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Haptic Technology: An Evolution towards Naturality in Communication

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Abstract: Haptics, the newest technology to arrive in the world of computer interface devices, promises to bring profound changes to the way humans interact with information and communicate ideas. Recent advances in computer interface technology now permit us to touch and manipulate imaginary computer-generated objects in a way that evokes a compelling sense of tactile "realness." Being able to touch, feel, and manipulate objects in an environment, in addition to seeing (and hearing) them, provides a sense of immersion in the environment that is otherwise not possible. Haptics is the science of touch. 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. It has been described as "(doing) for the sense of touch what computer graphics does for vision"

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 this paper we explicate basic concepts and history of haptics, haptic rendering and its working. We mention the different types of haptic devices. Then, we move on to a few applications of Haptic Technology. Finally we conclude by mentioning a few future developments.

Keywords: Haptics, Tactile, Kinaesthetics, PHANTOM, CyberGrasp

I. INTRODUCTION

Haptic technology, or haptics, is a feedback technology which takes advantage of a user's sense of touch by applying forces, vibrations, and/or motions upon the user. The word derives from the Greek haptikos meaning "being able to come into contact with".

Users are given the illusion that they are touching or manipulating a real physical object. This Technology has been evolving over the past decade. It communicates to the user via their sense of touch i.e. heat, movement, pressure and pain. 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. Many everyday objects communicate to us through movement (often, vibrations). Examples:

A. A phone may vibrate to signify a received message.
B. A game controlled may 'jiggle' to indicate feedback of in game events.

It is a science of applying tactile sensation to human interaction with computers. A haptic device is one that involves physical contact between the computer and the user, usually through an input/output device, such as a joystick or data gloves, that senses the body's movements.

The benefit of haptic technology is that it allows us to communicate with computers, and other users, in a way that's far more natural and comfortable than squinting at a glaring monitor, or straining our wrists over a keyboard. Haptics could also prove useful for people who, due to visual impairment, are unable to effectively operate computers as they are made today.

II. HISTORY OF HAPTIC TECHNOLOGY

In the 1950's, with the birth of nuclear industry, Goertz and his colleagues at Argonne National Lab in the US developed the first force-reflecting robotic manipulators, a master-slave telemanipulation system in which actuators, receiving feedback signals from slave sensors, applied forces to a master arm controlled by the user. In 1960s, haptic technology was used in the 1960s for applications such as military flight simulators, on which combat pilots honed their skills. Motors and actuators pushed, pulled, and shook the flight yoke, throttle, rudder pedals, and cockpit shell, reproducing many of the tactile and kinesthetic cues of real flight.

By the late 1970s and early 1980s, computing power reached the point where rich color graphics and high-quality audio were possible. This multimedia revolution spawned entirely new businesses in the late 1980s and early 1990s and opened new possibilities for the consumer. Flight simulations moved from a professional pilot-only activity to a PC-based hobby, with graphics and sound far superior to what the combat pilots in the 1960s had. The multimedia revolution also gave rise to the medical simulation industry. By the 1990s, high-end workstations displayed highly realistic renderings of human anatomy.

By the mid 1990s, shortcomings in simulation products were identified. Even though graphics and animations looked incredibly realistic, they could not possibly convey what it actually feels like to break through a venal wall with a needle or fight the flight yoke out of a steep dive. New industrial and consumer products were in need of enhanced programmable haptic technology that could provide sensations similar to an actual hands-on experience.

Then, in 1993, the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology (MIT) constructed a device that delivered haptic stimulation, finally making it possible to touch and feel a computer-generated object. The scientists working on the project began to describe their research area as computer haptics to differentiate it from machine and human haptics. Today, computer haptics is defined as the systems required -- both hardware and software -- to render the touch and feel of virtual objects. Computer haptics uses a display technology through which objects can be physically palpated. It is a rapidly growing field that is yielding a number of promising haptic technologies.

III. BASIC CONCEPTS OF HAPTICS

The haptic system can sense and act on the environment while vision and audition have purely sensory nature. Haptics means the combined sensation of mechanical, thermal and noci-perception (fig.1). As a result haptics consists of nocio-receptive, thermoceptive, kinaesthetic and tactile perceptions. The sense of balance takes an exceptional position as it is not counted among the five human senses having receptors of their own. Yet, it really exists making use of all other senses' receptors, especially the haptic ones.

