A

SEMINAR REPORT

ON

HAPTIC TECHNOLOGY

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CERTIFICATE

This is to certify that the following student of Final year Electronics & Communication Engineering have successfully submitted the seminar report entitled

HAPTICS TECHNOLOGY

The work prepared by him is found satisfactory.

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ACKNOWLEDGEMENT

I wish to extend my sincere gratitude to my seminar guide, Mr.Nikunj Patel Lecturer, Department of Electronics & Communication, for his valuable guidance and encouragement which has been absolutely helpful in successful completion of this seminar.

I am indebted to Prof. Mr.Ninand Bhatt, Professor and Head, Department of Electronics & Communication for his valuable support.

I am also grateful to my parents and friends for their timely aid without which I wouldn’t have finished my seminar successfully. I extend my thanks to all my well wishers and all those who have contributed directly and indirectly for the completion of this work.

And last but not the least; I thank God Almighty for his blessings without which the completion of this seminar would not have been Possible.

ABSTRACT

Users are given the illusion that they are touching or Manipulating a real Physical Object 'Haptics' is a technology that adds the sense of touch to virtual environments..

This seminar discusses the important concepts in Haptics, some of the most commonly used haptics systems like 'Phantom', 'Cyber glove', 'Novint Falcon' and such similar devices. Following this, a description about how sensors and actuators are used for tracking the position and movement of the haptic systems, is provided.

The different types of force rendering algorithms are discussed next. The seminar explains the blocks in force rendering. Then a few applications of haptic systems are taken up for discussion.

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CHAPTER 1 INTRODUCTION

1.1 What is 'Haptics'?

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 (teleoperators). This emerging 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. These objects are used to systematically probe human haptic capabilities, which would otherwise be difficult to achieve. These new research tools contribute to our understanding of how touch and its underlying brain functions work. 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.

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.

1.2 History of Haptics

In the early 20th century, psychophysicists introduced the word haptic to label the subfield of their studies that addressed human touch-based perception and manipulation. In the 1970s and 1980s, significant research efforts in a completely different field, robotics also began to focus on manipulation and perception by touch. Initially concerned with building autonomous robots, researchers soon found that building a dexterous robotic hand was much more complex and subtle than their initial naive hopes had suggested.

In time these two communities, one that sought to understand the human hand and one that aspired to create devices with dexterity inspired by human abilities found fertile mutual interest in topics such as sensory design and processing, grasp control and manipulation, object representation and haptic information encoding, and grammars for describing physical tasks.

In the early 1990s a new usage of the word haptics began to emerge. The confluence of several emerging technologies made virtualized haptics, or computer haptics possible. Much like computer graphics, computer haptics enables the display of simulated objects to humans in an interactive manner. However, computer haptics uses a display technology through which objects can be physically palpated.

CHAPTER 2 WORKING OF HAPTICS

2.1 Basic system configuration.

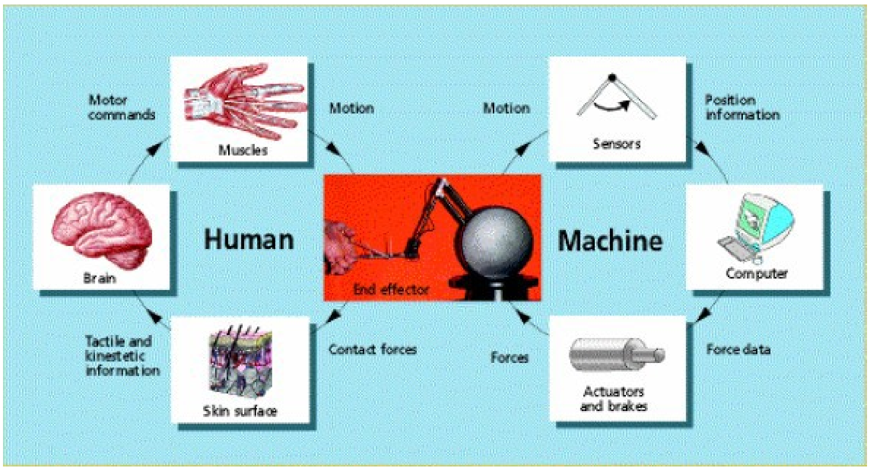

Fig 2.1 Basic Configuration of Haptics

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.

