Haptic Technology - A Sense of Touch

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Abstract: ***Haptics is the science of applying touch (tactile) sensation and control to interact with computer applications. Haptic device gives people a sense of touch with computer generated environments, so that when virtual objects are touched, they seem real and tangible. Haptic technology refers to technology that interfaces the user with a virtual environment 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. This paper includes how haptic technology works, about its devices, its technologies, its applications, future developments and disadvantages.***

Keywords: Human sense of touch, tactile feedback, Virtual object creation and control, Phantam, Haptic rendering

1. Introduction

Haptical Technology or haptics is tacticle feedbacks that take advantage of user sense of touch by applying forces, vibration and motion to the user. Haptics refers to sensing and manipulation through touch. The word Haptic is derived from the Greek word “haptesthai” [1].

Haptic Technology promises to have wide reaching applications as it already has in some fields. For example, 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.Haptics technology can be used to train people for tasks requiring hand-eye coordination, such as surgery and space ship maneuvers. 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. Through haptic interface, human can interact with the computer through body sensation and movement [2]. Several applications such as surgical training, gaming etc use haptic technology. 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.

2. Literature Review

Haptic interfaces are divided into two main categories:

- Force feedback
- Tactile feedback

Force feedback interfaces are used to explore and modify remote/virtual objects in three physical dimensions in applications including computer-aided design, computer-assisted surgery, and computer-aided assembly. Tactile feedback interfaces deals with surface properties such as roughness, smoothness and temperature.

2.1 Working of haptics

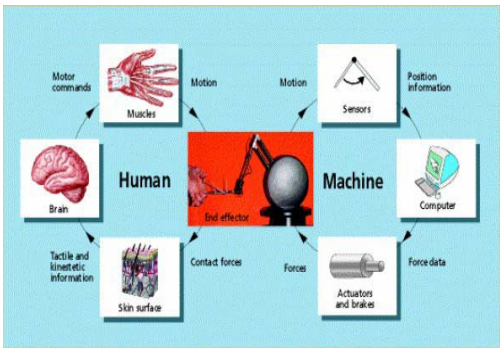

Figure 1: Basic configuration of haptics

Basically haptic system consists of two parts:

- Human part
- Machine part

From the above figure 1, human part (left) controls the position of the hand, while the machine part (right) exerts forces from the hand to simulate contact with a virtual object. Also both the systems will be provided with necessary sensors, processors and actuators. In the case of the human system, nerve receptors performs sensing, brain performs processing and muscles performs actuation of the motion performed by the hand while in case of the machine system, the above mentioned functions are performed by the encoders, computer and motors respectively [2].

2.2 Haptic devices

Haptic devices (or haptic interfaces) are mechanical devices acts as mediator in communicating between the user and the computer. Haptic devices allow users to touch, feel and manipulate three-dimensional objects in virtual environments and tele-operated systems.

Haptic devices are input-output devices that track a user's physical manipulations (input) and provide realistic touch sensations coordinated with on-screen events (output). Examples of haptic devices include consumer peripheral devices equipped with special motors and sensors such as force feedback joysticks and steering wheels and more

sophisticated devices designed for industrial, medical or scientific applications such as PHANTOM device.

Typically, a haptics system includes;

- Sensor(s)
- Actuator (motor) control circuitry
- One or more actuators that either vibrate or exert force
- Real-time algorithms (actuator control software, which we call a "player") and a haptic effect library
- Application programming interface (API), and often a haptic effect authoring tool
- The Immersion API is used to program calls to the actuator into your product's operating system (OS).

When the user interacts with your product's buttons, touch screen, lever, joystick/wheel, or other control, this control-position information is sent to the OS, which then sends the play command through the control circuitry to the actuator.

2.2.1 Phantom Device

Figure 2: Phantom Device

The above figure 2 shows Phantom device. PHANTOM haptic interface is one of the widely used haptic devices. This device measures a user's finger tip position and exerts a precisely controlled force vector on the finger tip. The device has enabled users to interact with and feel a wide variety of virtual objects and will be used for control of remote manipulators [3].

2.3 Human Senses

It is believed that vision and audition convey the most information about an environment while the other senses are more subtle. Because of this, their characteristics have been widely investigated over the last few decades by scientists and engineers, which have led to the development of reliable multimedia systems and environments.