Haptics describes the sensory as well as the motor capabilities within the skin, joints, muscles and tendons.

Tactile means perceptible to the sense of touch or mechanical interaction with the skin. Therefore tactile perception is the sensation of exclusively mechanical interaction. Tactile perception is not exclusively bound to forces or movements.

Kinaesthetics means the sense that detects bodily position, weight, or movement of the muscles, tendons, and joints. It describes both, actuatory and sensory capabilities of muscles and joints.

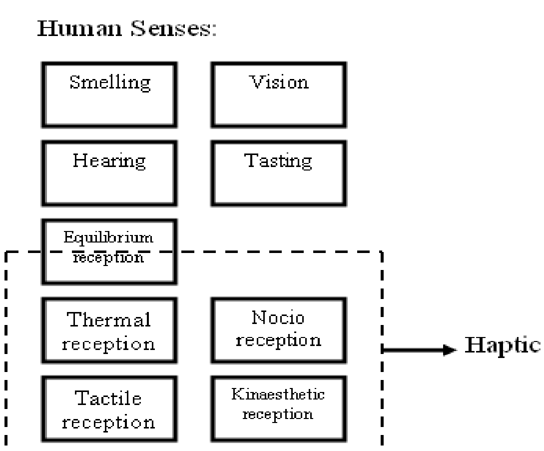

Figure. 1:- Distribution of senses

IV. TERMINOLOGY USED IN HAPTIC SYSTEMS

Some technical terminology used in haptic systems is listed below and illustrated via block diagrams. The arrows between the components of the block diagrams remain unlabeled as because they may represent different kinds of information depending on the devices they refer to. Haptic devices are capable of transmitting elongations, forces and temperature differences and in a few realizations they also stimulate pain receptors.

The terms "system" and "device" and "component" are not defined on an interdisciplinary basis. Dependent on one's point of view the same object can be e.g. "a device" for a hardware-designer, "a system" for the software-engineer, or "just a component" for another hardware-engineer.

A. A **haptic device** is a system generating an output which can be perceived haptically. It has (figure. 2) at least one output, but not necessarily any input. The tactile markers on the keys F and J of a keyboard represent information for the positioning of the index finger. By these properties the keys are already tactile devices. At a closer look the key itself shows a haptically notable point of actuation, the haptic click. This information is transmitted in a kinaesthetic and tactile way by the interaction of the key's mechanics with the muscles and joints and the force being transmitted through the skin. Such a key is a haptic device without a changing input and two outputs.
B. A **user** (in the context of haptic systems) is a receiver of haptic information.
C. A **haptic controller** describes a component of a haptic system for processing haptic information flows and improving transmission.

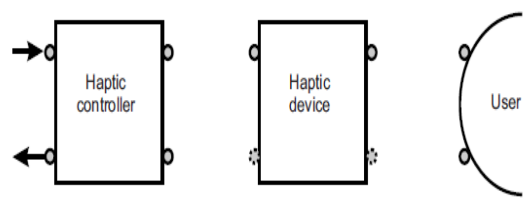

Figure. 2 - Haptic Device, User and Controller

D. **Haptic interaction** describes the haptic transmission of information. This transmission can be bi- or unidirectional (fig. 3). Moreover, specifically tactile (unidirectional) or kinaesthetic (uni- or bidirectional) interaction may happen. A tactile marker like embossed printing on a bill can communicate tactile information (the bill's value) as a result of haptic interaction.

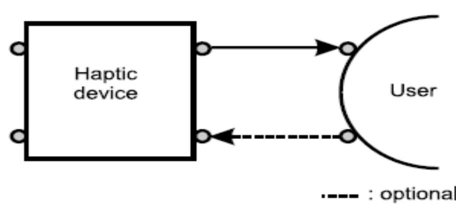

Figure. 3: Haptic interaction.

E. The **addressability** of haptic systems refers to the subdivision of an output signal of a device (frequently a force) or of the user (frequently a position).
F. The **resolution** of a haptic system refers to the capability to detect a subdivision (spatial or temporal) of an input signal. With reference to a device this is in accordance

with the measuring accuracy. With respect to the user this corresponds to his perceptual resolution.

