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HAPTIC TECHNOLOGY AND THEIR TRACES IN VARIOUS APPLICATIONS

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Abstract-Haptic technology is developed based on the science of applying tactile sensation to human interaction with computers. In this paper, we have discussed the concepts of haptic technology and haptic devices on how human's touch and force-feedback mechanism have been employed in different applications. Even very fragile objects can be inspected and addressed on virtual reality with haptic technology. The technique of emerging haptic interface to enhance the methods of learning and analyzing can be done through new computer interaction techniques. The advanced form of navigation assistance can be demonstrated using potential in haptics for both visually impaired and who have typical vision. Haptic accomplishes to be the aid to perform the most complicated surgeries with ease and experience. This reduces the risk in human lives with pre-operative planning, sharpening the skills necessary for correct execution of surgeries and expertise surgeons.
Keywords –haptics,visual impairments,gis,surgical training

1. INTRODUCTION

Out of our five senses, touch is most significant. Touch corresponds to simultaneous input and output. Touch can result in many psychological reactions. Haptics or haptic technology is a tactile feedback technology which makes use of the sense of touch by applying forces, vibrations or motions of the user to recreate actions [4]. The term'tactile' refers to the sense of touch, whereas "haptic" comprises touch as well as kinesthetic information and sense pertaining to position. Haptic technology enables to convert a visual picture into a touchable three dimensional embossed version. Therefore the desired picture could be felt virtually by humans [1].

The word haptic from the Greek (haptikos) means 'pertaining to the sense of touch' and comes from the Greek verb haptesthai meaning "to contact" or "to touch". The evolution of Haptics is summarized in TABLE 1. Haptics enable people use their sense of touch in various applications. Haptics has grown into popularity with the advent of touch computing. Day by day as the technology gets evolved, the key element that is missing is the ability to feel the object and texture by the user virtually; this is solved by haptic technologies. The hardness, softness, joints and peaks can be felt by modelling the surface properties and employing them in ideas [8].

Table-1 Evolution of haptic technology

First generation	Use of electromagnetic fields which produce a limited range of sensations
Second generation	Touch-coordinate specific responses allowing the haptic effects to be localized to the position on a screen or touch panel, rather than the whole device
Third generation	Delivers both touch-coordinate specific responses and customizable haptic effects.
Fourth generation	Pressure sensitivity, (i.e) how hard you press on a flat surface can affect the response.

The trace of Haptics is applied in variety of fields enriching the user's experience and also in finding easy solutions.Haptics has a broad and expansive range of potential applications from handheld electronic devices to remotely operated robots,Visual impairments, visuo-Haptic devices for blind, in Geographic Information System (GIS) and navigation and specifically in gaming industries. There are many applications based on this new technology. The possibility is on how humans can investigate the design of cautiously controlled haptic virtual objects with the sense of touch [2]. In this paper, a

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broad review of Haptic technology and traces of this technology in various fields is discussed along with some examples and their capabilities. The major terminologies utilized in the study of Haptics and the overview of the current technologies available is described briefly.

TYPES OF HAPTICS	FUNCTION
Human	Human touch perception and manipulation.
Machine	Concerned with robotics and the use of machines to augment human
Computer	Comprises of computer-mediated haptics to feel virtual objects.

Table-2 Types of haptics

The paper is organized as follows: section II contains a review of haptic device characteristics. In section III we provide a brief survey on improved access for visually disabled people and section IV is about the Geographic Information Systems based on haptics and finally in section V is on how surgical training is performed with visual haptics. Concluding remarks are given in section VI and the future development works in section VII.

2. DEVICE CHARACTERISTICS OF HAPTIC TECNOLOGY

In this paper we propose the potential and traces in various applications of haptic technology. To begin with the main terminologies used in study of haptics and haptic technology are described below.

