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PAPER PRESENTATION ON

HAPTIC TECHNOLOGY

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ABSTRACT

"**HAPTICS"--** a technology that adds the sense of touch to virtual environment .Haptic interfaces allow the user to feel as well as to see virtual objects on a computer, and so we can give an illusion of touching surfaces, shaping virtual clay or moving objects around.

The sensation of touch is the brain's most effective learning mechanism --more effective than seeing or hearing—which is why the new technology holds so much promise as a teaching tool.

Haptic technology is like exploring the virtual world with a stick. If you push the stick into a virtual balloon push back .The computer communicates sensations through a haptic interface –a stick, scalpel, racket or pen that is connected to a force-exerting motors.

With this technology we can now sit down at a computer terminal and touch objects that exist only in the "mind" of the computer.By using special input/output devices (joysticks, data gloves, or other devices), users can receive feedback from computer applications in the form of felt sensations in the hand or other parts of the body. In combination with a visual display, haptics technology can be used to train people for tasks requiring hand-eye coordination, such as surgery and space ship maneuvers.

In this paper we explicate how sensors and actuators are used for tracking the position and movement of the haptic device moved by the operator. We mention the different types of force rendering algorithms. Then, we move on to a few applications of Haptic Technology. Finally we conclude by mentioning a few future developments.

Introduction

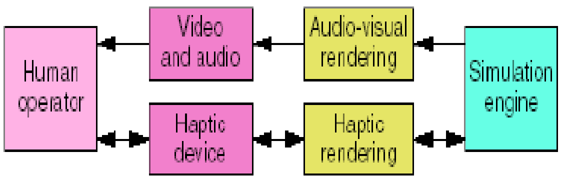
1 What is Haptics?

Haptics refers to sensing and manipulation through touch. The word comes from the Greek ‘haptesthai’, meaning ‘to touch’.

The history of the haptic interface dates back to the 1950s, when a master-slave system was proposed by Goertz (1952). Haptic interfaces were established out of the field of tele- operation, which was then employed in the remote manipulation of radioactive materials. The ultimate goal of the tele-operation system was "transparency". That is, an user interacting with the master device in a master-slave pair should not be able to distinguish between using the master controller and manipulating the actual tool itself. Early haptic interface systems were therefore developed purely for telerobotic applications.

Working of Haptic Devices

Architecture for Haptic feedback:



Basic architecture for a virtual reality application incorporating visual, auditory, and haptic feedback.

1 • Simulation engine:

Responsible for computing the virtual environment’s behavior over time.

1 • Visual, auditory, and haptic rendering algorithms:

Compute the virtual environment’s graphic, sound, and force responses toward the user.

• Transducers:

Convert visual, audio, and force signals from the computer into a form the operator can perceive.

1 • Rendering:

Process by which desired sensory stimuli are imposed on the user to convey information about a virtual haptic object.

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

Audio and visual channels feature unidirectional information and energy flow (from the simulation engine towards the user) whereas, 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.

System architecture for haptic rendering:

An avatar is the virtual representation of the haptic interface through which the user physically interacts with the virtual environment.

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.

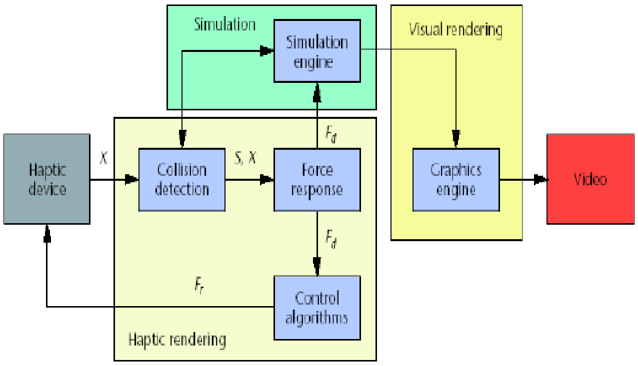


Figure 2.2 *Haptic rendering divided into three main blocks.*

S - contacts occurring between an avatar at position X and objects in the virtual environment

Fd - return the ideal interaction force between avatar and virtual objects.

