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Emerging Haptics Technology and its Applications

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Abstract- Haptics is the science of applying touch sensation and control to interaction with computer applications. It derives an additional dimension to a virtual reality or 3-D environment and is essential to the immersiveness of that environment. It recreates the sense of touch by applying forces, vibrations, or motions to the user. This simulation can be used to assist in the creation of virtual objects in a computer simulation, to control such virtual objects. This simulation can also be used to enhance the remote control of machines and devices like telerobotics. Haptic devices may incorporate tactile sensors that measure forces exerted by the user on the interface. The purpose of this paper is to give an overview of this technology, describe haptic devices and haptic applications.

Keywords:* *Haptic rendering, haptic devices, haptic interfaces, kinesthetic, tactile, ultra-haptics,laparoscopy

I.INTRODUCTION

Haptics is the emerging technology of adding the sensation of touch and feeling to computers. “Haptic”, is the term derived from the Greek word, “haptesthai”, which means ‘sense of touch’. It is defined as the “science of applying tactile sensation to human interaction with computers”.It permits users to sense (“feel”) and manipulate three dimensional virtual objects with respect to such features as shape, weight, surface textures, and temperature.

By using Haptic devices, the user can not only feed information to the computer but can 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 our paper we explain the basic concepts of ‘Haptic Technology and its Application.

II. HISTORY OF HAPTICS TECHNOLOGY

Haptics was described as “the sensibility of the individual to the world adjacent to his body by the use of his body”. This word was introduced at the beginning of the twentieth century by researchers in the field of experimental psychology to refer to the active touch of real objects by humans. In the late 1980s, the term was redefined to enlarge its scope to include all aspects of machine touch and human–machine touch interaction.

The ‘touching’ of objects could be done by humans, machines, or a combination of both, and the environment can be real, virtual, or a combination of both. Also, the interaction may or may not be accompanied by other sensory modalities such as vision or audition. Currently, the term has brought together many different disciplines, including biomechanics, psychology, neurophysiology, engineering, and computer science, that use this term refers to the study of human touch and force feedback with the external environment.

A.Generation of Haptic

a) *First Generation*– Use of Electromagnetic Technologies which produce a limited range of sensations.
b) *Second Generation*– Touch-Coordinates specific responses allowing the haptic effects to be localized to the position on a screen rather than the whole device.
c) *Third Generation* – Delivers both Touch-Coordinate specific responses and customized haptic effects.
d) Fourth Generation – Pressure Sensitivity, i.e. how hard you press on a flat surface can affect the response.

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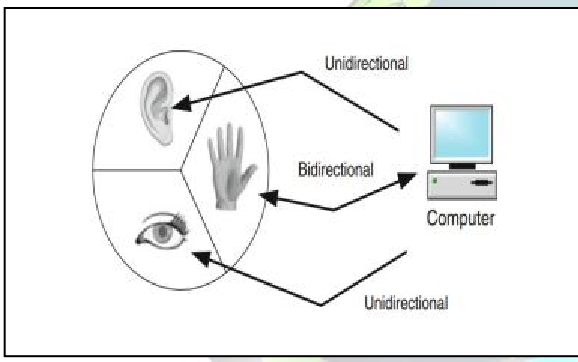
III.BASIC CONCEPT OF HAPTICS

Touch is a unique human sensory modality in contrast with other modalities. It enables bidirectional flow of energy due to the sensing and acting activities performed, as well as an exchange of information between the real or virtual environment and the end user (see Fig. 1). This is referred to as active touch. For instance, to sense the shape of a cup, one must run his/her fingers across its shape and surfaces to build a mental image of the cup. Furthermore, in a manipulation task, for instance sewing with a needle, the division between "input" and "output" is often very sharp and difficult to define. This co-dependence between sensing and manipulating is at the heart of understanding how humans can so deftly interact with the physical world.