2.2 Haptic Information

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

For example when we handle flexible materials like fabric and paper, we sense the pressure variation across the fingertip. This is actually a sort of tactile information. Tactile sensing is also the basis of complex perceptual tasks like medical palpation, where physicians locate hidden anatomical structures and evaluate tissue properties using their hands.

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.

2.3 Creation of Virtual environment (Virtual reality).

Virtual reality is the technology which allows a user to interact with a computer-simulated environment, whether that environment is a simulation of the real world or an imaginary world. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special or stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced, haptic systems now include tactile information, generally known as force feedback, in medical and gaming applications. Users can interact with a virtual environment or a virtual artifact (VA) either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, the Polhemus boom arm, and omnidirectional treadmill. The simulated environment can be similar to the real world, for example, simulations for pilot or combat training, or it can differ significantly from reality, as in VR games. In practice, it is currently very difficult to create a high-fidelity virtual reality experience, due largely to technical limitations on processing power, image resolution and communication bandwidth. However, those limitations are expected to eventually be overcome as processor, imaging and data communication technologies become more powerful and cost-effective over time. Virtual Reality is often used to describe a wide variety of applications, commonly associated with its immersive, highly visual, 3D environments. The development of CAD software, graphics hardware acceleration, head mounted displays; database gloves and miniaturization have helped popularize the motion. The most successful use of virtual reality is the computer generated 3-D simulators. The pilots use flight simulators. These flight simulators have designed just like cockpit of the airplanes or the helicopter. The screen in front of the pilot creates virtual environment and the trainers outside the simulators commands the simulator for adopt different modes. The pilots are trained to control the planes in different difficult situations and emergency landing. The simulator provides the environment. These simulators cost millions of dollars.

Fig 2.2 Virtual environment

The virtual reality games are also used almost in the same fashion. The player has to wear special gloves, headphones, goggles, full body wearing and special sensory input devices. The player feels that he is in the real environment. The special goggles have monitors to see. The environment changes according to the moments of the player. These games are very expensive.

2.4 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.

Figure below shows the structure of a VR application incorporating visual, auditory, and haptic feedback.

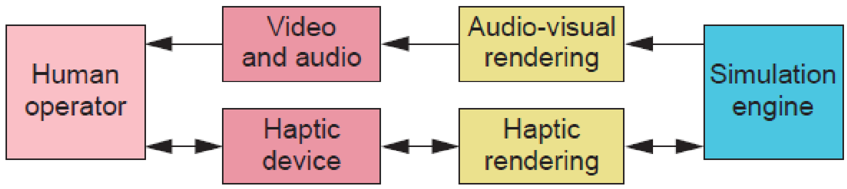

Fig 2.3 Haptic Feedback Block Diagram

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 (for example a computer screen or head-mounted display).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.

Chapter 3 HAPTIC DEVICES

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:-

3.1 Virtual reality/ Tele-robotics based devices:-

3.1.1 Exoskeletons and Stationary device

3.1.2 Gloves and wearable devices

3.1.3 Point-source and Specific task devices

3.1.4 Locomotion Interfaces

3.2 Feedback devices:-

3.2.1 Force feedback devices

3.2.2 Tactile displays

3.1 Virtual reality/Tele-robotics based devices:-

3.1.1 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.

3.1.2 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.

3.1.3 Point sources and specific task devices

This is a class of devices that are very specialized for performing a particular given task. Designing a device to perform a single type of task restricts the application of that device to a much smaller number of functions. However it allows the designer to focus the device to perform its task extremely well. These task devices have two general forms, single point of interface devices and specific task devices.

3.1.4 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.

3.2 Feedback Devices:-

3.2.1 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.

3.2.2 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.