G. A **haptic marker** refers to a mark communicating information about the object carrying the marker by way of a defined code of some kind. Examples are markers in Braille on bills or road maps.
H. A **haptic display** is a haptic device permitting haptic interaction, whereby the transmitted information is subject to change (fig. 4). Purely tactile as well as kinaesthetic displays are available.

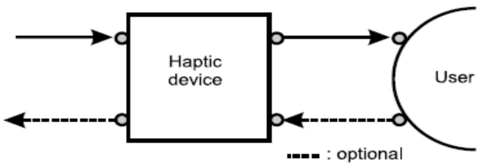

Figure. 4: Haptic Display

I. A **tactor** is a purely tactile haptic display generating a dynamic and oscillating output. They usually provide a translatory output, but could also be rotatory
J. A **haptic interface** devices are those that measure the motion of, and stimulate the sensory capabilities within, our hands and thus permitting a haptic interaction (Figure: 5). A haptic interface always refers to data and device.

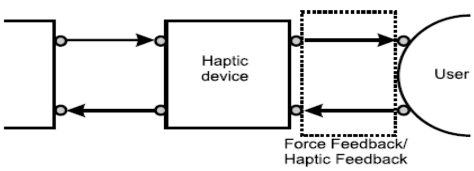

Figure. 5: Haptic Interface

K. **Force-Feedback (FFB)** refers to the information transmitted by kinaesthetic interaction (fig. 5). This term is widely used in advertising and numerous commercial products like FFB-joysticks, FFB-steering wheels and FFB-mice.
L. A **haptic manipulator** is a system interacting mechanically with objects whereby continuously information about positions in space and forces and torques of the interaction is acquired.

V. WORKING OF HAPTIC TECHNOLOGY

Typically, a haptics system includes

A. Sensor(s)
B. Actuator (motor) control circuitry
C. One or more actuators that either vibrate or exert force.
D. Real-time algorithms (actuator control software, which we call a "player") and a haptic effect library.
E. Application Programming Interface (API), and often a haptic effect authoring tool.

The Immersion API is used to program calls to the actuator into system's operating system (OS). The calls specify which effect in the haptic effect library to play.

When the user interacts with device's buttons, touch screen, lever, joystick/wheel, or other control, this control-position information is sent to the OS, which then sends the play command through the control circuitry to the actuator. Haptics applications use specialized hardware to provide sensory feedback that simulates physical properties and forces.

Haptic interfaces can take many forms; a common configuration uses separate mechanical linkages to connect a person's fingers to a computer interface. When the user moves his fingers, sensors translate those motions into actions on a screen, and motors transmit feedback through the linkages to the user's fingers.

VI. HAPTIC RENDERING

As graphical rendering is the process of generating an image in computer graphics, haptic rendering refers to the process of computing and displaying contact forces, vibration or other tactile representations of virtual objects in a computer simulated environment.

Some of the haptic rendering algorithms mainly consider the approach of touching virtual objects with a single contact point. Such rendering algorithms are typically referred to as three-degree-of-freedom (3-DoF) haptic rendering algorithms, since a point in 3D has only three DoFs.

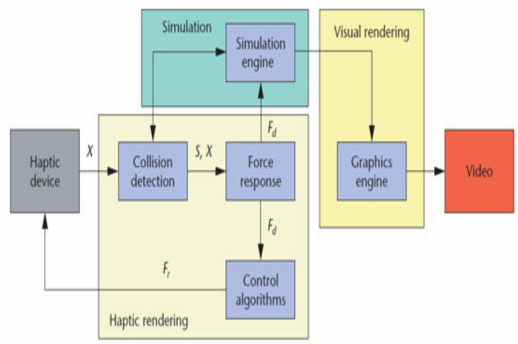

Figure. 6: Haptic Rendering

We split haptic rendering into three main blocks. *Collision-detection* algorithms provide information about contacts S occurring between an avatar at position X and objects in the virtual environment. *Force-response* algorithms return the ideal interaction force Fd between avatar and virtual objects. *Control algorithms* return a force Fr to the user, approximating the ideal interaction force to the best of the device's capabilities.