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IV. COMPONENTS OF HAPTICS

The working of a haptics sensation requires Sensors, Actuators, Drivers, Control Software and Interface.

a) *Sensors*: It is responsible for sensing the haptic information exerted by the user on a certain object and sending force reading to the haptic rendering module. Haptic rendering means the process of calculating the sense of touch, especially force.
b) *Actuators*:These Actuators create the force, vibration or texture that the user feels while interacting with the hardware. The type of actuator will determine the solution and quality of the haptic effects.
c) *Drivers*:art of the electrical design and is the bridge between the controller and the actuator.
d) *Control Software(MCU)*:The control software generate the haptic waveforms and can reside on an applications processors, microcontroller, or integrated driver.It controls the actuators response based on the data collected from the sensors and the algorithms embedded within it.
e) *Haptic Interface:*Consists of haptic device and software-based computer control mechanisms. It enables human-machine communication through the sense of touch

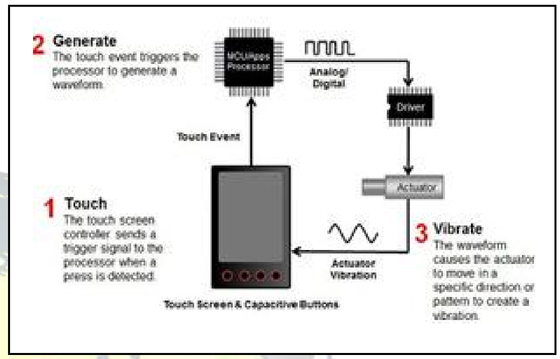

Fig. 2 Haptic Block diagram

V.WORKING CYCLES OF HAPTICS

To understand the basic working of haptics, consider the following diagram.

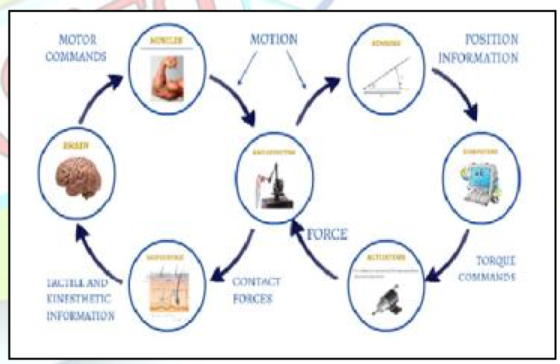

Fig. 3 Working cycles of haptics

The brain controls our body. It gives various instructions to different parts of our body. The brain tells the muscles to give specific input to the end effectors (as shown in fig 3).The end effectors are a sensitive haptic device. It has various sensors which sense the change in angle; amount of force applied etc and gives this information to the computer. The computer then processes this information and gives specific instructions to an actuator.

The actuator is a device that puts something in an automatic action. The actuator then applies force to

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haptic device, which, is perceived as feedback force by the user. The feedback force is felt on the surface of the skin and this feeling is interpreted by the brain. This is the basic working cycle of haptics.

Haptics refers to two kinds of information

a)Tactile information: This refers to the information acquired by the sensors connected to the user's body.
b)Kinesthetic information: This refers to the information acquired by the sensors in the joints.Haptics also introduces us to the concept of virtual reality. Virtual Reality allows a user to interact with a computer simulated environment. Users interact with VR either through input devices or through multimodal devices. Such a simulated environment can either be similar to ordifferent from reality. Virtual reality is used to describe awide variety of applications. However, it is very difficult to create a high fidelity virtual reality experience due to technical limitations.

VI.HAPTICS RENDERING

Haptics rendering is the process of generating and computing forces in response to the user's interaction with the virtual object. The process of interacting with the virtual object has been of great interest to many researchers worldwide. Rendering refers to a process by which desired stimuli are imposed on a user to convey the information about the virtual object. New technology always amazes people and just as the people were amazed to see the computers a few decades back, people are amazed to feel the virtual objects today. Haptic rendering is one of the most important parts of the haptic interfaces as, better the haptic rendering better the virtual feel. To enhance the haptic rendering various rendering algorithms are implemented. In this section we will study the approach of designing and implementing a haptic rendering algorithm.

As shown in the below fig 4, the haptic rendering algorithm forms the most important integral part of the haptic system. The haptic rendering algorithm generally consists of two sub-algorithms, collision detection algorithm and collision response algorithm. As the user changes his position or the force feedback (shown in Fig 4- a fingertip) the change in position or orientation is acquired and the Collision Detection algorithm detects the collision between the fingertip and the virtual environment. If a collision is detected, then the Collision Response algorithm calculates the force of interaction between the user and the virtual environment and then instructs the response device to generate the required force, thus generating the actual representation of the virtual object. The update rate of the haptic feedback loop must be at least 1KHz, in order to maintain the feel of the virtual object. The Object Database should be maintained so that all the physical properties of the object can be replicated correctly in the virtual environment. Moreover calculation of the contact forces is equally important than just calculating the collisions. Thus, better the haptic rendering algorithm, better the imitation of the real environment. Further we will see the applications of haptic interfaces which constitute the rendering algorithms to give accurate results for the respective application.

