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Haptic Technology: A comprehensive review on its applications and future prospects

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Abstract

Computer Science finds a variety of applications in different fields. In the modern scenario, the combination of human senses with field of computer science is becoming more and more common. A detailed study of haptic technology is described in this paper which is entirely related to touch. The complete potential of the field is yet to be explored. The science of applying touch sensation and control to interact with computer developed applications is the best definition given for haptic technology. With the help of Haptic device people get a sense of touch with computer generated environments, so that when virtual objects are touched, they seem to be real and tangible. Haptic technology enables the user to interface with a virtual environment via the sense of touch by applying forces, vibrations, or motions to the user. This mechanical simulation helps in the creation of virtual objects, controlling of virtual objects and to augment the remote control properties of machines and devices. This paper describes how haptic technology works, its devices, applications, and disadvantages. A brief explanation on haptics functions and its implementation in various fields of study is provided in this paper. A description on some of its future applications and a few limitations of this technology is also provided.

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1. Introduction

From a Greek word *haptikos* the word “haptics” is derived which means pertaining to sense of touch [1]. It is the most recent technology to arrive in the world of computer interface devices which promises to bring thoughtful changes to the way humans interact with information and communicate ideas. Recent advances in computer interface technology now consent us to touch and manipulate imaginary computer-generated objects in a way that evokes a compelling sense of tactile "realness”. Now it is able to sit down at a computer terminal and touch objects that exist only in the “mind” of computer. These interactions are as simple as touching a virtual wall, or as complex as performing a critical procedure in a surgical simulator. Haptics has collectively brought biomechanics, psychology, neurology, engineering and computer in study of human touch and force feedback [4].Human haptics is the process of manipulation through sensing through tactile and kinaesthetic sensation. Users are able to sense three

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dimensional virtual objects and manipulate them with respect to such features like shape, weight, surface textures, and temperature. It deals with manipulation of surroundings and manual sensing through touch. The process of interaction can be made by humans, machines, or a combination of both. Active touch means bidirectional information and energy flow between real (virtual environment) and the end user. To develop mental image of an object, we need to grasp and manipulate the object. The measure of force exerted by the user on the interface is provided by haptic. On touching an object interactions are felt on the skin and these forces convey the information and lead to awareness of the physical world. When perception is received, the muscles are activated by brain which results in the movement. Thus human haptics encircles to a closed loop between humans and the physical environment and all aspects related to sense of touch [6].

Mechanical, sensory, motor and cognitive components constitute the human haptic system. The mechanical components include the body parts which work as per the brain retort. Sensory mechanism includes nervous system receptors, which gets activated when physical stimulus occurs and thus message is conveyed to brain. The cognitive mechanism includes the brain which analyses and perceives the conveyed information and then activates motor components thereby completing the circle [13]. Machine haptics consists of several mechanical devices which come across physical contact with humans for information sharing. The main of haptics is to assess forces on any part of the body. Computer haptics consists of generating algorithms to create and touch the virtual atmosphere and objects. The two important criteria are visual rendering and haptic rendering which indicate the exchange of information about virtual environment to the user. Haptic rendering includes software based on algorithms to find location of contact and also the forces between the user and the virtual environment [7]. Visual rendering is a process of generating algorithms to compute real time behaviour of virtual environment graphics. Multimedia haptics is the acquirement of data through human touch-sensory system and coordinating with other sensory displays in a multimedia system which is also known as haptic audio visual environment (HAVE). It thus deals with harmonizing performance of haptic data and other types of media in HAVE for tactile sensing and tactile sensing [7].

2. Working of Haptics

Basically a Haptic system consists of two parts namely human part and the machine part. In the figure (1) Shown, left part is human part and right part is machine part. The human part senses and controls the position of the hand and machine part exerts forces from the hand to simulate contact with a virtual object. Both the systems are provided with necessary sensors, processors and actuators. In the case of the human system, nerve receptors perform sensing, brain performs actuation of the motion performed by the hand. In the machine system, above mentioned functions are performed by the use of encoders, compute and motors respectively.
To understand the basic working of haptics, consider the following diagram:

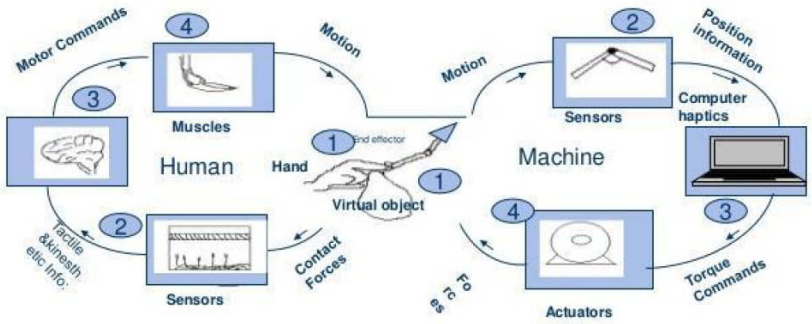

Fig. 1. Haptic system configuration [2].

The controlling action of our body is done by brain. To different parts of the body it provides various instructions. The brain tells the muscles to give exact input to the end effectors. An end effector is a sensitive haptic device which is placed at the end of a robotic arm, designed to interact with the environment. It consist of various sensors which sense any change in the angle, force applied and conveys this information to the computer [12]. The device that puts something into an automatic action is known as actuators. Then onto the haptic device the actuator applies force,

which is considered as a feedback force by the user. On the skin the feedback force is felt and is then interpreted by the brain. This refers to the basic working process of haptics. Haptics refers to two kind of information:

1) Kinesthetic information: refers to the information acquired by the sensors in the joint.
2) Tactile information: refers to the information acquired by the sensors connected to the user's body [5].

Typically a haptic system consist of

- Sensors
- Actuator control circuitry
- Actuators which vibrates or exerts force
- Real time algorithms and a haptic effect library
- Application programmable interface (API)
- Haptic effect authoring tool [14]

Specialized hardware is used in haptics applications to provide sensory feedback. A common haptic interface configuration uses mechanical linkages to link a person's finger to computer interface. When the user's fingers moves, the sensors translate those motions into actions on a screen [15]. Thus motors transmit feedback through the linkages to the fingers of the user. The process used by software to perform its calculation is called haptic rendering.

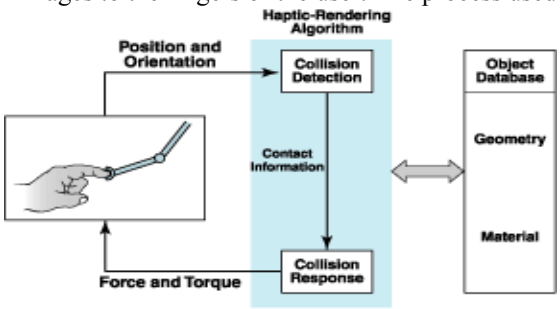

Fig. 3. Haptic rendering [5].

A. Haptic Devices

Mechanical devices that mediate between the user and the computer are referred to as haptic devices. Haptic devices are input- output devices. They are able to track the user's physical manipulation which is input and provide realistic touch sensations coordinated with the on – screen events as output.

Fig. 4. PHANTOM OMNI sensable device.

Haptic devices are of two types:

→Consumer peripheral devices with special motors and sensors such as force feedback joysticks, steering wheels

→Devices designed for industrial, medical, and scientific applications such as phantom [6].

Other Haptic Devices (low cost):

1. Haptic Paddles
2. Haptic knobs
3. Novint Falcon
4. Force Feedback Gaming Joysticks
5. SensAble's Omni Phantom [10]

3. Applications of Haptics

A. For the visually impaired

An integrated touch screen will be implemented in the haptic display device. Using this touch screen users can push on areas of screen to activate menus and icons which they can feel there. The wide world of graphical information displays available on computers today can be accessed by blind people. The ability to display graphical images and activating them by touch enables them to use these features. A multimodal tool allows blind people to create virtual graphs independently. These multimodal interactions are provided by a low-cost haptic device. Touchable maps are also developed for blinds using haptic technology [19].