Fr - Force to the user

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

2.) Force-response algorithms compute the interaction force between avatars and virtual objects when a collision is detected. This force approximates as closely as possible the contact forces that would normally arise during contact between real objects.

Hardware limitations prevent haptic devices from applying the exact force computed by the force-response algorithms to the user.

3.) Control algorithms command the haptic device in such a way that minimizes the error between ideal and applicable forces. The discrete-time nature of the haptic- rendering algorithms often makes this difficult.

The force response algorithms' return values are the actual force and torque vectors that will be commanded to the haptic device.

Existing haptic rendering techniques are currently based upon two main principles: "point-interaction" or "ray-based".

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.

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.

1.Tactile information refers to the information acquired through sensors in the skin with particular reference to the spatial distribution of pressure, or more generally, tractions, across the contact area.

To handle flexible materials like fabric and paper, we sense the pressure variation across the fingertip. 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.

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

To provide a haptic simulation experience, systems are designed to recreate the contact forces a user would perceive when touching a real object.

There are two types of forces:

1.Forces due to object geometry.

2.Forces due to object surface properties, such as texture and friction.

Geometry-dependent 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 textureless object.

Force-rendering algorithms are also grouped by the number of Degrees-of-freedom (DOF) necessary to describe the interaction force being rendered.

Surface property-dependent force-rendering algorithms:

All real surfaces contain tiny irregularities or indentations. Higher accuracy, however, sacrifices speed, a critical factor in real-time applications. Any choice of modeling technique must consider this tradeoff. Keeping this trade-off in mind, researchers have developed more accurate haptic-rendering algorithms for friction.

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.

Controlling forces delivered through haptic interfaces:

Once such forces have been computed, they must be applied to the user. Limitations of haptic device technology, however, have sometimes made applying the force's exact value as computed by force-rendering algorithms impossible. They are as follows:

1 • Haptic interfaces can only exert forces with limited magnitude and not equally well in all directions

2 • 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.

3 • A third issue is that haptic-rendering algorithms operate in discrete time whereas users operate in continuous time.

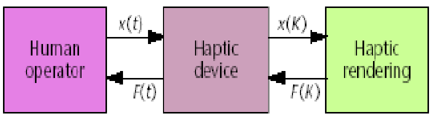


Figure 2.3 *Haptic devices create a closed loop between user and haptic rendering/ simulation algorithms. x(t) and F(t) are continuous-time position and force signals exchanged between user and haptic device. x(K) and F(K) are discrete-time position and force signals exchanged between haptic device and virtual environment*

Finally, haptic device position sensors have finite resolution. Consequently, attempting to determine where and when contact occurs always results in a quantization error. It can create stability problems.

All of these issues can limit a haptic application's realism. High servo rates (or low servo rate periods) are a key issue for stable haptic interaction.

Haptic Devices

Types of Haptic devices:

There are two main types of haptic devices:

1 • Devices that allow users to touch and manipulate 3-dimentional virtual objects.

2 • Devices that allow users to "feel" textures of 2-dementional objects.

Another distinction between haptic interface devices is their intrinsic mechanical behavior.

Impedance haptic devices simulate mechanical impedance—they read position and send force. Simpler to design and much cheaper to produce, impedance-type architectures are most common.

Admittance haptic devices simulate mechanical admittance—they read force and send position. Admittance-based devices are generally used for applications requiring high forces in a large workspace.

LOGITECH WINGMAN FORCE FEEDBACK MOUSE

It is attached to a base that replaces the mouse mat and contains the motors used to provide forces back to the user.

Figure 3.1 *Logitech mouse*

Interface use is to aid computer users who are blind or visually disabled; or who are tactile/Kinesthetic learners by providing a slight resistance at the edges of windows and buttons so that the user can "feel" the Graphical User Interface (GUI). This technology can also provide resistance to textures in computer images, which enables computer users to "feel" pictures such as maps and drawings.