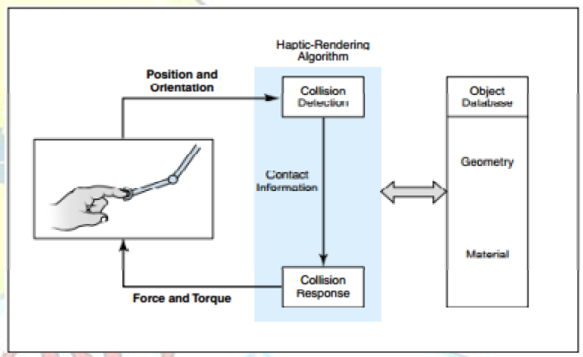

Fig. 4 Haptic Rendering

VI. APPLICATION OF HAPTICS

A. Haptic in GUI

Graphical User Interface (GUI) forms an integral part of any electronic system if human interaction is involved. GUI allows the user to interact with the system through graphical icons, visual indications on the screen, text based interfaces etc. If a third dimension is added to the graphical user interface, the interaction of the user with the electronic system can be more realistic. This third dimension that can be added to a GUI is haptics. The working of a haptic interface can be seen in the below diagram.

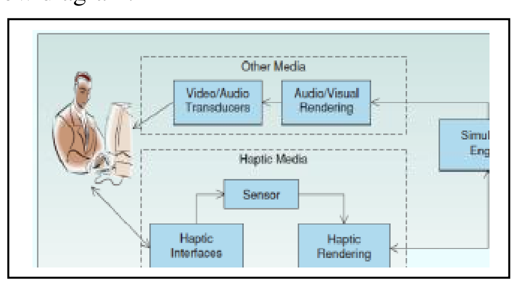

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Fig. 5 Haptic interfaces in GUI

As in Fig. 5, the user interacts with the computer in the form of audio or text inputs. The simulation engine simulates the inputs from the system, processes it and transfers the results to the haptic media. The haptic hardware gives outputs to the user in various formats such as touch sensations, force feedbacks, vibrations etc. This will enhance the user's experience of operating the system and will result in more efficiency in performing various functions. Real time experiences can be provided to the user in a GUI augmenting haptic feedback. Thus the modification of GUIs can be done in following ways to provide an enhanced experience to the user. Consider a scenario in which there is a graphical interface with buttons augmented with textures, friction and gravity-like effects.This graphical interface without a haptic feedback would just be a visual effect. Using haptic devices such as the FEELit mouse, Phantom the graphical user interfaces in a Desktop can be used to provide real time effects of all the above properties. For example the friction effect can be implemented by damping the user's effect using the FEELit mouse (Immersion Corporation).Another use of Haptic interfaces can be seen in mobile devices. It can be used for developing various applications. By varying the frequencies of touch senses user can experience various responses from the mobile device. Edutainment games are developed using haptic feedbacks. This can be a rich experience to the user thus eliminating the hackneyed gaming experience function.

B.Haptics For Medical And Visual Disabilities

Haptic interfaces for medical simulation have proved very useful.Touch and kinesthesis are subtle, effortless senses which are important for fast, accurate interaction with our environment.These prove to be very crucial for minimal invasive procedures.These include laparoscopy, interventional radiology and remote surgery. In open surgery, surgeons rely heavily on touch to distinguish healthy tissue from disease infected tissue.

Fig. 6 Haptic for visual disability

The advantage of using haptics technique is that surgeons can perform large number of similar operation with less fatigue. Also in opthalmology, the supporting springs that holds artificial lens within lens capsule after removal of cataract are done via haptics. Furthermore the virtual haptic feedback is useful for palpatory diagnosis that means detection of medical problem through touch.

Recent technology based on haptics is also utilised in fields of prosthetics. Haptics are also used to provide a feedback from prosthetic limb to its wearer.Haptics are widely used to help the visually impaired.The feeling of colour can be obtained through a haptic feedback device.A glove consisting of short range optical colour sensors on the fingertips and a belt with haptic feedback actuators constitute the system.The information of colour is provided through vibrations at different location and different modulation.

With a small amount of training the person can recognize which vibration associates to the respective colour. Volumetric data from computer tomography, haptic and visual feedback can be created from the dataset.This helps for patient specific simulation. In case of hip fracture this technique is particularly helpful.To simulate the drilling process repositioning is done first with help of segmentation.Then using visual and haptic feedback the simulation can be carried out. This provides the surgeons with a greater insight to the surgery.