2.1 Building blocks of a haptic system

A Haptic system is formed with various building blocks as shown inFigure 1.such as touch screen device with capacitive buttons, processor, a driver circuit and an actuator. Usually a piezo type actuatoror a Linear Resonant Actuator (LRA) as Fig. 2) is used nowadays. There are four key considerations when selecting an actuator are response time, bandwidth, mounting and power consumption. The trigger signal is sent to the processor from the touch screen controller whenever a press is detected. The touch screen consists of capacitive buttons for this process. The signal now triggers the processor to generate a waveform based on the events of touch. The waveform produced can be either analog or digital which gets into the driver circuit and later to the actuator to guide in a definite direction or pattern to create a vibration. The actuator feedback is given back to the touch screen device as a force feedback to be felt by the user virtually.

2.2 Haptic perception

Haptics is characterized by a prediction for the sense of touch. Haptics interaction occurring in many contexts is classified into human haptics, machine haptics and computer haptics.

2.3 Haptic information

Basically the haptic information provided by the system is the combination of the tactile information. Tactile information refers the information and acquired by the sensors which are actually connected to the skin of the human body. Kinesthetic information relates to the information obtained through the sensors from muscles, tendons and joints.

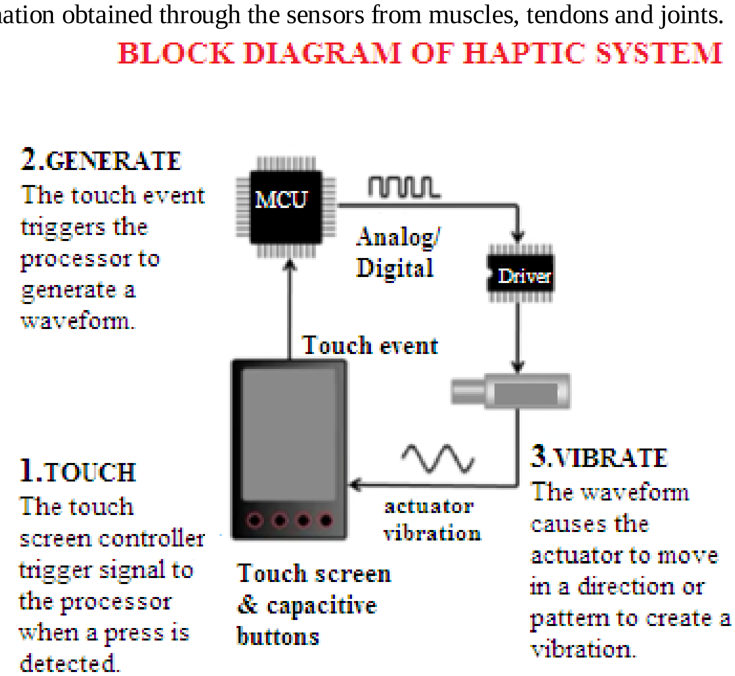

Figure1. Building blocks of an haptic system

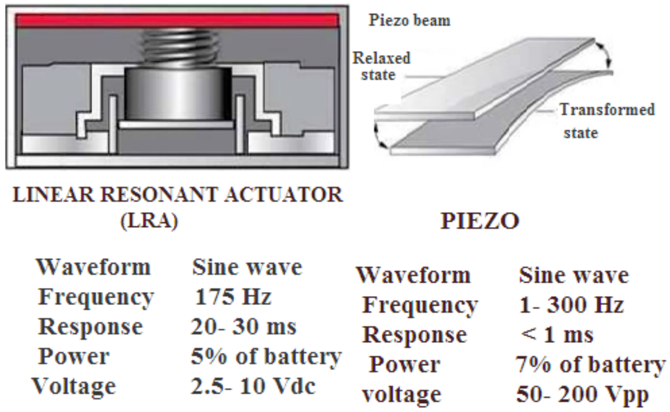

Figure 2. Characteristics of actuators.

2.4 Haptic technology

Haptic devices allow users to feel virtual objects. Haptic technology allows creating computers-generated Haptic Virtual Objects(HVOs), which can be touched and manipulated with one's hands and body. HVOs provided a rich combination of cutaneaus and kinesthetic stimulation through a bidirectional haptic(touch) information flow between HVOs and human users. HVOs can have many of the real object mechanical properties such as weight, shape, elasticity, surface, texture (rough,) etc. Technical integration of haptic sensation is significant, so are the estimation of the amount of technology's impact on learning and acceptance in technology [5].

