and the Medical Imaging, and Immersion [6] with products such as CathSim Vascular Access Simulator, AccuTouch Endoscopy Simulator and AccuTouch Endovascular Si



Geosciences & 3D modeling

In petroleum exploration, developing accurate models of the subsurface environment is a complex and challenging problem. Using existing 2 dimensional mouse-and-keyboard interaction devices to work with 3 dimensional data can be slow and cumbersome. By using some software's such as VoxelNotePad and Touchstone that makes it possible to work in 3D with 3D data, by adding haptic feedback and providing real time, 3D interaction to existing visualization techniques.

Mechanical Simulation

Some haptic applications are developed for the simulation of mechanical parts or several other systems (e.g. landing gear system of planes) aiming at the control and testing of the system operation before the production of the prototype. Boeing Co. has experimentally developed some haptic applications with the Phantom haptic 3D interface.

Entertainment - Games

The first commercial products with some elementary application of Haptics are the Force-Feedback Joysticks that provide the user with the sense of force effects while playing, known as force feedback.

Education

In the Education field the sense of touch and force-feedback can offer Great improvements to the existing teaching methods, thus enhancing the quality of education procedures. Haptics Educational Applications are an under development research field.

VII. BENEFITS OF HAPTICS

Reconfigurability

Computer-controlled tactile feedback is dynamic and can be easily adjusted to the user interaction state. Examples include modifying the number of detents on a knob to reflect different selection criteria or using dynamically configurable button arrays for POS systems.

Continuous Control:-

Tactile feedback provides immediate information to users during task execution, allowing them to modify their behavior to more effectively execute the task or to leverage the additional information for another purpose.

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Affective Computing:-

Haptic feedback, because of its intimacy, can add missing social context in situations where typical feedback or social cues are absent. One example is a child's plush toy that responds to how it's being treated through use of an actuator (motor) that emits growling or purring vibrations.

Comfort and Aesthetics:-

In many interactions, tactile feedback is expected. When the interface does not provide it, users may become irritated or confused.

Dealing with Complexity:-

There are numerous situations where human task performance suffers due to overly complex procedures or visual sensory overload. Tactile feedback can help to offload the visual channel for the operator, reducing stress and improving efficiency.

VIII. LIMITATION OF CURRENT HAPTIC TECHNOLOGY

Single Point Contact

-all contact is through a single point (like a single finger or a probe). There are no whole hand devices that yet provide high fidelity force-feedback. This limits the range of applications that haptic devices are currently good for.

Limited cutaneous feedback-

-cutaneous feedback is very limited in most haptic devices as they simulate the sense of touch by applying output to the user in the form of forces and movement. Subtle surface textures are normally perceived cutaneous as tiny deformations in the surface of the skin. This is very difficult to do mechanically and most haptic devices do not do it at all. This limits the range of surface textures that can be displayed

IX. CONCLUSION

The word **haptic**, means pertaining to the sense of touch and thus Haptic Technology refers to the science of touch in real and virtual environment. This paper has covered basic branches of haptics viz. computer haptics, human haptics, machine haptics, and basic internal mechanism of haptic technology. We have also covered main building blocks of haptic technology which are **force feedback mechanism, tactile and kinesthetic devices, haptic interfaces, haptic devices-PHANTOM and Cyber Grasp, high precision computers, robots.**

This has made Haptic Technology most convincing and prevalent era of virtual reality. Thus Haptics has found emerging applications not only in education and entertainment but also in social, medical, and astronomical and related various fields. Haptics has proved its importance in social fields by providing imaginary world (virtual reality) for blind people and for museums.

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