Fig. 7 Haptic with fingertips

Haptics has a very large future scope in the field of medical application.It will be possible to construct a central work station which will be used by surgeons to perform operations remotely.Thus the surgeon will become a telepresence.This will lead to an increased availability of expert medical care.

Haptics provide a tactile and resistance feedback to surgeons operating on robotic devices. As surgery is carried on the ligaments are felt as if being directly worked on patient.Haptics can also develop technology to

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simulate surgery. Simulated surgery can be used for training.

Haptics aids in simulation by creating realistic environment of touch. Similar to telepresence surgery, surgeons can feel simulated ligaments or pressure of virtual incision as if real. This will help in training of surgeons.

C.Haptics In Teleoperation

Teleoperation means operation of a machine situated at a distance.It is very similar to a remote control but is usually seen in research, academics, and technical environment.Although it is usually associated with robotics and mobile robots, it can still be applied to a machine or a device which a person is operating from a distance.The origin of teleoperation can be traced back to the beginning of radio communication and Nikola Tesla.He developed the fundamental principle and system for teleoperation in 1880's usually scenes perceived by 3D vision. Hence visual modality is a predominant source of perception, but material as well as surface characteristics are also necessary. Hence haptic exploration is required.Also in telerobotics manipulation is required. Manipulation requires closed human – environment interaction. Thus, exploration and manipulation are necessary for telerobotics.

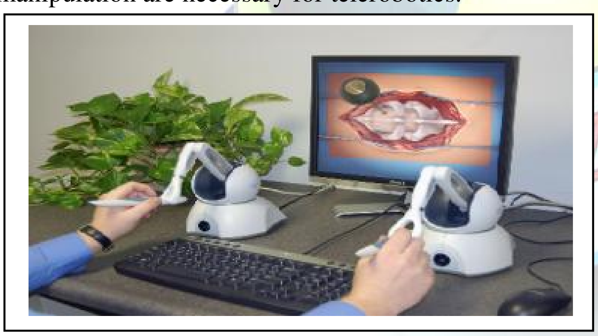

Fig. 8 Haptic in teleoperation

Haptics has led to an increase in precision of teleoperation by force and surface information feedback. Force feedback is obtained by sending back pressure and force through haptic devices at the point of interest. Such applications find use in assistive surgical robotics.

Fig. 9 Haptic in telerobotics

They are also used in simulators to train medical and military personnel. In assistive robotic surgery it is possible to carry a precise surgical procedure that will improve and hence shorten the healing process. Also teleopearted robotic system can be used for avoiding hazardous environments. Dangerous environments can be monitored from a remote location. However a large number of problems are associated with remote monitoring. The use of haptics enables us to improve telepresence at such locations. At times even fuzzy expert systems are used to provide the teleoperator with haptic improvisation to improve task performance. Thus haptics are widely used in telerobotics applications ranging from surgery,simulation, space, maintenance and manufacturing.

D.Data Visualisation

Use of graphics and animation to analyze or solve problems is data visualisation. They are used in scientific analysis and also for visually impaired people. Using haptics a high quality and accurate data visualisation is possible.

For example SCIRun is scientific data visualisation for problem solving. Scientific data visualisation is also used for fluid flow model, molecular interaction, force field analysis. For visually impaired people touch is used as a channel to provide information. Using graphical model made from haptic feedback, even a real city can be explored for the blind people.

Fig. 10 Haptic in data visualisation

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E.Arts And Design

Haptics also enables virtual modelling and sculpting. Sculpting and modelling are based on tactile feedback model. Hence with haptic feedback and touch virtual sculpting becomes easier

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Fig. 11 Haptic for visual disability

VII. BENEFITS OF HAPTIC TECHNOLOGY

The technology enhances user-experience through the following factors:

*a)Better Usage:*Haptic sensation, along with its audio and visual setup, enhances user experience. Users feel assured on receiving feedback that the task is being executed on the device interface. Haptic technology engages a user's senses and aids in better usage.

*b)Realistic Environment:*Haptics enable users to experience a realistic environment, with users feeling the action of the application being accessed. For instance, in gaming applications the user might feel gun recoil or a car collision, adding a sense of realism.

c) AssuredFeedback: Currenttouch screens do not provide the desired physical feedback. Haptics, on the other hand, provide tactile confirmation and also a confident and safe user experience. Haptics provide distraction-free feedback, assuring the user that an application is being accessed.

