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HAPTICS TECHNOLOGY: (sense of touch)

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ABSTRACT: Haptics is a recent enhancement to virtual environments allowing users “to touch” and feel the simulated objects they interact with. Current commercial products allow tactile feedback through desktop interfaces (such as the FEELIt mouse or the PHANToM arm) and force feedback at the fingertips through haptic gloves (such as the CyberTouch and the CyberGrasp).

Haptics is a recent enhancement to virtual environments allowing users “to touch” and feel the simulated objects they interact with. Current commercial products allow tactile feedback through desktop interfaces (such as the FEELIt mouse or the PHANToM arm) and force feedback at the fingertips through haptic gloves (such as the CyberTouch and the CyberGrasp)., etc. It is at present difficult to simulate complex virtual environments that have a realistic behavior. This task is added by the recent introduction of haptic toolkits.

The simulation of natural phenomenon is an important goal for this technology. Current systems may not be able to generate forces with the speed required to simulate real world situations. Accurate and high-speed devices must be perfected in order to create real-world simulations

1. Introduction

1.1 Haptic Feedback

Haptics, a fairly recent enhancement to virtual reality technology, gives users the touch and feel of simulated objects they interact with. The touch technology is making its way into key areas such as the automotive industry and medical practice, and a few companies are successfully marketing haptic devices, which trace their roots to academic research. With this technology we can now sit down at a computer terminal and touch objects that exist only in the "mind" of the computer. These interactions might be as simple as touching a virtual wall or button, or as complex as performing a critical procedure in a surgical simulator.

Virtual Reality systems present a computer-generated visual and auditory experience that allows a user to be immersed within a computer generated “world” for various purposes. Used in conjunction with traditional computer input systems this can be used. The addition of haptic systems to virtual reality will greatly increase its effectiveness at simulating real-world situations. One example can potentially include a medical training system using a simulator and virtual reality where a haptic system provides doctors with the “feel” of virtual patients. Virtual Reality (VR) has revealed itself as an excellent tool for teleoperation applications, and combined with haptic technologies, true telepresence systems can be foreseen, letting the user not only operate at distance, but feel as being physically in the remote site.

1.2 Background

We are using an immersive virtual environment that we have named a Haptic Workbench and described by Stevenson .It is an extension of a Virtual Workbench developed by the institute of Systems Science at the National University of Singapore,

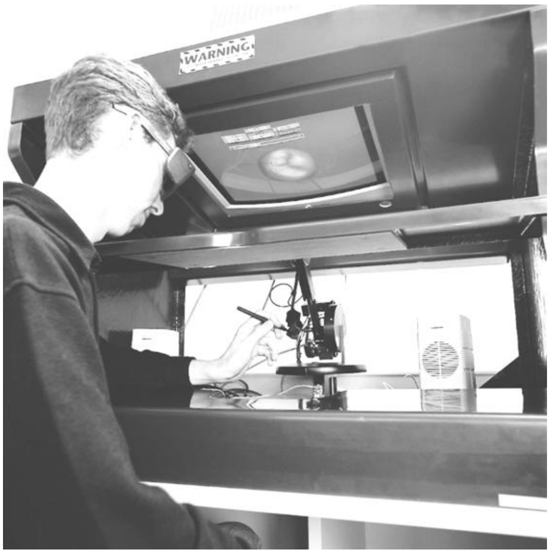

Figure 1: The Haptic Workbench, showing PHANToM haptic device.

To produce a 3D effect, the user wears polarising shutter glasses, synchronised with a left-and-right image displayed alternatively on the screen at 30 hertz per eye. The left and right eye convergence point is set such that the model being viewed appears to be behind the screen. This, by itself, produces a 3 dimensional effect, but does not provide any immersion. To achieve this, the computer monitor is mounted on a frame, and pointed vertically down onto a mirror, mounted at approximately 45 degrees. The user then looks at the mirror, not the monitor. This means that they can now place their hands behind the mirror, exactly where the model appears to be. With their hands in that position, they can now pick up and use two tools. The left-hand tool is tracked in 3D space by a Polhemus tracker. Typically it moves and rotates all the objects in the scene.
The right-hand tool is a haptic feedback device, known as a PHANToM, manufactured by Sensible Technologies [3]. It consists of a probe connected to a multi-linked mechanical arm. The arm has internal cables driven by sensitive electric motors. It provides force feedback to the user's hand as they move the probe in the space below the mirror. The user can see the objects in 3D and 'feel' them through the haptic tool.