PHANTOM:

Figure 3.2 *Phantom*

The PHANTOM provides single point, 3D force-feedback to the user via a stylus (or thimble) attached to a moveable arm. The position of the stylus point/fingertip is tracked, and resistive force is applied to it when the device comes into 'contact' with the virtual model, providing accurate, ground referenced force feedback. The physical working space is determined by the extent of the arm, and a number of models are available to suit different user requirements.

The phantom system is controlled by three direct current (DC) motors that have sensors and encoders attached to them. The number of motors corresponds to the number of degrees of freedom a particular phantom system has, although most systems produced have 3 motors.

The encoders track the user’s motion or position along the x, y and z coordinates the motors track the forces exerted on the user along the x, y and z-axis. From the motors there is a cable that connects to an aluminum linkage, which connects to a passive gimbals which attaches to the thimble or stylus. A gimbal is a device that permits a body freedom of motion in any direction or suspends it so that it will remain level at all times.

Used in surgical simulations and remote operation of robotics in hazardous environments

Cyber Glove:

Cyber Glove can sense the position and movement of the fingers and wrist.

The basic Cyber Glove system includes one CyberGlove, its instrumentation unit, serial cable to connect to your host computer, and an executable version of VirtualHand graphic hand model display and calibration software.

Figure 3.3 CyberGlove

The CyberGlove has a software programmable switch and LED on the wristband to permit the system software developer to provide the CyberGlove wearer with additional input/output capability. With the appropriate software, it can be used to interact with systems using hand gestures, and when combined with a tracking device to determine the hand's position in space, it can be used to manipulate virtual objects.

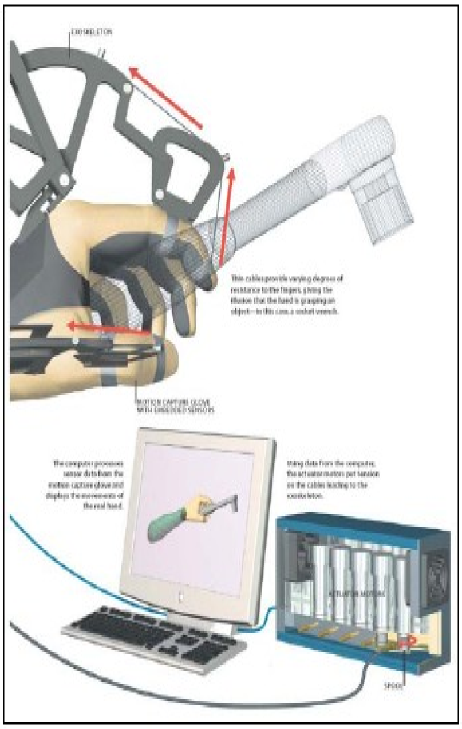
Figure3.4 CyberGrasp

Cyber Grasp:

The Cyber Grasp is a full hand force-feedback exo skeletal device, which is worn over the CyberGlove.

CyberGrasp consists of a lightweight mechanical assembly, or exoskeleton, that fits over a motion capture glove. About 20 flexible semiconductor sensors are sewn into the fabric of the glove measure hand, wrist and finger movement. The sensors send their readings to a computer that displays a virtual hand mimicking the real hand's flexes, tilts, dips, waves and swivels.

The same program that moves the virtual hand on the screen also directs machinery that exerts palpable forces on the real hand, creating the illusion of touching and grasping. A special computer called a force control unit calculates how much the exoskeleton assembly should resist movement of the real hand in order to simulate the onscreen action. Each of five actuator motors turns a spool that rolls or unrolls a cable. The cable conveys the resulting pushes or pulls to a finger via the exoskeleton.