2.5 Haptic interface

HVOs are created through free feedback generated by computer controlled mechanical systems called Haptic interface(HI).An HI delivers the force to the person's head or body.This produces major aspects of what actually happens when touching real,everyday objects.

2.6 Haptic rendering

The software controlled Haptic visual objects (HVO) creation process is called Haptic rendering. The computer controlled devices executes haptic rendering events (collision detection, force calculation and generation when necessary at high rate of about 1KHZ).Haptic rendering consists of 3 main blocks shown in figure 3.

- Collision-detection algorithms
- Force-response algorithm
- Control algorithms

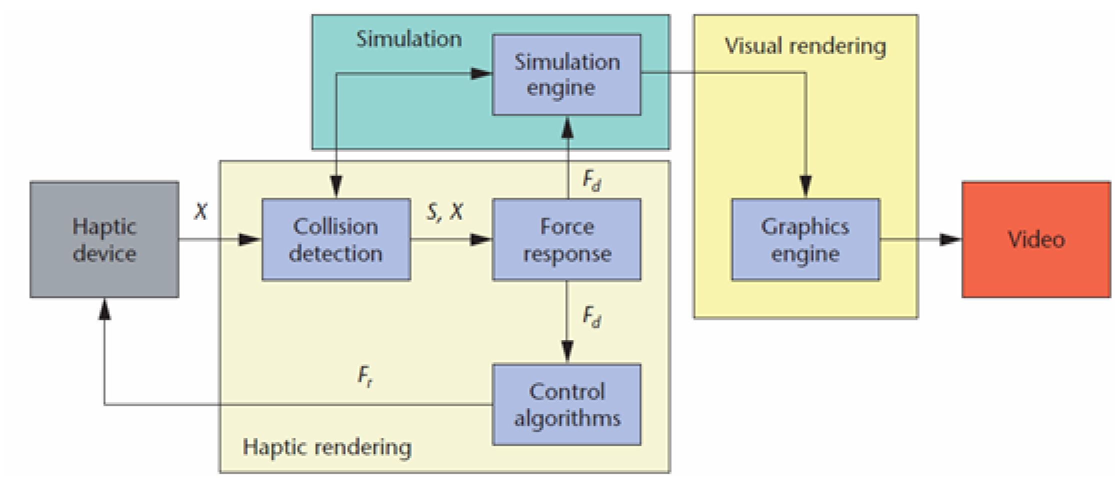

Figure 3. Block diagram of Haptic Rendering.

3.IMPROVED ACCESS FOR VISUALLY DISABLED PEOPLE

Understanding and interpreting complex scientific data is improved by representing them graphically. On a contrary for people with visual impairments, this method is inadequate [9]. Haptic technologies are an alternative to represent the data using kinesthetic feedback that provides the sense of touch. For textual data alone, screen reading speech synthesizers operating with scanners and Optical Character Recognition (OCR) software, Braille cell displays and Braille embossing printers are the media of choice for blind computer users. For pictorial scientific information such as graphs, maps, drawings and photographs, this is not the case [9]. The wide adaption of the internet is not able to be accessed by the visually impaired persons, hence digital objects can be accessed haptically by this new way of communication [8].

The main haptic device used to overcome this hurdle is the PHANToM(as depicted in figure 4). This is a very high resolution six degrees of freedom (DOF) device in which the user holds the end of a motor-controlled, jointed arm with number of dimensions of movement according to the number of degrees of freedom [6]. A thimble attachment is available where it allows the users to put a finger into to feel textures and shapes of virtual objects, modulate and deform objects with high degree of realism [1].Virtual 3D space in which the PHANToM operates is called haptic scene. The free floating three-dimensional objects can be explored syntactically where the visually disabled persons could feel the object at all of its dimensions (say front, back, top, bottom-just as if holding it in his/her own hand).Even the skill of writing can be restored after a stroke with stimulation in brain, recovery of muscle stiffness and customized software [7].