B. Automotive

Nowadays new car buyers want a separate climate control for the driver and front seat passenger and separate controls in the rear. The problem arrives when more sophisticated the climate control system, more complex its operation. Many monitors fail to understand their systems. Haptic can make climate control systems easier to operate. Touch feedback can convey significant quantities of information. User doesn't need to be confined to simple notifications. It is made easier by touch. The climate control system may be much more complex, but the touch feedback haptic makes it much easier. Reaction of humans towards touch is immediate. So receiving information in this way improves the accuracy of user and speed and reduces the distractions. With the help of touch feedback guiding controls, users may not need to look at the controls. Thus it improves safety also [16].

C. Virtual education

Majority portion of people are kinaesthetic learners-they understand and catch up things easily when education involves movement and touch. From earlier times itself former education is focused on visual and auditory learning. A door to entirely different learning method is opened up by haptics. Even for visual and auditory learners haptics can improve learning. For a wide range of subject matter, by incorporating sensory data and feedback it allows for a richer understanding of concepts [18]. Both to teach concepts and to train students in different techniques haptic tools are used in variety of educational settings. Some faculties use haptic device to teach physics thus students can manipulate and experience the physical properties of objects and the forces on them. In subjects such as biology and chemistry, virtual models of molecules and microscopic structures can be manipulated.

D. Research

Researches have been done to simulate different kinds of tactitions by using high speed vibrations or other stimuli. One such device of this type is a pad array of pins. The pins vibrate to simulate a surface being touched. This method doesn't provide any realistic feel. But it provides a useful feedback, allowing discrimination between various sizes, shape.

E. Medicine

Haptic interfaces for medical simulation are useful for training of minimally invasive procedures (laparoscopy) and remote surgery using tele operators. The key advantage of this type is that the surgeon can perform many operations of the same type with less fatigue. Haptic interfaces are also used in rehabilitation robotics. Haptics is also used in ophthalmology to remove cataracts [20].

F. Arts and design

Haptics enables sculpting and virtual modelling. It is based on tactile feedback model. With the help of haptic feedback and touch virtual sculpting becomes easier.

4. Limitations

Some of the limitations of haptic technology are:

- Being a new technology it requires a very high initial investment and hence costly.
- Haptic devices are bulky, large in size and greater in length. Thus become problems for wearable haptic device.
- Haptic interface exerts force with limited magnitude and unequal in all directions. Haptic rendering algorithm operates in discrete time whereas real time users operate in continuous time.
- Bandwidth limitation is another limitation. Limited bandwidth is allotted for data transmission. Haptic data is heavy and usually requires greater bandwidth. If the required bandwidth is not available, it may lead to wrong interpretation.
- Universal operability of haptic interfaces: for specific applications specific haptic interfaces are developed. For every new task, new implementation is required. These adaptations can be boring. Thus a uniform universally accepted interface is required.
- Instability and vibration: The update rate of graphic rendering is 60Hz. But haptic rendering rate must be of 100Hz.it leads to instability if required rates are not met. Thus system becomes unstable [17].

5. Future Applications

A. Holographic Interaction

Researches are carried on to combine haptic technology with holographic projection. By this feedback, user receives response from hologram. It is based on ultrasound waves. Through tactile response the user perceives the object

B. Biometric Haptics

Biometrics also uses haptics. A unique ID and password is used for conventional biometrics. Hence to remember these password and ID is difficult thus less secure. This can be easily hacked. The haptic based biometric system measures the position, velocity and force and thus unique physical patterns are developed which are used for identification.

C. E- Commerce

By using haptic device in electronic commerce, consumers are able to physically interact with the commodity. By touching the product can be felt and its texture and roughness can be determined.

D. Education

Visualisation of geometric problems can be done in actual 3-D space. Thus a better and clear understanding of problem can be achieved.

6. Conclusion

Haptics is still in its beginning stage. It has immense potential within it to bring about a drastic change in communication filed. However it has few limitations relates to its hardware, cost and its implementation. Haptics is finding its application in every field such as education, entertainment, art, medical etc. Development of various kinds of haptic interfaces is continuing, which provides more lifelike interactions with the virtual objects and virtual environment. Advancement in hardware will provide more opportunities to produce haptic devices in smaller packages. Consumer grade haptic devices have already arrived in the market. Haptic is the future for online computing and e-commerce. It will enhance the shopper experience and thus help online shoppers to feel merchandise without leaving their homes. Because of this increasing need for haptic applications, the cost of haptic devices will surely drop in future. Haptics will soon be a part of a person's normal computer interaction.

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