The haptic tool can be animated in the scene as any type of simulated tool, often a fork or a pencil, and can perform work on the objects in the scene.

2 Towards the Technology

The idea behind in Touch is to create the illusion that two people, separated by distance, are interacting with a shared physical object. In reality, each user is interacting with his/her own object; however, when one of the objects is manipulated, both users' objects are affected. In our current design, the two connected objects each consist of three cylindrical rollers mounted on a base .When one of the rollers is rotated, the corresponding roller on the remote object rotates in the same way. This behavior can be achieved using haptic (force-feedback) technology with sensors to monitor the physical states of the rollers and internal motors to synchronize these states.
When we examine objects and surfaces in the real world, our sense of feeling (touch) is as important as seeing and hearing. Normally we use all of our senses in continuous and parallel cooperation to observe, orientate, learn and receive information. The most important combination of our senses are seeing, hearing and feeling.
For many tasks feeling provides vital information to the operator, such as situations with poor lighting conditions and jobs where details are so small that they are covered by the hands and tools that do the job. An example may illustrate this: Modern surgical robot equipment is still operated by doctors, who have to do their job without the sense of feeling since the robots do not have the ability to pick up and replay this touch information. When using computers and software for modeling processes and analyzing complex systems, we

2.1 Fuzzy Feedback

We then extended this concept to provide a type of '*fuzzy*' feedback. A conventional computer user interface usually provides feedback to the user in the form of an error message and a 'beep'. This gives only a binary form of feedback; either you're right or your wrong. Even a warning message, which does provide a form of advice without enforcing an action, is disruptive to the flow of work, and usually has to be acknowledged. It does not provide the ability to continuously vary an influence on the user; to guide and advise continuously as they are working.
Haptics, however, provides just this ability. We can introduce a gentle force, guiding the user's hand in a certain direction. We can vary the strength and direction of that force as they move the pointer, giving the ability to smoothly vary the amount of 'advice' we are sending. This is a *fuzzy* feedback mechanism. The user can easily over-ride the force by simply pressing harder against it. Our trials have shown that it is intuitive and immediate. It doesn't interrupt the flow of work and mimics many real world situations.

2.2 The Problem Domain: Underground Mine Planning

We investigated several types of constraint by building a prototype application based on the underground mining industry. A particular problem with the planning of an under-ground mine, is that of drawing the proposed access tunnel. This is often referred to as the 'drive' or 'decline', and is generally a road that slopes down to the ore bodies that are to be mined. Since this is a 3 dimensional drawing problem, the 3D immersive view is of immediate benefit for producing the initial sketch. However, there are certain restrictions on the route that the decline can take. Obviously it should pass *close to*, but not necessarily *through* the valuable ore. It should also avoid any known dangerous areas, such as water logged or unstable rock. It should have a limited gradient, determined by the capabilities of the vehicles that are to be used. Any bends should be of such a curvature that the vehicles can negotiate them. The route should be as 'smooth' and short as possible, minimising twists and turns. There may be an outer boundary, perhaps introduced by the limits of the mining lease. These requirements may well conflict with each other and require some expert knowledge, in the form of user interaction, to make decisions between different options.
This problem domain seemed a suitable one to investigate a haptically constrained CAD system. We have written a prototype application allowing a user to sketch a line in 3-space around some solid objects representing geological entities. The application has a series of haptic buttons with which the user can turn on or off various types of constraint. Each constraint type also has a slider to modify its intensity. The haptic force on the user's sketching tool, is the resultant of all forces currently turned on. A visual meter in the bottom left corner displays the magnitude of each component of the force, allowing the user to glance at this if they are unsure which particular constraint is dominating at any one time. The bottom left corner of the scene has a 3D 'compass' that rotates with the users left hand tool. This was found necessary, as, when the user rotates the scene it is very easy to forget which is up/down/east/west etc.

3 Haptic Rendering

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
Improved accuracy and richness in object modeling and haptic rendering will require advances in our understanding

of how to represent and render psychophysically and cognitively germane attributes of objects, as well as algorithms and perhaps specialty hardware (such as haptic or physics engines) to perform real-time computations. Development of multimodal workstations that provide haptic, visual, and auditory engagement will offer opportunities for more integrated interactions
To satisfy the requirement of guiding the user away from certain areas (eg. dangerous zones), we implemented a repulsive force from nominated solid objects in the scene. The idea is that the user can 'feel' the danger, and be guided away. However, they may be constrained by other effects, and have the option to proceed further, by pushing against the force.