2.3.1 Vision

The visual sense is based on the level of absorption of light energy by the eye and the conversion of this energy into neural messages. The acceptable wavelength range for human eyes is between 0.3 and 0.7_m (1_mD10_6m). The temporal resolution sensitivity of the human visual system is biologically limited and not sufficient to detect the presentation of sequential video frames past a certain speed. This is the reason why we do not perceive a digital movie as a series of still images, but rather as moving pictures.

2.3.2 Audition

The human auditory system transmits sound waves through the outer, middle, and inner ears. This sound wave is transformed into neural energy in the inner ear. It is then transmitted to the auditory cortex for processing. The audible frequency of humans ranges from 16 to 20,000Hz and is most efficient between 1,000 and 4,000Hz.

2.3.3 Touch

The sense of touch is mainly associated with active tactile senses such as our hands. Such senses can be categorized in several ways, and they have a link to the kinesthetic senses. According to Heller and Schiff, touch is twenty times faster than vision, so humans are able to differentiate between two stimuli just 5ms apart; Bolanowskiet al. found that touch is highly sensitive to vibration up to 1KHz, with the peak sensitivity around 250 Hz; and skin receptors on the human palm can sense displacements as low as 0.2_m in length

2.4 Haptic feedback

Haptic / Tactile feedback (or haptics) is the use of advanced vibration patterns and waveforms to convey information to a user or operator. Haptic feedback has two major benefits for manufacturers. Firstly, it can improve user experience. Even everyday products are now being built with touch displays and interfaces. They're cheaper to construct than control panels with buttons or switches, and designers can make context specific user interfaces simply by changing the graphical layout on the screen [4].

3. Haptic Concepts

Tactile cues include textures, vibrations, and bumps kinesthetic cues- include weight, impact. In the following section, we present some crucial concepts and terminology related to haptics:

Haptic: Haptic is the science of applying tactile, kinesthetic, or both sensations to human–computer interactions. It refers to the ability of sensing and/or manipulating objects in a natural or synthetic environment using a haptic interface.

Cutaneous: Relates to or involving the skin. It includes sensations of pressure, temperature, and pain

Tactile: Pertaining to the cutaneous sense, but more specifically the sensation of pressure rather than temperature or pain.

Kinesthetic: Relates to the feeling of motion. It is related to sensations originating in muscles, tendons, and joints.

Force Feedback: Relates to the mechanical production of information that can be sensed by the human kinesthetic system.

Haptics or Haptic Technology: An emerging interdisciplinary field that deals with the understanding of human touch (human haptics), motor characteristics (machine haptics), and with the development of computer-controlled systems (computer haptics) that allow physical interactions with real or virtual environments through touch.

Haptic Communication: This means by which humans and machines communicate via touch. It mostly concerns networking issues

Haptic Device: It is a manipulator with sensors, actuators, or both. A variety of haptic devices have been developed for their own purposes. The most popular are tactile-based, pen-based, and 3 degree-of-freedom (DOF) force feedback devices.

Haptic Interface: This consists of a haptic device and software-based computer control mechanisms. It enables human–machine communication through the sense of touch. By using a haptic interface, someone can not only feed the information to the computer but can also receive information or feedback from the computer in the form of a physical sensation on some parts of the body.

Haptic Perception: This is the process of perceiving the characteristics of objects through touch

Haptic Rendering: This is the process of calculating the sense of touch, especially force. It involves sampling the position sensors at the haptic device to obtain the user's position within the virtual environment. The position information received is used to check whether there are any collisions between the user and any objects in the virtual environment. In case a collision is detected, the haptic rendering module will compute the appropriate feedback forces that will finally be applied onto the user through the actuators .Haptic rendering is, therefore, a system that consists of three parts, a collision detection algorithm, a collision response algorithm, and a control algorithm [5].

Sensors and Actuators: A sensor is responsible for sensing the haptic information exerted by the user on a certain object and sending these force readings to the haptic rendering module. The actuator will read the haptic data sent by the haptic rendering module and transform this information into a form perceivable by human beings [6].

Tele-Haptics: This is the science of transmitting haptic sensations from a remote explored object/environment, using a network such as the Internet, to a human operator. In other words, it is an extension of human touching sensation/capability beyond physical distance limits.