3.3 COMMONLY USED HAPTIC INTERFACING DEVICES:-

3.3.1 PHANTOM

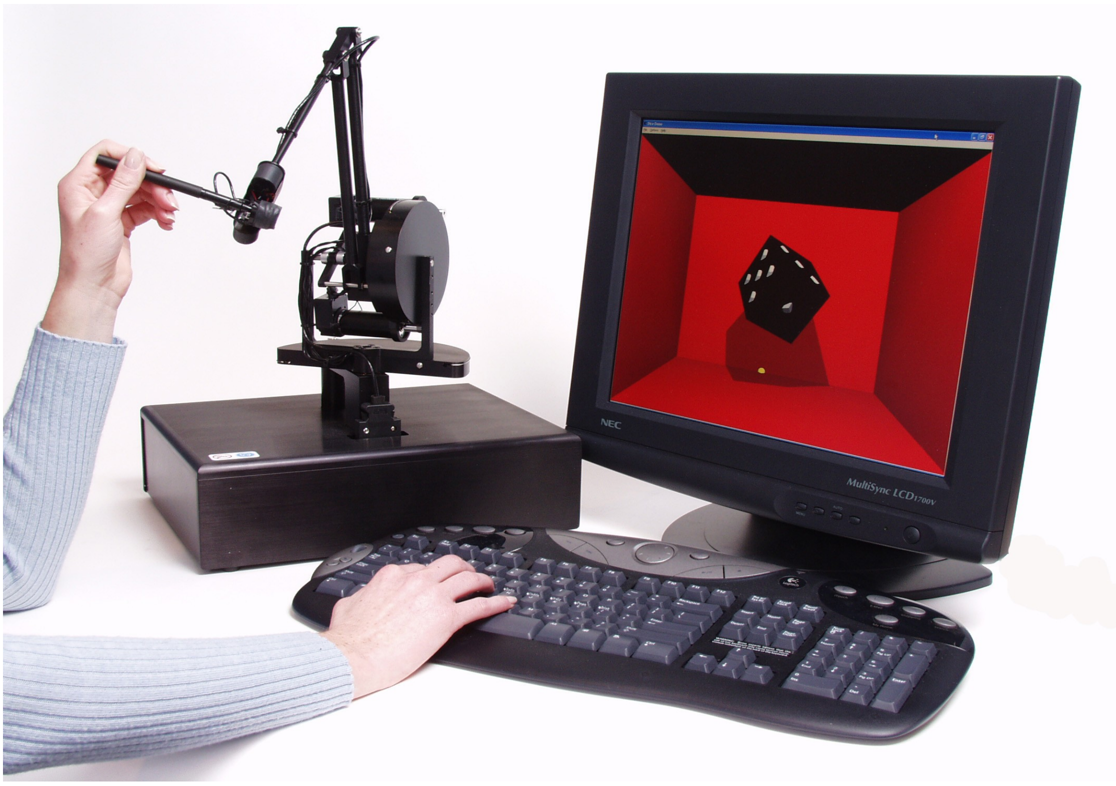

Fig 3.1 PHANTOM (Haptic Device)

It is a haptic interfacing device developed by a company named Sensible technologies. It is primarily used for providing a 3D touch to the virtual objects. This is a very high resolution 6 DOF device in which the user holds the end of a motor controlled jointed arm. It provides a programmable sense of touch that allows the user to feel the texture and shape of the virtual object with a very high degree of realism. One of its key features is that it can model free floating 3 dimensional objects.

3.3.2 Cyber glove

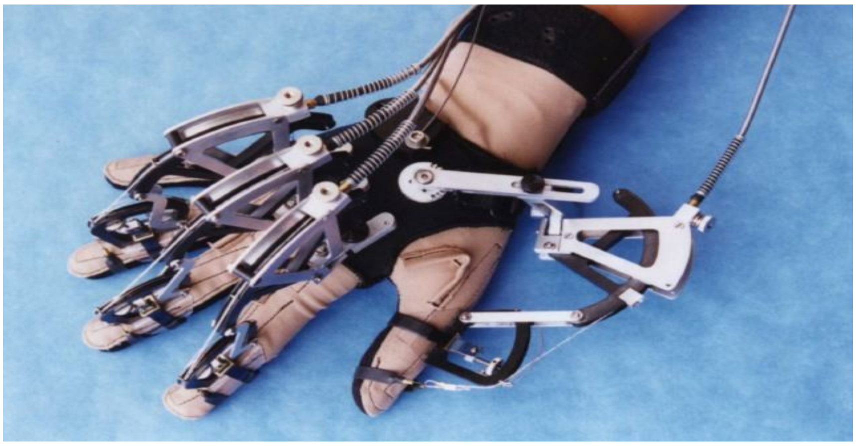

Fig 3.2 Cyber glove (Haptic Device)

The principle of a Cyber 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.

