



A Study on SensAble Technology and its Applications - HAPTICS

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Abstract: *Haptics refers to sensing and manipulation through touch. Exploring part of the environment and achieving tactile identification of objects, positions and orientations can be done through haptic interfaces. Currently we focused on the involvement of haptics in solving challenging problems in the streams of mechanical design, actuators, real time system. In this paper, we have presented a description of study on haptic virtual environments, haptic interfaces and different applications like touch-based surgical simulation which is not only made to improve realism of virtual environments, but also to provide important diagnostic information through the sense of touch. We also have presented many more applications of haptics in various areas.*

Keywords: *Haptic Virtual Environment(HVE), Surgical Simulation, Haptic Interfaces, Tele-manipulators, Actuators.*

I. INTRODUCTION

Our working definition of haptics includes all aspects of information acquisition and object manipulation through touch by humans, machines, or a combination of the two and the environments can be real, virtual or teleoperated. This is the sense in which substantial research and development in haptics is being pursued around the world today. Recently the term "haptic interfaces" has begun to be used by human interface technologists to describe devices that measure the motions of, and stimulate the sensory capabilities within, our hands. There is a long and respectable history in the development of devices to permit humans to control remotely located robots (tele-manipulators). Yet, it has taken the explosion of computer capability and the yearning for better ways to connect to newly complex computer-generated worlds to drive the creation and development of practical devices for haptic interaction. Haptics can be subdivided into three areas. They are 1) Human haptics - the study of human sensing and manipulation through touch, 2) Machine haptics – the design, construction, and use of machines to replace or augment human touch. 3) Computer haptics -algorithms and software associated with generating and rendering the touch and feel of virtual objects. Virtual Reality is "the illusion of participation in a synthetic environment rather than external observation of such an environment".

II. TOUCHING REAL AND VIRTUAL OBJECTS

When a human user touches a real object directly or through a tool, forces are imposed on the user's skin. The associated sensory information, mediated by sensors in the skin, joints, tendons and muscles, is conveyed to the brain by the nervous system and leads to haptic perception. The subsequent motor commands issued by the brain activate the muscles and result in, say, hand and arm motion that modifies the touch sensory information. This sensorimotor loop continues to occur during both exploration and manipulation of objects[5]. In order to create the sensation of touching virtual objects, we need to generate the reaction force of objects applied on the skin. Touching a real object through a tool is mimicked by the use of a force reflecting haptic interface device. When the human user manipulates the end-effector of the haptic interface device, the position sensors on the device convey its tip position to the computer. The models of objects in the computer calculate in real-time the torque commands to the actuators on the haptic interface, so that appropriate reaction forces are applied on the user, leading to haptic perception of virtual objects.

2.1 Haptics Virtual Environment(HVE):

Virtual Environments (VEs), generally referred to as virtual reality in the popular press, have caught the imagination of lay public as well as researchers working in a wide variety of disciplines. VEs are computer-generated synthetic environments with which a human user can interact to perform perceptual and motor tasks. A typical VE system consists of a helmet that can project computer-generated visual images and sounds appropriate to the gaze direction, and special gloves with which one can command a computer through hand gestures.

Applications of this technology include a large variety of human activities such as training, education, entertainment, health care, scientific visualization, telecommunication, design, manufacturing and marketing. Virtual environment systems that engage only the visual and auditory senses of the user are limited in their capability to interact with the user[2]. In particular, the human hand is a versatile organ that is able to press, grasp, squeeze or stroke objects; it can

explore object properties such as surface texture, shape and softness; it can manipulate tools such as a pen or a jack-hammer. Being able to touch, feel, and manipulate objects in an environment, in addition to seeing (and/or hearing) them, gives a sense of compelling immersion in the environment that is otherwise not possible. Real or virtual environments that deprive the human user of the touch and feel of objects seem deficient and seriously handicap human interaction capabilities.

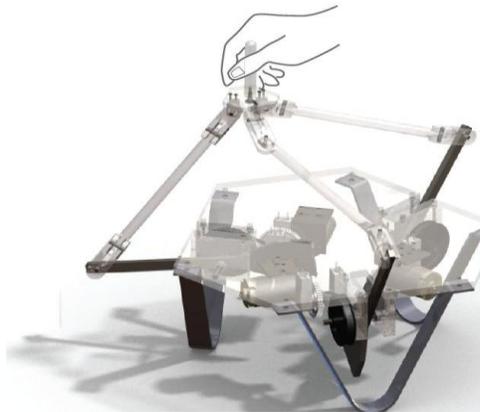


Fig. 1 Haptic Poster

III. HAPTIC INTERFACE

This is a force reflecting device which allows a user to touch, feel, manipulate, create, and/or alter simulated D-objects in a virtual environment. This could be used to train physical skills such as those jobs requiring specialized hand-help tools, to provide haptic feedback modeling of three dimensional objects without a physical medium or to mock-up developmental prototypes directly from CAD databases (rather than in a machine shop).

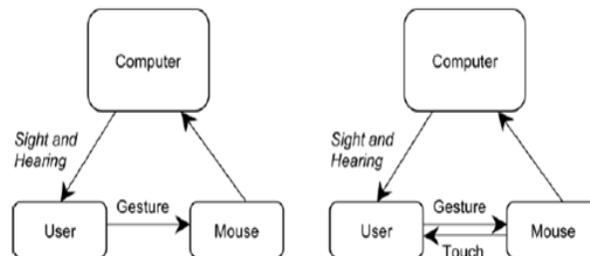


Fig. 2 Types of Haptics

A haptic system is defined as "The sensibility of the individual to the world adjacent to his body by use of his body". The haptic perceptual system is unusual in that it can include the sensory receptors from the whole body and is closely linked to the movement of the body so can have a direct effect on the world being perceived. A distinguishing feature of haptic interfaces is the simultaneous exchange of information between the user and the machine.