The technology behind this imaging is haptic graphing in Virtual Environment (VE) that allows modeling and exploration of scientific data in three or more dimensions [10]. Haptic interface being a force feedback mechanism that is used to feel computer generated objects or forces that a remote robot is sensing. In such a case, these forces are concentrated and calculated at a point called the Interface Point (IP). The IP location is determined in the coordinate system of the haptic mechanism via sensors and then transformed to the coordinate system of the Virtual Environment (VE).

Figure 4. PHANToM haptic device with directions

At once the force is inside VE, the force is determined on the basis of the position of virtual objects with respect to this point. For example, when a "Virtual Wall" placed in a VE workspace is considered. When the user moves the IP through the wall, the motor generates forces to oppose the motion. This is based on Hooke's law F=kxwhere x is the distance into the wall, and k is a proportionally constant. Thus, the haptic interface determines the coordinates of the IP, sends them to the VE and the value of force to be displayed to the user is received. By this way more complex photographic information is adequately represented to the visually impaired user. Beyond the application of blind students, even sighted students can gain insight into specific data through an additional medium.

4. HAPTIC GIS

Integration and crossover of Geographic Information System (GIS) and Haptics is possible for navigation assistance or Pedestrian route planning. Human haptic sense is equally good at perceiving properties such as roughness, smoothness, etc as a visual system. In last decade GIS data and route mapping move from the desktop application and desktop web browser to the dynamically loaded mobile device with high interfacing features query responsive times and visualization. Enhancements of pedestrian navigation, map visualization, city exploration and assisted navigation can be done by Haptics. Involving virtual map reading applications where the maps of states are made tactile on screen (i.e) users may feel mild bumps for country boundaries large bumps for state boundaries and vibrating constantly over cities. The users could move through multi-model3D GIS with a haptic interface over thematic maps. Multimodal interface improves the human computer interaction which is less in the traditional map interfaces due to information overload and emphasized on the need of audio, haptic or sonification. Variables such as temperature, humidity and their increase,decrease vibration is given to alert the user using a vibration feedback. Henceforth, haptic clues allow individuals to build haptic mental models for better navigation skills in 3D virtual environments. Pedestrians use a "neck-down" approach and take their vision off their current environment which causes serious consequences like not paying attention to traffic in a busy street and not looking at dangerous edges and narrow trails. Wearable haptic devices is designed for assisting the pedestrians for navigation about how the vibration alert can be used in conveying direction and deviation cues to the user such a way it does not obstruct the user main activity.

From the Fig. 5, it is clear that the interaction model relies heavily on spatial data for decision making. Spatial data is the source data of maps and directions. Non-spatial data include real-time data such as weather forecast reports, pollen counts, and environmental information. Spatial data and non-spatial data along with real-time data is combined together into a block. Next is the data fusion component consisting of enhanced data algorithms provides the spatial decision making for the haptic model.

These decisions are fed to haptic interaction model. The haptic interaction model component is where haptic actions, signals or interactions are produced based on output from the data fusion component. These interactions can take any of the haptic forms mentioned above including vibration, pulsing, sound, text or graphics [4]. This interaction is delivered to the haptic enabled device hardware using API software which instructs the user to take some action. Feedback is then provided by the user. This process differs in different forms based on the application.