The solution that we have chosen uses a mechanical structure with three passive joints which, with the interphalangian joint, make up a flat four-bar closed-link mechanism. This solution use cables placed at the interior of the four-bar mechanism and following a trajectory identical to that used by the extensor tendons which, by nature, oppose the movement of the flexor tendons in order to harmonize the movement of the fingers. Among the advantages of this structure one can cite:-

- Allows 4 dof for each finger
- Adapted to different size of the fingers

- Located on the back of the hand
- Apply different forces on each phalanx (The possibility of applying a lateral force on the fingertip by motorizing the abduction/adduction joint)
- Measure finger angular flexion (The measure of the joint angles are Independent and can have a good resolution given the important paths traveled by the cables when the finger shut.

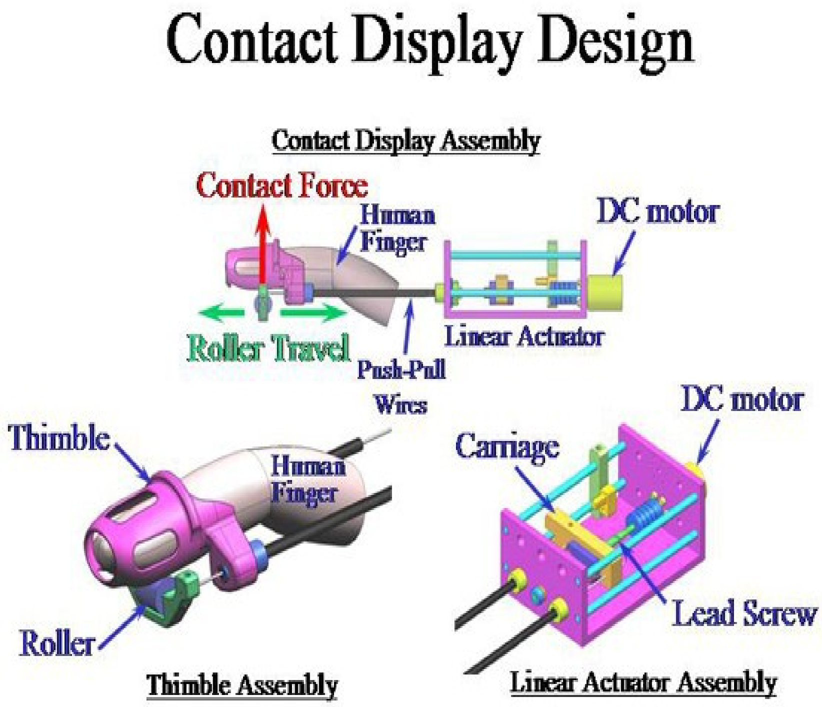

Fig 3.3 Cyber glove Mechanism

3.3.2.1 Mechanical structure of a Cyber glove

The glove is made up of five fingers and has 19 degrees of freedom 5 of which are passive. Each finger is made up of a passive abduction joint which links it to the base (palm) and to 9 rotoid joints which, with the three interphalangian joints, make up 3 closed-link mechanism with four bar and 1 degree of freedom. The structure of the thumb is composed of only two closed-links, for 3 dof of which one is passive. The segments of the glove are made of aluminum and can withstand high charges; their total weight does not surpass 350 grams. The length of the segments is proportional to the length of the phalanxes. All of the joints are mounted on miniature ball bearings in order to reduce friction.

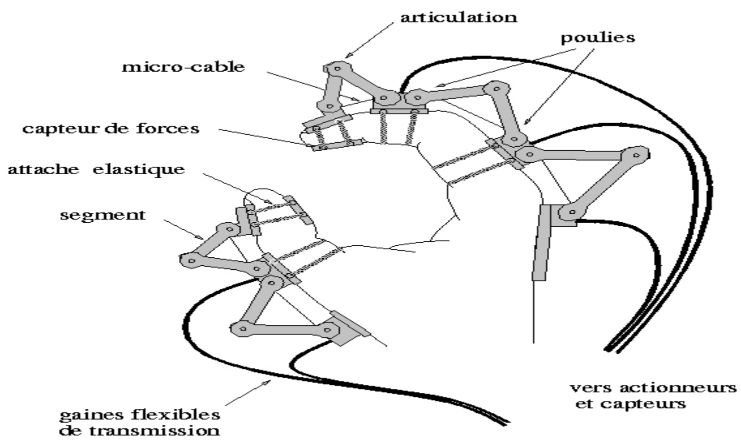

Fig 3.4 Mechanical Structural of Cyber glove

The mechanical structure offers two essential advantages: the first is the facility of adapting to different sizes of the human hand. We have also provided for lateral adjustment in order to adapt the interval between the fingers at the palm. The second advantage is the presence of physical stops in the structure which offer complete security to the operator. The force sensor is placed on the inside of a fixed support on the upper part of the phalanx. The sensor is made up of a steel strip on which a strain gauge was glued. The position sensor used to measure the cable displacement is incremental optical encoders offering an average theoretical resolution equal to 0.1 deg for the finger joints.