Applications

Medical training applications:

Such training systems use the Phantom's force

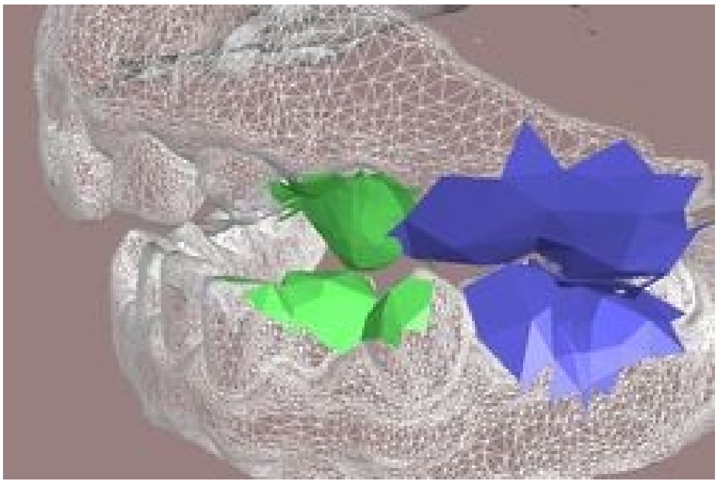
display capabilities to let medical trainees

experience and learn the subtle and complex
physical interactions needed to become skillful in their art.

A computer based teaching tool has been developed using haptic technology to train veterinary students to examine the bovine reproductive tract, simulating rectal palpation. The student receives touch feedback from a haptic device while palpating virtual objects. The teacher can visualize the student's actions on a screen and give training and guidance.

Collision Detection:-

Collision detection is a fundamental problem in computer animation, physically-based modeling, geometric modeling, and robotics. In these fields, it is often necessary to compute distances between objects or find intersection regions.



In particular, I have investigated the computation of global and local penetration depth, distance fields, and multiresolution hierarchies for perceptually-driven fast collision detection. These proximity queries have been applied to haptic rendering and rigid body dynamics simulation.

Minimally Invasive Surgery:

The main goal of this project is to measure forces and torques exerted by the surgeon during minimally-invasive surgery in order to optimize haptic feedback. A standard da Vinci tool affixed with a 6 DOF force/torque transducer will be used to perform basic surgical procedures and the forces applied by the tool will be recorded and analyzed. This will help determine in which degrees of freedom forces are most commonly applied.

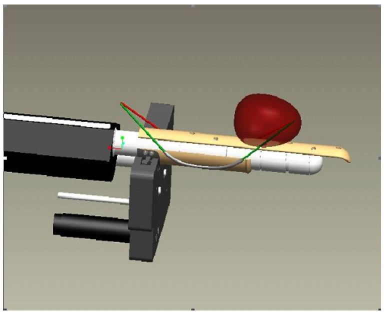
Stroke patients:

Stroke patients who face months of tedious rehabilitation to regain the use of impaired limbs may benefit from new haptics systems -- interfaces that add the sense of touch to virtual computer environments -- in development at the University of Southern California's Integrated Media Systems Center (IMSC).

The new systems, being designed by an interdisciplinary team of researchers from the Viterbi School of Engineering and the Annenberg School for Communication, are challenging stroke patients to grasp, pinch, squeeze, throw and push their way to recovery.

Prostate Cancer:

Prostate cancer is the third leading cause of death among American men, resulting in approximately 31,000 deaths annually. A common treatment method is to insert needles into the prostate to distribute radioactive seeds, destroying the cancerous tissue. This procedure is known as brachytherapy.