3.1 Haptic interface.

Haptic interfaces are devices that stimulate the sense of touch such as the sensory capabilities within our hands. The surge of computer capability and the desire for better ways to connect to computer-generated worlds has driven the creation and development of practical devices for haptic interaction. A haptic interface is a force-reflecting device, which allows a user to touch, feel, manipulate, create, and/or alter simulated D-objects in a virtual environment.It could be used to train physical skills such as those jobs requiring specialized hand-help tools (e.g. surgeons, astronauts, mechanics), to provide haptic-feedback modelling of 3D objects without a physical medium (such as automobile body designers working with clay models), Haptic interface technologies: -

Tactile interface technologies.

Force feedback interface technologies.

Haptics refers to the sense of touch: conveying information on physical properties such as inertia, friction, compliance, temperature, and roughness. This sense can be divided into two categories:

kinesthetic sense, through which we sense movement or force in muscles and joints

tactile sense, through which we sense shapes and textures.

The development of even more capable devices that can accurately reproduce a large range of haptic information is an important component for the technologies of virtual reality and telepresence. In medical applications it is vital that a surgeon be able to "feel" the difference between hard and soft tissues. For general robotic telepresence applications it is equally important that an operator be able to feel what the remote robot is touching, to allow the operator to run the robot in a more natural and responsive manner.

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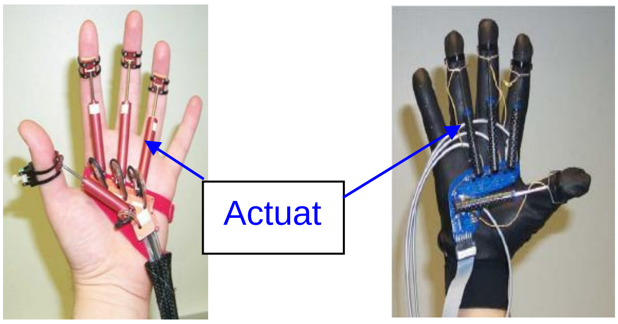
variation of the repulsion from an object, is the situation where the tool needs to be inside a volume and must be prevented from venturing outside it. We are implementing this as a series of bounding surfaces with repulsion. This introduces the problem of how to turn the boundary on and off if the control widgets are not within the boundary. (See Control Widgets, below).

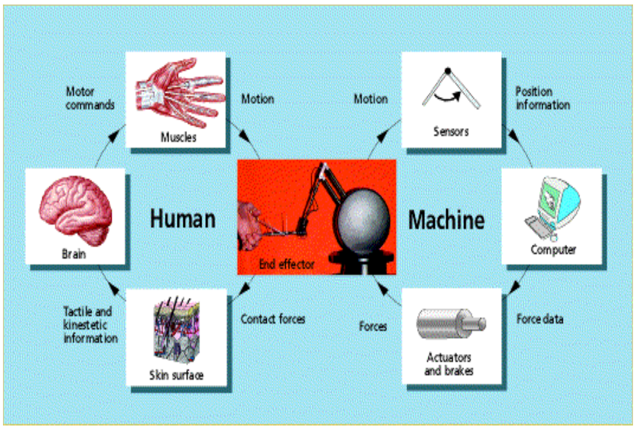
3.2 Force feedback data glove

It consists of opposing the movement of the hand in the same way that an object squeezed between the fingers resists the movement of the latter. The glove, in the absence of a real object must be capable of recreating the forces applied by the object on the human hand with the same intensity and the same direction. The mechanical structure created was made up of five fingers and had 19 degrees of freedom, five of which were passive. The mechanical structure adapted to different sizes of human hands and had a physical stop to offer security to the operator. 14 torque motors with continuous current equal to 1.4Nm control the glove. The global scheme has two command loops. Man is considered as a displacement generator while the glove is considered as a force generator.

When the person receiving the sensation matches the movements of the person feeling the object, he not only understands how the person moved his hand, but also at the same time he feels exactly the system uses a virtual-reality data glove to capture the hardness or softness of an object being felt by one person. This feeling is communicated instantaneously to another person seated at a computer terminal who is using a sensing tool, follows a point on the computer screen that tracks and transmits the movements and sensations of what the first person is feeling. The sensations are transmitted in the form of exerted force and through information about the position of the objects being touched, the kind of forces the other person is feeling



3. Working:



In the real world, persons receive and disseminate information in three-dimensional space. In a virtual world, the user can access information by imitating that three-dimensional space. Haptic devices are in contact with skin surface i.e. with the mechanoreceptors, which gives tactile & kinesthetic information to the brain i.e. Primary Sensory Cortex part, which in turn supply this information in form of motor commands to the muscles resulting in desired motion. Similarly at machine interface cycle this motion is trapped in sensors, which gives the position information to computer that forces data to actuators & brakes of haptic device.

