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Haptic Technology

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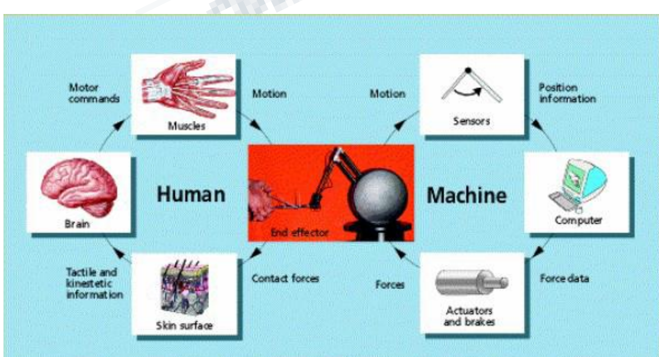
Abstract:-- **The word haptic means "pertaining to the sense of touch" Haptic communication recreates the sense of touch by applying forces, vibrations, or motions to the user. The most sophisticated touch technology is found in industrial, military and medical applications. Training with haptics is becoming more and more common. Haptic technology is also widely used in teleoperation, or telerobotics. Haptic technology is an intuitive way for a human user to interact with a computer or other haptic device, and have that device display information back into the real world. 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. It provides the user with 22 kinds of touch sensations. This emerging technology promises to have wide reaching applications as it already has in some fields. These new research tools contribute to our understanding of how touch and its underlying brain functions work. By using haptic devices, the user can not only feed information to the computer but can also receive information from the computer in the form of a felt sensation on some part of the body. This is referred to as a haptic interface. In this field there are two different main technologies which may be primary in the near future Vibrotaction stimulation and Friction modulation techniques. Haptics enables the physically challenged (for e.g.: deaf and blind) to access applications or browse the internet or even play games on mobile devices. In video games, the addition of haptic capabilities is nice to have. It increases the reality of the game and, as a result, the user's satisfaction. But in training and other applications, haptic interfaces are vital of applying touch sensation and control to association with computer applications. Developers in this space are essentially on the ground floor of advanced technology.**

Keywords:-- **Haptic, Communication, Technology.**

WHAT IS HAPTICS

The term haptic originated from the Greek word ἁπτικός (haptikos) meaning pertaining to the sense of touch and comes from the Greek verb ἅπτεσθαι (haptesthai) meaning to "contact" or "touch. 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 for control of such virtual objects, and to enhance the remote control of machines and devices. This emerging technology promises to have wide reaching applications as it already has in some fields.

WORKING OF HAPTICS



Basic system configuration

Basically a haptic system consist of two parts namely the human part and the machine part.

In the figure shown above, the human part (left) senses and 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 the case of the machine system, the above mentioned functions are performed by the encoders, computer and motors respectively.

Haptic Information

Basically the haptic information provided by the system will be the combination of (i) Tactile information and (ii) Kinesthetic information.

Tactile Information:

Tactile information refers the information acquired by the sensors which are actually connected to the skin of the human body with a particular reference to the spatial distribution of pressure, or more generally, tractions, across the contact area.

Kinesthetic Information:

Kinesthetic information refers to the information acquired through the sensors in the joints. Interaction forces are normally perceived through a combination of these two information's.

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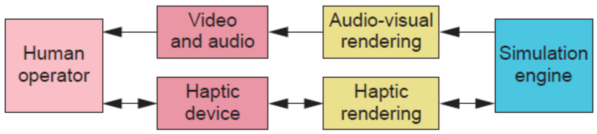


Haptic feedback

Virtual reality (VR) applications strive to simulate real or imaginary scenes with which users can interact and perceive the effects of their actions in real time. Ideally the user interacts with the simulation via all five senses. However, today's typical VR applications rely on a smaller subset, typically vision, hearing, and more recently, touch.

The application's main elements are:

1) The simulation engine, responsible for computing the virtual environments

Behavior over time.