3.3.2.2 Control of Cyber glove

The glove is controlled by 14 torque motors with continuous current which can develop a maximal torque equal to 1.4 Nm and a continuous torque equal to 0.12 Nm. On each motor we fix a pulley with an 8.5 mm radius onto which the cable is wound. The maximal force that the motor can exert on the cable is thus equal to 14.0 N, a value sufficient to ensure opposition to the movement of the finger. The electronic interface of the force feedback data glove is made of PC with several acquisition cards. The global scheme of the control is given in the figure shown below. One can distinguish two command loops: an internal loop which corresponds to a classic force control with constant gains and an external loop which integrates the model of distortion of the virtual object in contact with the fingers. In this schema the action of man on the position of the fingers joints is taken into consideration by the two control loops. Man is considered as a displacement generator while the glove is considered as a force generator.

Chapter 4 HAPTIC RENDERING

4.1 Principle of haptic interface:-

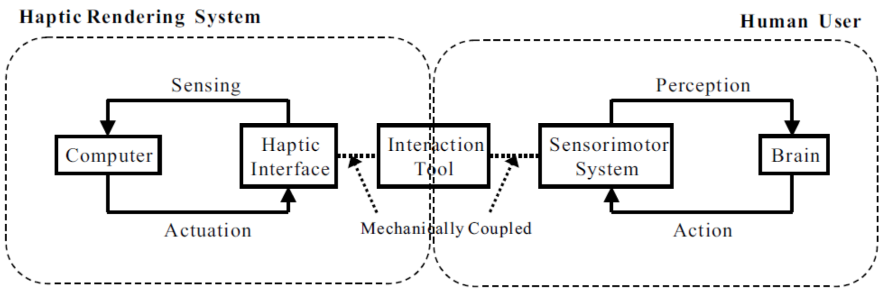

Fig 4.1 Haptics Rendering System

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.

4.2 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 regularizing 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.

4.3 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.

4.4 System architecture for haptic rendering:-

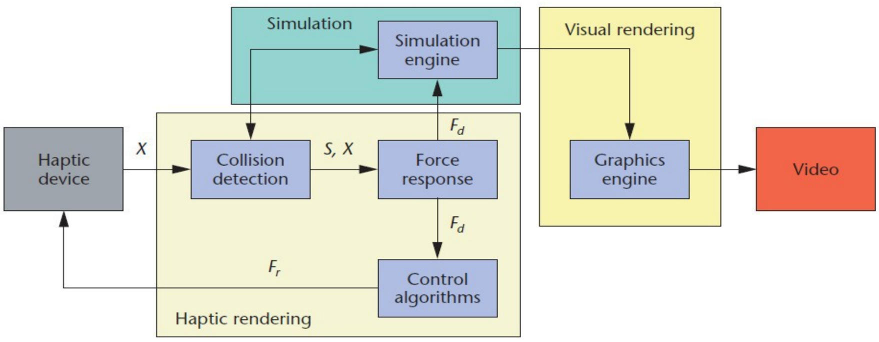

Fig 4.2 Haptic Rendering Architecture

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 blow.
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.

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.

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.

The simulation engine then uses the same interaction forces to compute their effect on objects in the virtual environment. Although there are no firm rules about how frequently the algorithms must repeat these computations, a 1-KHz servo rate is common. This rate seems to be a subjectively acceptable compromise permitting presentation of reasonably complex objects with reasonable stiffness. Higher servo rates can provide crisper contact and texture sensations, but only at the expense of reduced scene complexity (or more capable computers).

4.5 Computing contact-response forces:-

Humans perceive contact with real objects through sensors (mechanoreceptors) located in their skin, joints, tendons, and muscles. We make a simple distinction between the information these two types of sensors can acquire. i.e. Tactile information and kinesthetic information. A tool based interaction paradigm provides a convenient simplification because the system need only render forces resulting from contact between the tool's avatar and objects in the environment. Thus, haptic interfaces frequently utilize a tool handle physical interface for the user.