Tele-Presence: This is the situation of sensing sufficient information about the remote task environment and communicating this to the human operator in a way that is sufficient for the operator to feel physically present at the remote site. The user's voice, movements, actions, etc. may be sensed, transmitted, and duplicated in the remote location. Information may be traveling in both directions between the user and the remote location [7].

Virtual Reality (VR): This can be described as the computer simulation of a real or virtual world where users can interact with it in real time and change its state to increase realism. Such interactions are sometimes carried out with the help of haptic interfaces, allowing participants to exchange tactile and kinesthetic information with the virtual environment.

Virtual Environment (VE): This is an immersive virtual reality that is simulated by a computer and primarily involves audiovisual experiences. Despite the fact that the terminology is evolving, a virtual environment is mainly concerned with defining interactive and virtual image displays.

Collaborative Virtual Environments (CVE): This is one of the most challenging fields in VR because the simulation is distributed among geographically dispersed computers. Potential CVE applications vary widely from medical applications to gaming.

Simulation Engine: This is responsible for computing the virtual environment behavior over time [8].

Collaborative Haptic Audio Visual Environment (C-HAVE): In addition to traditional media, such as image, audio, and video, haptics as a new media plays a prominent role in making virtual or real-world objects physically palpable in a CVE. A C-HAVE allows multiple users, each with his/her own haptic interface, to collaboratively and/or remotely manipulate shared objects in a virtual or real environment.

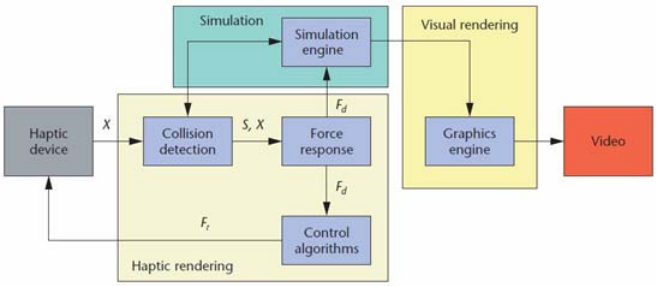

Figure 3: Haptic system block diagram

Figure 3 consists of three blocks, Haptic Rendering, Visual modeling and Simulation. Haptic rendering is divided into three blocks [9].

Control Detection Algorithm: Detects collision between objects and avatar in the virtual environment and yield information.

Force Response Algorithm: Computes interaction between the virtual objects and avatar when the collision is detected [10].

Control Algorithms: Command the haptic devise in order to minimize the error between ideal and application forces [8].

3.1 Comparison of Haptic devices

Table 1: Comparison of haptic device types

Characteristics of Haptic Devices	*Mechanical Arm*	*Cable Driven*	*Magnetic Levitation*
Workspace	Satisfied	Unsatisfied	Unsatisfied
Maximum Force	Satisfied	Unsatisfied	Satisfied
Maximum Torque	Satisfied	Unsatisfied	Satisfied
Back Drive Friction	Satisfied	Satisfied	Satisfied
Stiffness	Satisfied	Satisfied	Satisfied
Backlash	Satisfied	Satisfied	Satisfied
Resolution	Satisfied	Unsatisfied	Satisfied
Apparent Mass	Satisfied	Satisfied	Satisfied

All types of haptic devices should be evaluated according to their characteristics in order to design a flawless haptic device. Generally, they should have seven basic design characteristics; workspace, maximum force/torque, stiffness, resolution should be maximized and backdrive friction, backlash, apparent mass at tip point should be minimized in order to simulate accurately any virtual environment. The above Table shows the characteristics of three different types of haptic devices and its satisfactions for general haptic applications.

4. Applications and Disadvantages

Haptic technology is widely used in many applications such as in gaming, surgical simulation and medical training, military training in virtual environment, Robotics, Virtual arts and design, mobile devices, research and entertainment [10]. Implementation of haptic technology is expensive. Haptics applications can be extremely complex, requiring highly specialized hardware and considerable processing power.

5. Conclusion

We finally conclude that the haptic technology is the solution for interacting with the virtual environment and used widely in many applications Haptic device acts as an input and output device tracking user physical manipulations as an input and providing realistic touch sensations as an output coordinated with onscreen events. As technology evolves and computer power grows, haptic devices and effects evolve and get more realistic. This technology has proved that virtual objects can also be touched, felt and controlled. This technology must be made available for the affordable cost and the haptic devices must be made simpler and easier to use.

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