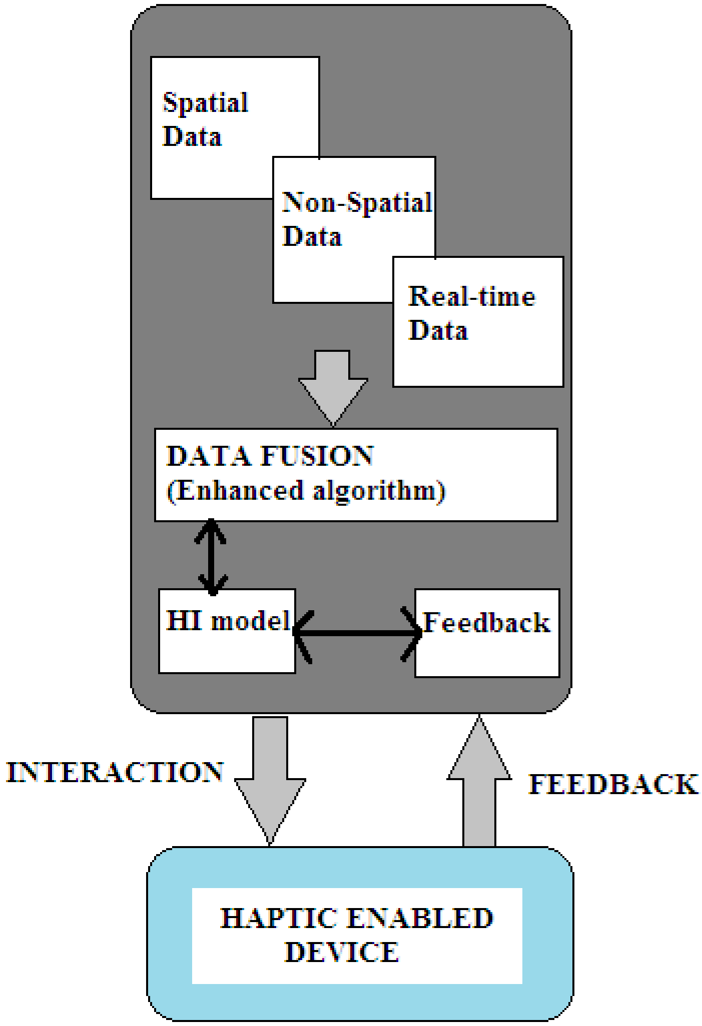

Figure 5. Haptic Interaction with spatial data

5. SURGICAL TRAINING

Computer simulations have played remarkable role in surgical training, pre-operative planning and biomedical research. Haptic surgical training is the development of advanced e-learning systems facilitating blooming surgeons. Surgeons must possess complex knowledge on technical and medical tasks to meet inevitable and serious challenges [6]. Haptics provide with visual information broadly on the defects of the disease. Visuo-haptics simulation can be adapted to areas of minimally invasive surgical training. Difficulty and potential dangers on learning how to examine and operate on humans can be avoided abruptly. The visuo-haptic system includes a PHANToM Desktop Unit and simulated a suturing procedure. (e.g) After demonstrating and explaining to each subject by the experimenter about test sutures. The participants can be asked to perform on suture across a surgical incision, with the specification provided by the experimenter. By this way surgical training can be made friendlier for the surgeons using visual-haptics. Medical Surgeries that posses any range of complexity such as venipuncture, vertebroplasty, laparoscopy, simulation of deformable tissues, planning properties of medical procedure and even surgical knot-tying can be primarily given to the residents for remote training using the effect of force feedback mechanism [5]. Consequently, residents and also experienced surgeons can use these systems for learning, assessing and improving their surgical procedures and heighten their skills [3].

Advantages:

- Improvement in the safety of human lives.
- Allows residents practicing medicine to access rare or unusual cases with ease.
- Surgeries with high range of complexity can be revised using this technology.
- Lessen invasive, wear-tear due to lack of experience.

- Complex tasks can be classified to basic tasks and procedural tasks modules and explored.

6. CONCLUSION

In this paper we have presented a brief description on the potential for exploring information of different kinds virtually using haptic technology. Sidelining the major sense of vision and emphasizing the sense of touch to acquire knowledge is described in this paper. Especially, the widespread usage of HI in education can provide hands-on-learning experience that is conductive for acquiring knowledge without difficulties. Though scalability of these new areas of work depends on the availability and affordability of the devices, their prices have fallen considerably in recent years (are now same as an inexpensive microscope). As a final conclusion, this paper presented a succinct overview of existing haptic system technologies, their advancements in many fields and traces of applications.

7. FUTURE WORK

The devices and applications so far designed is about feeling virtual reality through devices physically, now the desired goal is to create environment for Ultrahaptics. Ultra haptics is how we create that sensitive touch in mid air so we can create buttons, sliders and switches like virtual objects in mid air where they do not exist. This is done changing the amplitude of ultrasonic transducers individually and all the sound waves are brought to a single point at the same time. The skin responds to ultrasonic frequencies of 0-500Hz hence, we modulate the ultrasonics at frequency 2-400Hz which creates the sense of touch. This modulation requires more development and research so that we can recreate a material in mid air. More work is also needed to test and extend the existing technology.

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