2) Visual, auditory, and haptic rendering algorithms, which compute the virtual

Environment's graphic, sound, and force responses toward the user; and

3) Transducers, which convert visual, audio, and force signals from the

Computer into a form the operator can perceive. The human operator typically holds or wears the haptic interface device and perceives

audiovisual feedback from audio (computer speakers, headphones, and so on) and visual displays. Whereas audio and visual channels feature unidirectional information and energy flow (from the simulation engine toward the user), the haptic modality exchanges information and energy in two directions, from and toward the user. This bi-directionality is often referred to as the single most important feature of the haptic interaction modality.

Haptic Device

A haptic device is the one that provides a physical interface between the user and the virtual environment by means of a computer. This can be done through an input/output device that senses the body's movement, such as joystick or data glove. By using haptic devices, the user can not only feed information to the computer but can also receive

information from the computer in the form of a felt sensation on some part of the body. This is referred to as a haptic interface.

These devices can be broadly classified into:-

1. Virtual reality/ Tele-robotics based devices:-

- Exoskeletons and Stationary device
- Gloves and wearable devices
- Locomotion Interfaces

2. Feedback devices:-

- Force feedback devices
- Tactile displays

1. Virtual reality/ Tele-robotics based devices:-

➢ Exoskeletons and Stationary devices

The term exoskeleton refers to the hard outer shell that exists on many creatures. In a technical sense, the word refers to a system that covers the user or the user has to wear. Current haptic devices that are classified as exoskeletons are large and immobile systems that the user must attach him or her to.

➢ Gloves and wearable devices

These devices are smaller exoskeleton-like devices that are often, but not always, take the down by a large exoskeleton or other immobile devices. Since the goal of building a haptic system is to be able to immerse a user in the virtual or remote environment and it is important to provide a small remainder of the user's actual environment as possible. The drawback of the wearable systems is that since weight and size of the devices are a concern, the systems will have more limited sets of capabilities

➢ Locomotion interface

An interesting application of haptic feedback is in the form of full body Force Feedback called locomotion interfaces. Locomotion interfaces are movement of force restriction devices in a confined space, simulating unrestrained mobility such as walking and running for virtual reality. These interfaces overcomes the limitations of using joysticks for maneuvering or whole body motion platforms, in which the user is seated and does not expend energy, and of room environments, where only short distances can be traversed.

2. Feedback Devices:-

➢ Force feedback devices

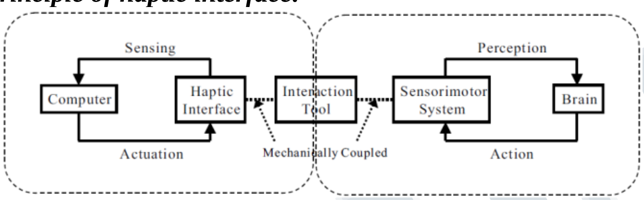
Force feedback input devices are usually, but not exclusively, connected to computer systems and is designed to apply forces to simulate the sensation of weight and resistance in order to provide information to the user. As such, the feedback hardware represents a more sophisticated form of input/output devices, complementing others such as keyboards, mice or trackers. Input from the user in the form of hand, or other body segment whereas feedback from the computer or other device is in the form of hand, or other body segment whereas feedback from the computer or other device is in the form of force or position. These devices translate digital information into physical sensations.

➢ Tactile display devices

Simulation task involving active exploration or delicate manipulation of a virtual environment require the addition of feedback data that presents an object's surface geometry or texture. Such feedback is provided by tactile feedback systems or tactile display devices. Tactile systems differ from haptic systems in the scale of the forces being generated. While haptic interfaces will present the shape, weight or compliance of an object, tactile interfaces present the surface properties of an object such as the object's surface texture. Tactile feedback applies sensation to the skin.

HAPTIC RENDERING

Principle of haptic interface:-



As illustrated in Fig. given above, haptic interaction occurs at an interaction tool of a haptic interface that mechanically couples two controlled dynamical systems: the haptic interface with a computer and the human user with a central nervous system. The two systems are exactly symmetrical in structure and information and they sense the environments, make decisions about control actions, and provide mechanical energies to the interaction tool through motions.