VII. HAPTICS DEVICES

A. *Cyberglove*

The CyberGlove system has been used in a wide variety of real-world applications, including digital prototype evaluation, virtual reality biomechanics, and animation. The CyberGlove has become the de facto standard for high-performance hand measurement and real-time motion capture. It is designed for Comfort and Functionality. The CyberGlove is constructed with stretch fabric for comfort and a mesh palm for ventilation. The 18-sensor CyberGlove includes open fingertips, which allow the user to type, write and grasp objects while wearing the glove.

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

Figure. 7: Cyberglove

B. Joystick

Gwangju Institute of Science and Technlogy introduced a wearable vibration haptic joystick at the IT-SoC 2005 & New Generation PC Fair recently. You can feel the particular product upon clicking a mouse after updating the database with the products' texture and tactile sensation figures. Tactile impression, hearing, and seeing will be made available when a 3D TV is released. In the medical field, this means you can feel an embryo in the womb.

Figure. 8: Haptic joystick

C. Trackball

Keyson (1996) described a haptic device in the form of familiar trackball that was used to gain many insights into the effects of haptic feedback in GUI navigation.
The trackball device includes a sensor device that detects the movement of a sphere in two rotary degrees of freedom. An actuator applies a force preferably along a z-axis perpendicular to the plane of the surface supporting the device, where the force is transmitted through the housing to the user. The output force is correlated with interaction of a controlled graphical object, such as a cursor, with other graphical objects in the displayed graphical environment.

D. The Pantograph

Various versions have been used in the rehabilitation of visually handicapped persons, micro-gravity experiments, etc. The pantograph has one prominent characteristic: the surface which is being touched neither needs to be grasped not does it need to brace a finger (from an ecological view point, people very seldom use styluses or thimbles to explore objects. Using the pantograph resembles exploring surfaces though a small plate, which is closer to normality). Another feature is very high fidelity: irregularities in the frequency response start at 400Hz and it has 3 orders of magnitude of dynamic range. It has negligible friction and very low inertia which give the illusion (when no force signal is applied) of gliding over an icy surface. A new digital version is being developed as we speak and the blue prints will be put in the public domain.

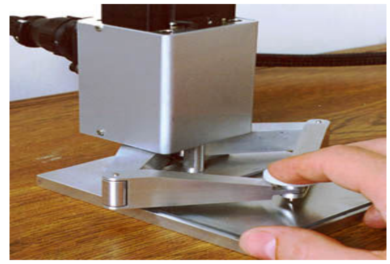

Figure. 9: Pantograph

E. Reconfigurable Keyboard

The reconfigurable keyboard is a haptic device mainly addressing the kinaesthetic sensation, but has strong tactile properties, too. The user of the device is the controller of the keyboard, receiving haptic information in form of the changing shape of keys and their switching characteristics during interaction. The keyboard is at least a haptic display. As it communicates with another unit about the switching event and the selection, it is also a haptic interface.

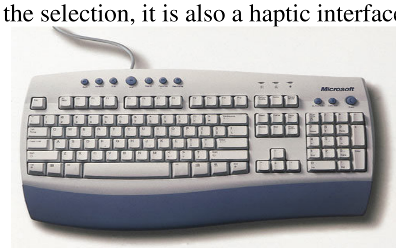

Figure. 10: Reconfigurable Keyboard

F. Haptic Pen

The Haptic Pen is a simple low-cost device that provides individualized tactile feedback for multiple simultaneous users and can operate on large touch screens as well as ordinary surfaces. A pressure-sensitive stylus is combined with a small solenoid to generate a wide range of tactile sensations. The physical sensations generated by the Haptic pen can be used to enhance our existing interaction with graphical user interfaces as well as to help make modern computing systems more accessible to those with visual or motor impairments.

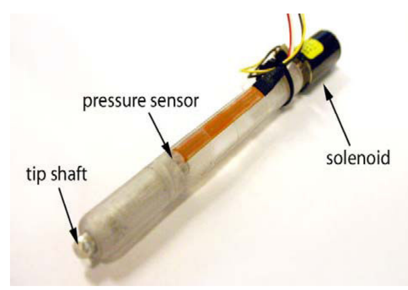

Figure. 11*: Haptic pen*

VIII.APPLICATIONS

A. Teleoperators and simulators

Teleoperators are remote controlled robotic tools, and when contact forces are reproduced to the operator, it is called "haptic teleoperation". The first electrically actuated teleoperators were built in the 1950's at the Argonne National Lab, USA, by Dr. Goertz, to remotely handle radioactive substances. Since then, the use of force feedback has become more widespread in all kinds of teleoperators such as underwater exploration devices controlled from a remote location.