To provide a haptic simulation experience, we've designed our systems to recreate the contact forces a user would perceive when touching a real object. The haptic interfaces measure the user's position to recognize if and when contacts occur and to collect information needed to determine the correct interaction force. Although determining user motion is easy, determining appropriate display forces is a complex process and a subject of much research. Current haptic technology effectively simulates interaction forces for simple cases, but is limited when tactile feedback is involved.

Compliant object response modeling adds a dimension of complexity because of non negligible deformations, the potential for self-collision, and the general complexity of modeling potentially large and varying areas of contact. We distinguish between two types of forces: forces due to object geometry and forces due to object surface properties, such as texture and friction

4.6 Geometry-dependant force-rendering algorithms:-

The first type of force-rendering algorithms aspires to recreate the force interaction a user would feel when touching a frictionless and texture fewer objects. Such interaction forces depend on the geometry of the object being touched, its compliance, and the geometry of the avatar representing the haptic interface inside the virtual environment.

Although exceptions exist, 5 of the necessary DOF to describe the interaction forces between an avatar and a virtual object typically matches the actuated DOF of the haptic device being used. Thus for simpler devices, such as a 1-DOF force-reflecting gripper, the avatar consists of a couple of points that can only move and exchange forces along the line connecting them. For this device type, the force-rendering algorithm computes a simple 1-DOF squeeze force between the index finger and the thumb, similar to the force you would feel when cutting an object with scissors. When using a 6-DOF haptic device, the avatar can be an object of any shape. In this case, the force-rendering algorithm computes all the interaction forces between the object and the virtual environment and applies the resultant force and torque vectors to the user through the haptic device. We group current force-rendering algorithms by the number of DOF necessary to describe the interaction force being rendered.

4.7 Surface property-dependent force-rendering algorithms:-

All real surfaces contain tiny irregularities or indentations. Obviously, it’s impossible to distinguish each irregularity when sliding a finger over an object. However, tactile sensors in the human skin can feel their combined effects when rubbed against a real surface.

Micro-irregularities act as obstructions when two surfaces slide against each other and generate forces tangential to the surface and opposite to motion. Friction, when viewed at the microscopic level, is a complicated phenomenon. Nevertheless, simple empirical models exist, such as the one Leonardo Da Vinci proposed and Charles Augustin de Coulomb later developed in 1785. Such models served as a basis for the simpler frictional models in 3 DOF Researchers outside the haptic community have developed many models to render friction with higher accuracy, for example, the Karnopp model for modeling stick-slip friction, the Bristle model, and the reset integrator model. Higher accuracy, however, sacrifices speed, a critical factor in real-time applications. Any choice of modeling technique must consider this trade off. Keeping this trade off in mind, researchers have developed more accurate haptic-rendering algorithms for friction. A texture or pattern generally covers real surfaces. Researchers have proposed various techniques for rendering the forces that touching such textures generates.

4.8 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.

Chapter 5 APPLICATIONS, LIMITATION & FUTURE VISION

5.1 APPLICATION:-

5.1.1 Graphical user interfaces

Fig 5.1 Graphical Interface for Laptop Games

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. The Novint Falcon haptics controller is already making this promise a reality. The 3-D force feedback controller allows you to tell the difference between a pistol report and a shotgun blast, or to feel the resistance of a longbow's string as you pull back an arrow.

Graphical user interfaces, like those that define Windows and Mac operating environments, will also benefit greatly from haptic interactions. Imagine being able to feel graphic buttons and receive force feedback as you depress a button. Some touch screen manufacturers are already experimenting with this technology. Nokia phone designers have perfected a tactile touch screen that makes on-screen buttons behave as if they were real buttons. When a user presses the button, he or she feels movement in and movement out. He also hears an audible click. Nokia engineers accomplished this by placing two small piezoelectric sensor pads under the screen and designing the screen so it could move slightly when pressed. Everything, movement and sound is synchronized perfectly to simulate real button manipulation.