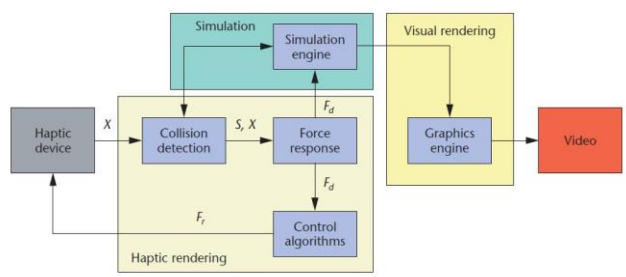
Characteristics commonly considered desirable for haptic interface devices:-

- ➢ Low back-drive inertia and friction;
- ➢ Minimal constraints on motion imposed by the device kinematics so free motion feels free;
- ➢ Symmetric inertia, friction, stiffness, and resonant frequency properties (thereby egularizing the device so users don't have to unconsciously compensate for parasitic forces);
- ➢ Balanced range, resolution, and bandwidth of position sensing and force reflection; and Proper ergonomics that let the human operator focus when wearing or manipulating the haptic interface as pain, or even discomfort, can distract the user, reducing overall performance.

Creation of an AVATAR:-

An avatar is the virtual representation of the haptic through which the user physically interacts with the virtual environment. Clearly the choice of avatar depends on what's being simulated and on the haptic device's capabilities. The operator controls the avatar's position inside the virtual environment. Contact between the interface avatar and the virtual environment sets off action and reaction forces. The avatar's geometry and the type of contact it supports regulate these forces. Within a given application the user might choose among different avatars. For example, a surgical tool can be treated as a volumetric object exchanging forces and positions with the user in a 6D space or as a pure point representing the tool's tip, exchanging forces
and positions in a 3D space

System architecture for haptic rendering:-



Haptic-rendering algorithms compute the correct interaction forces between the haptic interface representation inside the virtual environment and the virtual objects populating the environment. Moreover, haptic rendering algorithms ensure that the haptic device correctly renders such forces on the human operator. Several components compose typical haptic rendering algorithms. We identify three main blocks, illustrated in Figure shown

1.Collision-detection algorithms detect collisions between objects and avatars in the virtual environment and yield information about where, when, and ideally to what extent collisions (penetrations, indentations, contact area, and so on) have occurred.

2.Force-response algorithms compute the interaction force between avatars and virtual objects when a collision is detected. This force approximates as closely as possible the contact forces that would normally arise during contact between real objects. Force response algorithms typically operate on the avatars' positions, the positions of all objects in the virtual environment, and the collision state between avatars and virtual objects. Their return values are normally force and torque vectors that are applied at the device-body interface. Hardware limitations prevent haptic devices from applying the exact force computed by the force-response algorithms to the user.

3.Control algorithms command the haptic device in such a way that minimizes the error
between ideal and applicable forces. The discrete-time nature of the haptic-rendering algorithms often makes this difficult; as we explain further later in the article. Desired force and torque vectors computed by force response algorithms feed the control algorithms. The algorithms' return values are the actual force and torque vectors that will be commanded to the haptic device.

A typical haptic loop consists of the following sequence of events:-

- Low-level control algorithms sample the position sensor sat the haptic interface device joints.
- These control algorithms combine the information collected from each sensor to obtain the position of the device-body interface in Cartesian space—that is, the avatar's position inside the virtual environment
- The collision-detection algorithm uses position information to find collisions between objects and avatars and report the resulting degree of penetration.
- The force-response algorithm computes interaction forces between avatars and virtual objects involved in a collision.
- The force-response algorithm sends interaction forces to the control algorithms, which apply them on the operator through the haptic device while maintaining a stable overall behavior.