When such devices are simulated using a computer (as they are in operator training devices) it is useful to provide the force feedback that would be felt in actual operations. Since the objects being manipulated do not exist in a physical sense, the forces are generated using haptic (force generating) operator controls. Data representing touch sensations may be saved or played back using such haptic technologies.

Haptic simulators are currently used in surgery training and flight simulators for pilot training (2004).

B. In Casino gaming

a. Add richness to the experience by giving people the option to touch as well as use their sight and hearing
b. Allows users to feel sensations that intuitively guide them through operation or provide a more realistic and immersive experience
c. Synchronize haptic feedback with sound and graphical images to create a more immersive, multisensory experience
d. Compensate for the noisy casino environment where sight and sound aren't giving adequate feedback.

Fig. 12: Casino Gaming

C. In Haptic Readers

The Haptic reader is a breakthrough technological achievement that has ample chances of bringing about great changes in the life of all the visually impaired. Making use of a scanner, this reader is capable of converting a normal book into Braille text.

Scores of books are published every year around the globe. Book lovers are found in every corner of the world. Being visually impaired does not discourage reading. In fact a book can be capable of creating visions in the minds of the blind. But it is a sad fact that all books are not available in Braille. The numbers are limited. A book published in normal text may take some time before a Braille edition is released. In such a situation even though a reader is willing to read the book is not available.

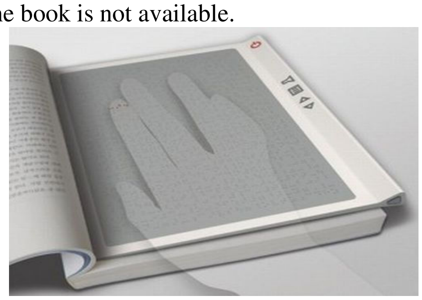

Figure. 13: Haptic readers

D. Haptics in virtual reality

Haptics are gaining widespread acceptance as a key part of virtual reality systems, adding the sense of touch to previously visual-only solutions. Most of these solutions use stylus-based haptic rendering, where the user interfaces to the virtual world via a tool or stylus, giving a form of interaction that is computationally realistic on today's hardware. Systems are also being developed to use haptic interfaces for 3D modeling and design that are intended to give artists a virtual experience of real interactive modeling.

E. Research

Some research has been done into simulating the different kinds of taction by means of high-speed vibrations or other stimuli. One device of this type uses a pad array of pins, where the pins vibrate to simulate a surface being touched. While this does not have a realistic feel, it does provide useful feedback, allowing discrimination between various shapes, textures, and resiliencies.

F. Medicine

Various haptic interfaces for medical simulation may prove especially useful for training of minimally invasive procedures (laparoscopy/interventional radiology) and remote surgery using teleoperators. 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.

G. Literature

The use of haptic devices in entertainment appeared in the 1932 futurist fiction book Brave New World by Aldous Huxley. The author described a future entertainment theater where the arm rests of the seats had positions for the hands to rest that gave haptic stimulation. Rather than "the movies" these theaters and shows were called "the feelies". The programs exhibited were of an erotic nature.

H. In ATMs and Kiosks

Most public machines like ATMs and Kiosks are designed to accommodate the maximum usability features for the largest user groups, but unfortunately the disabled and Senior Citizens are often minimized due to lesser use and lower numbers. The completed and unnatural designs not only cause usability concerns but in some cases, accessibility is also compromised. Blind and disabled users may have serious accessibility issues which may hinder or restrict use of such public machines. Haptics resolves such issues and provides a bridging effect for disabled and blind users. It adds another somatosensory channel for Human Computer Interaction (HCI) that can prove to be critical.