4.1 Prons

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

Haptic Technology enables people to control prosthetic (artificial body parts) devices with their minds and the aid of some computational device instead of mechanical device.

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

The addition of tactile feedback to computer mice can significantly enhance user performance.

When objects can be captured, manipulated, modified and rescaled digitally, working time is reduced.

Haptic technology can be used in telemedicine, where a doctor can physically examine and palpate areas on a patient's body, receiving accurate and informative tactile feedback even though the patient and doctor are in different locations.

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

The technology is also being investigated as a tool for analyzing data. Just as color and graphical representations have enhanced the ability to manipulate and understand masses of data, haptics may contribute the ability to sense additional dimensions in a single view.

4.2 Cons

The communication links necessary for telemedicine must have fault rates at 0% for extended periods of time.

Debugging haptic systems is very complicated since they involve real-time data analysis.

Touch is an extremely precise sense in its own way, but to use its precision requires a lot of advance design.

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

The high bandwidth requirement of haptics is not met by current Internet technology. As a result it is not possible at present to have a large number of remote participants interacting hapticly in a shared virtual space.

5. Implementation and Recommendation

The simulation of natural phenomenon is an important goal for this technology. Current systems may not be able to generate forces with the speed required to simulate real world situations. Accurate and high-speed devices must be perfected in order to create real-world simulations. Much work is being done to provide computer and actuation systems that work on such fast speeds and the outlook for improvement in this area is encouraging.

Many of the applications for tele-robotics, whether for medical purposes or space-related purposes, requires that the system be able to simulate remote sensation in real-time. A remote surgical system must be able to provide instantly updated information so that a surgeon can perform work instantaneously. The slightest delay may be the difference between a *life or death* situation for the patient.

One of the stumbling blocks for a real-time system is in the area of communications. A sensation must be read remotely, converted into a digital form, sent by some communications link to the user, converted back to a form that is useable by the actuation system, and the force must be generated for the user based on that information, the users response must then be read and the process must be repeated to send instructions back to the remote site. This system requires high-speed communications links and methods in order to insure that the actions of the remote robot accurately and in a timely fashion mirror the instructions of the operator. Advances must be made in this area in order to be able to implement these haptic technologies in all of the exciting ways that have been imagined. With the advances and leaps that are being made by universities, laboratories and institutions around the world the future of haptic technology is indeed looking (and feeling) very bright.

Haptics will present 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.” From the original gaming, so much has come about in less than 10 years. It is exciting to think what might happen in the next 10 years.

6. Conclusion

Haptics technologies provide the next important step towards realistically simulated environments that have been envisioned by science fiction authors and futurists alike. The sense of touch is so important to the way in which humans interact with the world that it’s absence in simulation technologies of the past has been a major shortcoming. Adding the sense of touch to the sense of hearing and sight currently addressed by simulation technologies is a very exciting development.

The practical applications of such technologies that have been presented show the enormous potential that this technology has for providing realistic simulations for medical and military training resulting in better trained doctors and soldiers. This alone will enhance the lives and security of countless numbers of people.

The application to entertainment, although less critical than the medical application, will greatly enhance the enjoyment of artistic and leisurely pleasures as well. This report has provided an overview of the state of the art of haptic technology and research.

Much work is being done and great strides seem to be on the horizon to create useful and practical haptic systems. However, Some innovations are still required before the large-scale adoption of haptic technology can occur, such as miniaturization, high-speed devices and communications innovations. Many of the haptic devices must be miniaturized so that they are lighter, simpler and easier to use. The introduction of Electro-Rheological Fluid based devices shows one way in which miniaturization of haptic devices can occur.

Greater computation capabilities, combined with expected advances in motor technology, further understanding of haptic psychophysics, and sensible product design, will make haptic technology an important adjunct to the way we work with computers. The current haptic interface paradigm embodied in the PHANToM focuses on the simplest of interactions -- forces at the fingertip or tool tip. There are other aspects of human haptic perception -- such as pressure distribution, temperature and high-frequency vibration -- that could enhance the quality of interaction.

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