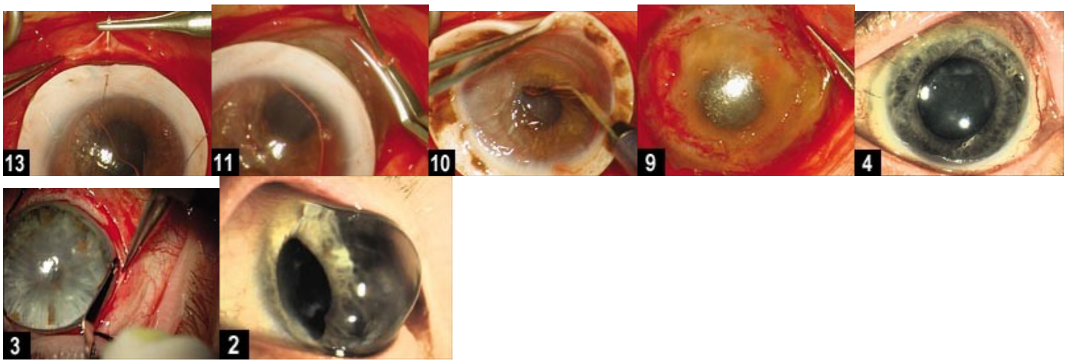


The prostate itself and the surrounding organs are all soft tissue. Tissue deformation makes it difficult to distribute the seeds as planned. In our research we have developed a device to minimize this deformation, improving brachytherapy by increasing the seed distribution accuracy.

Removal of lens segment:

surgeons complete removal of the lens segments in the same way: by holding them at the mouth of the laser/aspiration probe using vacuum and firing the laser to fragment them for aspiration. However, several surgeons have developed different techniques for nuclear disassembly. These include:

Nuclear prechop. This technique, developed by Dr. Dodick himself, involves inserting two Dodick-Kallman Choppers under the anterior capsulotomy, 180? apart and out to the equator of the lens. The surgeon rotates the choppers downward and draws them towards each other, bisecting the lens inside the capsular bag. A similar maneuver then bisects each half. Using the irrigation probe to support the segments during removal is helpful.



Settings: Aspiration: 275 to 300 mmHg; Air infusion: 80 to 100 mmHg; Laser pulses: 1 Hz.

Wehner backcracking. This technique, developed by Wolfram Wehner, M.D., uses the Wehner Spoon, an irrigating handpiece that resembles a shovel at the tip. The surgeon lifts the nucleus using the laser/aspiration probe, inserts the Wehner spoon underneath, and uses the two probes to backcrack the nucleus. The Wehner spoon provides support during removal of the lens segments.

Settings: Aspiration: 275 mmHg; Air infusion: 95 mmHg; Laser pulses: 3 Hz.

Intelligent machines:

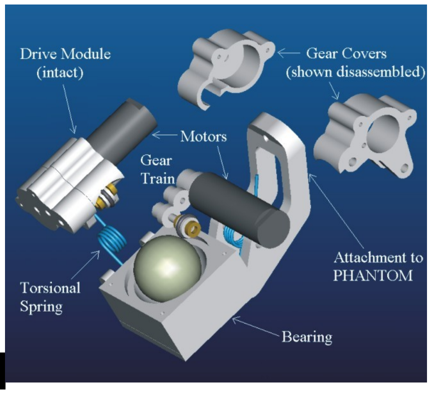
The Centre for Intelligent Machines is an inter-departmental inter-faculty research group which was formed to facilitate and promote research on intelligent systems.

Intelligent systems and machines are capable of adapting their behavior by sensing and interpreting their environment, making decisions and plans, and then carrying out those plans using physical actions. The mission of CIM is to excel in the field of intelligent machines, stressing basic research, technology development, and education. CIM seeks to advance the state of knowledge in such domains as robotics, automation, artificial intelligence, computer vision, systems and control theory, and speech recognition.

This is being achieved by collaborative efforts involving researchers with very different interests - CIM faculty and students come from the School of

Computer Science, Department of Electrical and Computer Engineering, and the Department of Mechanical Engineering. It is this diversity of interests along with the spirit of collaboration which forms the driving force behind this dynamic research community.

Tactile slip display:



Human fingers are able to manipulate delicate objects without either dropping or breaking them, but lose this ability to a certain degree when using a tele-operated system. One reason for this is that human fingers are equipped with sensors that tell us when our fingerprints at the edge of the contact area start to come off the object we are holding, allowing us to apply the minimum force necessary to hold the object. While several other researchers have built synthetic skins for their robot fingers that work in a similar way to human fingerprints, a tactile haptic device is needed to display these sensations to a human using a tele-operated system. For this purpose we have designed the 2 degree of freedom Haptic Slip Display. We have conducted psychophysical experiments validating the device design and demonstrating that it can improve user performance in a delicate manipulation task in a virtual environment.