I. Arts and design

Touching is not limited to a feeling, but it allows interactivity in real-time with virtual objects. Thus, haptics are commonly used in virtual arts, such as sound synthesis or graphic design/animation. The haptic device allows the artist to have direct contact with a virtual instrument that produces real-time sound or images. For instance, the simulation of a violin string produces real-time vibrations of this string under the pressure and expressiveness of the bow (haptic device) held by the artist. This can be done with physical modelling synthesis.

Designers and modelers may use high-degree of freedom input devices that give touch feedback relating to the "surface" they are sculpting or creating, allowing faster and more natural workflow than with traditional methods.

J. Mobile consumer technologies

Tactile haptic feedback is becoming common in cellular devices. Handset manufacturers like LG and Motorola are including different types of haptic technologies in their devices. In most cases this takes the form of vibration response to touch. Alpine Electronics uses a haptic feedback technology named PulseTouch on many of their touch-screen car navigation and stereo units.

K. Education

Haptics tools are used in a variety of educational settings, both to teach concepts and to train students in specific techniques. Some faculties employ haptic devices to teach physics, for example, giving students a virtual environment in which they can manipulate and experience the physical properties of objects and the forces that act on them. Such devices allow students to interact with experiments that demonstrate gravity, friction, momentum, and other forces. In subjects such as biology and chemistry, haptic devices create virtual models of molecules and other microscopic structures that students can manipulate. In this way, students can “feel” the surfaces of B cells and antigens, for example, testing how they fit together and developing a deeper understanding of how a healthy immune system functions.

IX. ADVANTAGES AND DISADVANTAGES OF HAPTIC TECHNOLOGY

Some Advantages are as follows:

A. Communication is centered through touch and that the digital world can behave like the real world.

B. Reduction of working time as objects can be captured, manipulated, modified and rescaled digitally.

C. Haptic touch technology can be applied to small and large surfaces and a wide range of form factors.

D. With haptic hardware and software, the designer can maneuver the part and feel the result, as if he/she were handling the physical object.

E. Medical field simulators allow would be surgeons to practice digitally, gaining confidence in the procedure before working on breathing patients.

Some disadvantages are as follows:

The precision of touch requires a lot of advance design.

A. Haptic applications can be extremely complex requiring highly specialized hardware and considerable processing power.

B. Haptics projects are not easily portable.

C. With only a sense of touch, haptic interfaces cannot deliver warnings.

D. Debugging issues—these are complicated since they involve real-time data analysis.

E. Haptic project needs fixed installation.

X. CONCLUSION AND FUTURE SCOPE

Haptics technologies provide the next important step towards realistically simulated environments that have been envisioned by science fiction authors and futurists alike. Adding the sense of touch to the sense of hearing and sight currently addressed by simulation technologies is a very exciting development. Researchers at SUNY have completed experiments where they were able to transmit, from one person to another over the Internet, the sensation of touching a hard or soft object. Medical researchers at Rutgers filed a patent application for a new, PC-based virtual reality system that provides stroke patients with virtual hands.

Researchers at the University of Tokyo are currently working on adding haptic feedback to holographic projections. The feedback allows the user to interact with a hologram and receive tactile response as if the holographic object were real. One currently developing medical innovation is a central workstation surgeons would use to perform operations remotely—local nursing staff would set up the machine and prepare the patient. Rather than travel to an operating room, the surgeon becomes a telepresence. This allows expert surgeons to operate from across the country, increasing availability of expert medical care. Haptic technology will provide tactile and resistance feedback to the surgeon as he operates the robotic device.

Haptics doesn't just close the gaps in our current computer interfaces--it can open up new possibilities. Blending haptics with recent advances in the field of robotics allows doctors to train for intricate procedures virtually, with increasingly accurate sensory feedback--and the technology can bring a new dimension to remotely controlled machines, helping negotiate obstacles in distant settings. To make haptic technology work, scientists and engineers must fine-tune a variety of sensors, actuators, magnets and motors to simulate the textures and pressures that help us feel our way around our world. Haptics presents new challenges for the development of novel data structures to encode shape material properties, as well as new techniques for data processing, analysis, physical modeling, and visualization. And by making available a whole new category of sensations, haptic technology will open up gigantic possibilities for developers, a future where online shoppers can feel the garment they want to buy, and where gamers feel the force of each virtual impact.

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