Haptic interaction techniques:-

Many of these techniques are inspired by analogous techniques in modern computer graphics. In computer graphics, texture mapping adds realism to computer generated scenes by projecting a bitmap image onto surfaces being rendered. The same can be done haptically. Minsky first proposed haptic texture mapping for 2D and later extended his work to 3D scenes. Existing haptic rendering techniques are currently based upon two main principles: "point interaction" or "ray-based rendering". In point interactions, a single point, usually the distal point of a probe, thimble or stylus employed for direct interaction with the user, is employed in the simulation of collisions. The point penetrates the virtual objects, and the depth of indentation is calculated between the current point and a point on the surface of the object. Forces are then generated according to physical models, such as spring stiffness or a spring damper model. In ray-based rendering, the user interface mechanism, for example, a probe is modeled in the virtual environment as a finite ray. Orientation is thus taken into account, and collisions are determined between the simulated probe and virtual objects. Collision detection algorithms return the intersection point between the ray and the surface of the simulated object.

APPLICATION:-

Graphical user interfaces:

Video game makers have been early adopters of passive haptics, which takes advantage of vibrating joysticks, controllers and steering wheels to reinforce on-screen activity. But future video games will enable players to feel and manipulate virtual solids, fluids, tools and avatars

Surgical Simulation and Medical Training

Various haptic interfaces for medical simulation may prove especially useful for training of minimally invasive procedures (laparoscopy/interventional radiology) and remote surgery using teleoperators. In the future, expert surgeons may work from a central workstation, performing operations in various locations, with machine setup and patient preparation performed by local nursing staff. Rather than traveling to an operating room, the surgeon instead becomes a telepresence. A particular advantage of this type of work is that the surgeon can perform many more operations of a similar type, and 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.

Advantages:

1. Digital world can behave like the real world.
2. Working time is reduced
3. Medical field simulators allow would be surgeons to practice digitally
4. Easy to use and access
5. With haptic technology the hardware and software designer can feel the result as if he were handling physical objects.

Disadvantages:

1. The precision of touch requires a lot of advance design.
2. Haptics applications require highly specialized.
3. Hardware and considerable processing power and hence its complex.
4. Haptics projects rely on fixed installations of equipment and are not easily portable.
5. Debugging issues.
6. Higher cost

LIMITATIONS OF HAPTIC SYSTEMS:-

Limitations of haptic device systems have sometimes made applying the force's exact value as computed by force-rendering algorithms impossible. Various issues contribute to limiting a haptic device's capability to render a desired force or, more often, desired impedance are given below:-

- Haptic interfaces can only exert forces with limited magnitude and not equally well in all directions, thus rendering algorithms must ensure that no output components saturate, as this would lead to erroneous or discontinuous application of forces to the user. In addition, haptic devices aren't ideal force transducers.
- An ideal haptic device would render zero impedance when simulating movement in free space, and any finite impedance when simulating contact with an object featuring such impedance characteristics. The friction, inertia, and backlash present in most haptic devices prevent them from meeting this ideal.
- A third issue is that haptic-rendering algorithms operate in discrete time whereas users operate in continuous time, as Figure shown below illustrates. While moving into and out of a virtual object, the sampled avatar position will always lag behind the avatar's actual continuous-time position. Thus, when pressing on a virtual object, a user needs to perform less work than in reality. And when the user releases, however, the virtual object returns more work than its real-world counterpart would have returned. In other terms, touching a virtual object extracts energy from it. This extra energy can cause an unstable response from haptic devices.
- Finally, haptic device position sensors have finite resolution. Consequently, attempting to determine where and when contact occurs always results in a quantization error. Although users might not easily perceive this error, it can create stability problems.

Future Vision:

As haptics moves beyond the buzzes and thumps of today's video games, technology will enable increasingly believable and complex physical interaction with virtual or remote objects. It's not unreasonable to expect that future advancements in haptics will have equally deep effects. Though the field is still in its infancy, hints of vast, unexplored intellectual and commercial territory add excitement and energy to a growing number of conferences, courses, product releases, and invention efforts.

CONCLUSION :

Finally we shouldn't forget that touch and physical interaction are among the fundamental ways in which we come to understand our world and to effect changes in it. This is true on a developmental as well as an evolutionary level. Our efforts to communicate information by rendering how objects feel through haptic technology, and the excitement in our pursuit, might reflect a deeper desire to speak with an inner, physically based language that has yet to be given a true voice.