VIII. LIMITATIONS

There are some of limitations associated with haptics, which, if overcome, can cause haptics to bring about a revolution. Some of the limitations are:

a) Haptics being a new technology requires a very highinitial investment and hence is very costly.
b) The haptic devices are usually bulky. These devicesare large in size and greater in weight which become abig problem in case of wearable haptic devices.
c) Haptic interfaces exert forces with limited magnitudeand not equally well in all directions.
d) Haptic rendering algorithm which provides the virtual environment operates in discrete time whereas the real-time users operate in continuous time.
e) Bandwidth limitation is a major problem associated with haptics.
f) Instability and vibration: Graphic rendering requires updates at the rate of 60 Hz. But haptic update rates must be of 1000Hz. If the required updates rates are not met, this may lead to instability. Thus the system may become unstable.

IX. FUTURE APPLICATIONS

Future applications of haptic technology cover a wide spectrum of human interaction with technology. Currentresearch focuses on the mastery of tactile interaction with holograms and distant objects, which if successful may result in applications and advancements in gaming, movies, manufacturing, medical, and other industries The medical industry stands to gain from virtual and telepresence surgeries, which provide new options for medical care.

A.Holographic Interaction:

Research is carried on by adding haptic feedback to holographic projection. Using this feedback, the user receives tactile response from holograph as if it were a real object. It is based on using ultrasound waves thereby creating acoustic radiation pressure. It is through tactile response that user percieves the object.

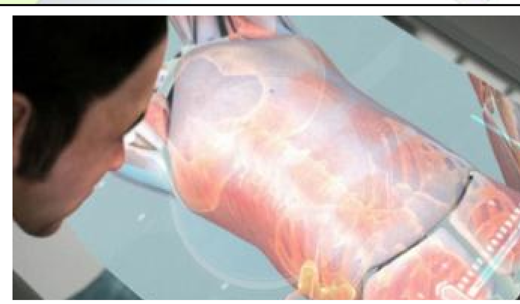

Fig. 12 Haptic for holographic interaction

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B.Biometric Haptics:

Haptics can also be used for biometric. Conventional biometrics requires a unique ID and password. These can be tedious to remember and hence are inconvenient. Further these passwords are less secure. These can be hacked without being known and hence are not very safe and reliable. The haptic based biometeric measure the position, velocity and force. After these measurements using algorithms, unique physical patterns can be developed which can be used for identification.

Fig. 13 Haptic for biometric haptics

C.E-Commerce:

Using haptic feedback in electronic commerce enables consumers to physically interact with the commodity. The product can be felt by touching and properties such as texture, roughness can be determined. Consumers usually like to feel and touch the object before buying. For example: while buying a fabric, the roughness, friction and softness can be actually felt by the customer and hence aids in their decision making.

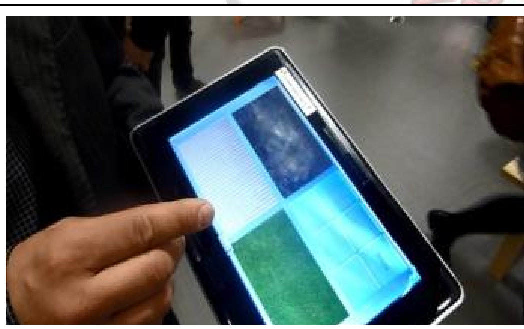

Fig. 14 Haptic for fabric purchase

D.Education:

Haptics can allow for visualization of geometric problems in actual 3-D space. This allows a better and clear understanding of the problem which is beneficial in the field of education.

Fig. 15 Haptic for education

X. FUTURE IN HAPTIC

A. Ultra-Haptics

Ultra-haptics focuses on the innovation of tech that you feel without having to touch anything – almost like *being touched*, instead of having to touch. They take inspiration from a very simple natural element that we automatically feel – the wind.

XI. CONCLUSION

Now, haptics is still in its development stage. It has the potential to bring the drastic improvements in intercommunication with the virtual world. However, it does have a few limitations in hardware, developmentcost, and its implementation. Day by day, the cost of technology is decreasing. Haptics is finding applications in every possible field such as education, entertainment, art, medical, teleoperation. Haptics has a very large future scope in every possible field. With an increase in investments in terms of money, time, dedication and space haptics is bound to remodel the world.

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