Gaming technology:

Flight Simulations: Motors and actuators push, pull, and shake the flight yoke, throttle, rudder pedals, and cockpit shell, replicating all the tactile and kinesthetic cues of real flight. Some examples of the simulator's haptic capabilities include resistance in the yoke from pulling out of a hard dive, the shaking caused by stalls, and the bumps felt when rolling down concrete runway. These flight simulators look and feel so real that a pilot who successfully completes training on a top-of-the-line Level 5 simulator can immediately start flying a real commercial airliner.

Today, all major video consoles have built-in tactile feedback capability. Various sports games, for example, let you feel bone-crushing tackles or the different vibrations caused by skateboarding over plywood, asphalt, and concrete. Altogether, more than 500 games use force feedback, and more than 20 peripheral manufacturers now market in excess of 100 haptics hardware products for gaming.

Mobile Phones: Samsung has made a phone, which vibrates, differently for different callers. Motorola too has made haptic phones.

Cars: For the past two model years, the BMW 7 series has contained the iDrive (based on Immersion Corp's technology), which uses a small wheel on the console to give haptic feedback so the driver can control the peripherals like stereo, heating, navigation system etc. through menus on a video screen.

The firm introduced haptic technology for the X-by-Wire system and was showcased at the Alps Show 2005 in Tokyo. The system consisted of a "cockpit" with steering, a gearshift lever and pedals that embed haptic technology, and a remote-control car. Visitors could control a remote control car by operating the steering, gearshift lever and pedals in the cockpit seeing the screen in front of the cockpit, which is projected via a camera equipped on the remote control car.

Robot Control: For navigation in dynamic environments or at high speeds, it is often desirable to provide a sensor-based collision avoidance scheme on-board the robot to guarantee safe navigation. Without such a collision avoidance scheme, it would be difficult for the (remote) operator to prevent the robot from colliding with obstacles. This is primarily due to (1) limited information from the robots' sensors, such as images within a restricted viewing angle without depth information, which is insufficient for the user's full perception of the environment in which the robot moves, and (2) significant delay in the communication channel between the operator and the robot.

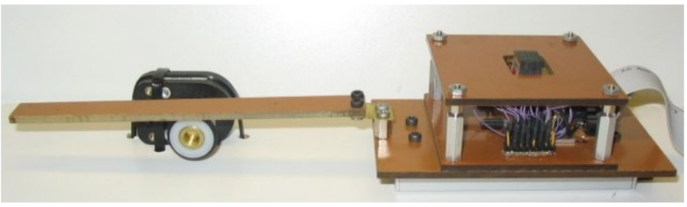
Experiments on robot control using haptic devices have shown the effectiveness of haptic feedback in a mobile robot tele-operation system for safe navigation in a shared autonomy scenario.

Future Enhancements:

Force Feedback Provided In Web Pages:

This underlying technology automatically assigns "generic touch sensations" to common Web page objects, such as hyperlinks, buttons, and menus.

Virtual Brailee Display:



The Virtual Braille Display (VBD) project was created to investigate the possibility of using the lateral skin stretch technology of the STReSS tactile display for Braille. The project was initially conducted at VisuAide inc. and is now being continued in McGill's Haptics Laboratory.

Haptic torch for the blind: The device, housed in a torch, detects the distance to objects, while a turning dial on which the user puts his thumb indicates the changing distance to an object. The pictured device was tested and found to be a useful tool.

Figure 5.1 Haptic torch

CONCLUSION:

Haptic is the future for online computing and e-commerce, it will enhance the shopper experience and help online shopper to feel the merchandise without leave their home. Because of the increasing applications of haptics, the cost of the haptic devices will drop in future. This will be one of the major reasons for commercializing haptics.

With many new haptic devices being sold to industrial companies, haptics will soon be a part of a person's normal computer interaction.

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