5.1.2 Surgical Simulation and Medical Training

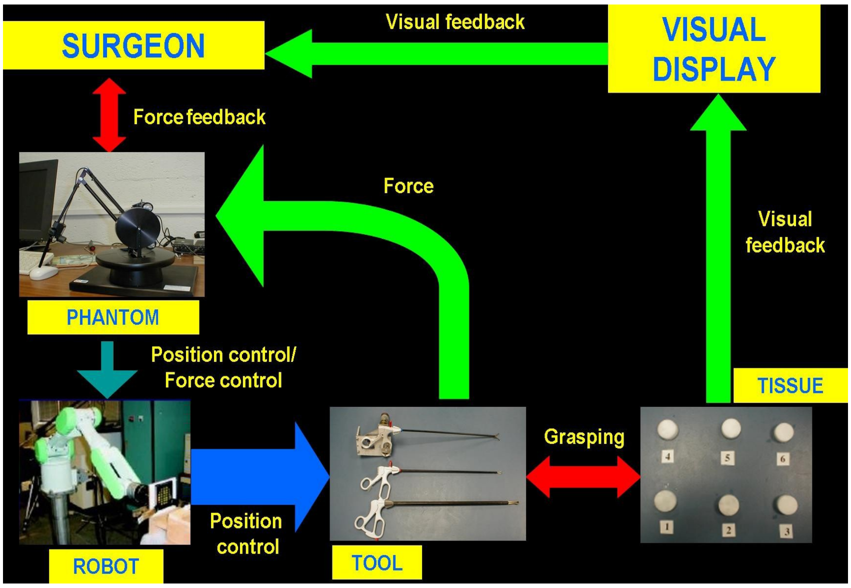

Fig 5.2 Medical Training Purpose

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.

In ophthalmology, "haptic" refers to a supporting spring, two of which hold an artificial lens within the lens capsule (after surgical removal of cataracts).

A 'Virtual Haptic Back' (VHB) is being successfully integrated in the curriculum of students 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 compliance (reciprocal of stiffness) properties of human backs, which are palpated with two haptic interfaces (Sensible Technologies, Phantom 3.0).

Reality-based modeling for surgical simulation consists of a continuous cycle. In the figure given above, the surgeon receives visual and haptic (force and tactile) feedback and interacts with the haptic interface to control the surgical robot and instrument. The robot with instrument then operates on the patient at the surgical site per the commands given by the surgeon. Visual and force feedback is then obtained through endoscopic cameras and force sensors that are located on the surgical tools and are displayed back to the surgeon.

5.1.3 Military Training in virtual environment

From the earliest moments in the history of virtual reality (VR), the United States military forces have been a driving factor in developing and applying new VR technologies. Along with the entertainment industry, the military is responsible for the most dramatic evolutionary leaps in the VR field.

Virtual environments work well in military applications. When well designed, they provide the user with an accurate simulation of real events in safe, controlled environment. Specialized military training can be very expensive, particularly for vehicle pilots. Some training procedures have an element of danger when using real situations. While the initial development of VR gear and software is expensive, in the long run it's much more cost effective than putting soldiers into real vehicles or physically simulated situations. VR technology also has other potential applications that can make military activities safer.

Today, the military uses VR techniques not only for training and safety enhancement, but also to analyze military maneuvers and battlefield positions. In the next section, we'll look at the various simulators commonly used in military training. Out of all the earliest VR technology applications, military vehicle simulations have probably been the most successful. Simulators use sophisticated computer models to replicate a vehicle's capabilities and limitations within a stationary and safe computer station.

Fig 5.3 Virtual Environment in Military Training

Possibly the most well-known of all the simulators in the military are the flight simulators. The Air Force, Army and Navy all use flight simulators to train pilots. Training missions may include how to fly in battle, how to recover in an emergency, or how to coordinate air support with ground operations.

Although flight simulators may vary from one model to another, most of them have a similar basic setup. The simulator sits on top of either an electronic motion base or a hydraulic lift system that reacts to user input and events within the simulation. As the pilot steers the aircraft, the module he sits in twists and tilts, giving the user haptic feedback. The word "haptic" refers to the sense of touch, so a haptic system is one that gives the user feedback he can feel. A joystick with force-feedback is an example of a haptic device.

Some flight simulators include a completely enclosed module, while others just have a series of computer monitors arranged to cover the pilot's field of view. Ideally, the flight simulator will be designed so that when the pilot looks around, he sees the same controls and layout as he would in a real aircraft. Because one aircraft can have a very different cockpit layout than another, there isn't a perfect simulator choice that can accurately represent every vehicle. Some training centers invest in multiple simulators, while others sacrifice accuracy for convenience and cost by sticking to one simulator model.

Ground Vehicle Simulators: although not as high profile as flight simulators, VR simulators for ground vehicles are an important part of the military's strategy. In fact, simulators are a key part of the Future Combat System (FCS) -- the foundation of the armed forces' future. The FCS consists of a networked battle command system and advanced vehicles and weapons platforms. Computer scientists designed FCS simulators to link together in a network, facilitating complex training missions involving multiple participants acting in various roles.

Fig 5.4 Military Training with help of Haptics Device

The FCS simulators include three computer monitors and a pair of joystick controllers attached to a console. The modules can simulate several different ground vehicles, including non-line-of sight mortar vehicles, reconnaissance vehicles or an infantry carrier vehicle.

The Army uses several specific devices to train soldiers to drive specialized vehicles like tanks or the heavily-armored Stryker vehicle. Some of these look like long-lost twins to flight simulators. They not only accurately recreate the handling and feel of the vehicle they represent, but also can replicate just about any environment you can imagine. Trainees can learn how the real vehicle handles in treacherous weather conditions or difficult terrain. Networked simulators allow users to participate in complex war games.

5.1.4 Telerobotics

In a telerobotic system, a human operator controls the movements of a robot that is located some distance away. Some teleported robots are limited to very simple tasks, such as aiming a camera and sending back visual images. Haptics now makes it possible to include touch cues in addition to audio and visual cues in telepresence models. It won't be long before astronomers and planet scientists actually hold and manipulate a Martian rock through an advanced hapticsenabled telerobot, a high-touch version of the Mars Exploration Rover.

5.2 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.

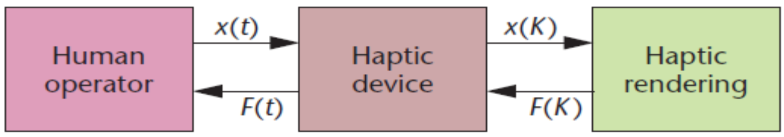

Fig 5.5 Haptic-rendering Block Diagram

- 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.

All of these issues, well known to practitioners in the field, can limit haptic application's realism. The first two issues usually depend more on the device mechanics; the latter two depend on the digital nature of VR applications.

5.3 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. Already haptically enabled commercial products let designers sculpt digital clay figures to rapidly produce new product geometry, museum goers feel previously inaccessible artifacts, and doctors train for simple procedures without endangering patients.

Past technological advances that permitted recording, encoding, storage, transmission, editing, and ultimately synthesis of images and sound profoundly affected society. A wide range of human activities, including communication, education, art, entertainment, commerce, and science, were forever changed when we learned to capture, manipulate, and create sensory stimuli nearly indistinguishable from reality. 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.

For the field to move beyond today's state of the art, researchers must surmount a number of commercial and technological barriers. Device and software tool-oriented corporate efforts have provided the tools we need to step out of the laboratory, yet we need new business models. For example, can we create haptic content and authoring tools that will make the technology broadly attractive?

Can the interface devices be made practical and inexpensive enough to make them widely accessible? Once we move beyond single-point force-only interactions with rigid objects, we should explore several technical and scientific avenues. Multipoint, multi-hand, and multi-person interaction scenarios all offer enticingly rich interactivity. Adding sub-modality stimulation such as tactile (pressure distribution) display and vibration could add subtle and important richness to the experience. Modeling compliant objects, such as for surgical simulation and training, presents many challenging problems to enable realistic deformations, arbitrary collisions, and topological changes caused by cutting and joining actions.

Improved accuracy and richness in object modeling and haptic rendering will require advances in our understanding of how to represent and render psychophysically and cognitively germane attributes of objects, as well as algorithms and perhaps specialty hardware (such as haptic or physics engines) to perform real-time computations.

Development of multimodal workstations that provide haptic, visual, and auditory engagement will offer opportunities for more integrated interactions. We're only beginning to understand the psychophysical and cognitive details needed to enable successful multimodality interactions. For example, how do we encode and render an object so there is a seamless consistency and congruence across sensory modalities—that is, does it look like it feels? Are the object's densities, compliance, motion, and appearance familiar and unconsciously consistent with context? Are sensory events predictable enough that we consider objects to be persistent, and can we make correct inference about properties?

Hopefully we could get bright solutions for all the queries in the near future itself.

CONCLUSIONS

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. For early primates to survive in a physical world, as Frank Wilson suggested, "a new physics would eventually have to come into this their brain, a new way of registering and representing the behavior of objects moving and changing under the control of the hand. It is precisely such a representational system—a syntax of cause and effect, of stories, and of experiments, each having a beginning, a middle, and an end— that one finds at the deepest levels of the organization of human language."

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.

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