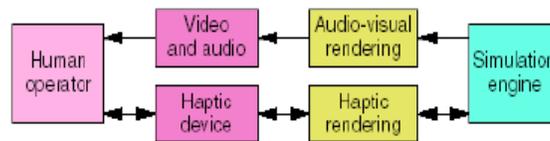


Fig. 3 Haptic Feedback

When we use our hands to explore the world around us, we receive two types of feedback -- kinesthetic and tactile.[3] Tactile information refers the information acquired by the sensors which are actually connected to the skin of the human body with a particular reference to the spatial distribution of pressure, or more generally, tractions, across the contact area. For example when we handle flexible materials like fabric and paper, we sense the pressure variation across the fingertip. This is actually a sort of tactile information. 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. Kinesthetic information refers to the information acquired through the sensors in the joints. Interaction forces are normally perceived through a combination of these two information's.

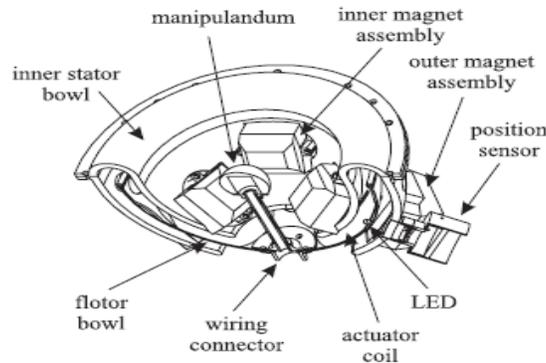


Fig. 4 Design cutaway for Haptic Interface

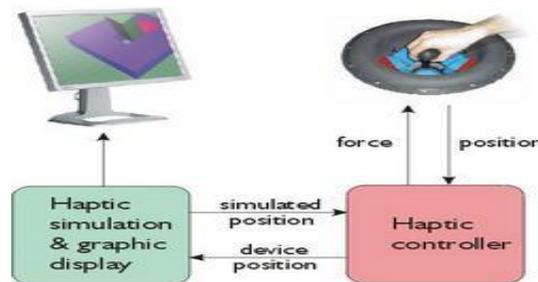


Fig. 5 Sample setup for Haptic Interface

When the fingers touch the ball, contact is made between the finger pads and the ball surface. Each finger pad is a complex sensory structure containing receptors both in the skin and in the underlying tissue. There are many types of these receptors, one for each type of stimulus: light touch, heavy touch, pressure, vibration and pain. The data coming collectively from these receptors helps the brain understand subtle tactile details about the ball. As the fingers explore, they sense the smoother texture of the leather, the raised coarseness of the laces and the hardness of the ball as force is applied. Even the thermal properties of the ball are sensed through tactile receptors.

IV. HAPTICS WORKING PROCEDURE

An Immersion haptics system includes Sensor(s), Actuator (motor) control circuitry , One or more actuators that either vibrate or exert force, Real-time algorithms (actuator control software, which we call a “player”) and a haptic effect library and finally Application programming interface (API), and often a haptic effect authoring tool. The Immersion API is used to program calls to the actuator into your product’s operating system (OS). The calls specify which effect in the haptic effect library to play. When the user interacts with your product’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[4] . 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. “The actual process used by the software to perform its calculations is called haptic rendering[6].”

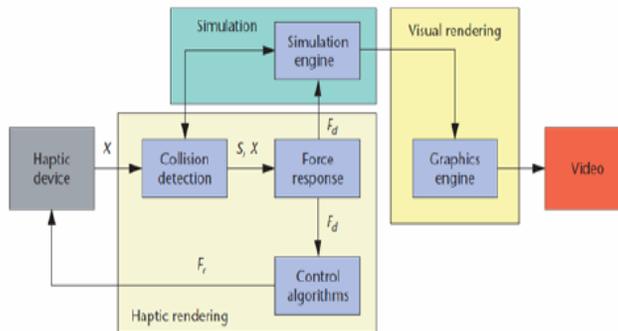


Fig. 6 Haptic Rendering Diagram

We split haptic rendering[5] into three main blocks.

Collision-detection algorithms: The collision-detection algorithm uses position information collected through sensors to find collisions between objects and avatars and report the resulting degree of penetration or indentation.

Force-response algorithms: The force-response algorithm computes interaction forces between avatars and virtual objects involved in a collision.

Control algorithms: The control algorithm collects interaction force information from force response and applies them on the operator through the haptic device while maintaining a stable overall behavior.

V. APPLICATIONS

5.1 Graphical user interfaces

Video game makers have been early adopters of passive haptics, which takes advantage of vibrating joysticks, controllers and steering wheels to reinforce on-screen activity. But future video games will enable players to feel and manipulate virtual solids, fluids, tools and avatars. The Novint Falcon haptics controller is already making this promise a reality. The 3-D force feedback controller allows you to tell the difference between a pistol report and a shotgun blast, or to feel the resistance of a longbow's string as you pull back an arrow.



Fig. 7 Novint Falcon

Some touch screen manufacturers are already experimenting with this technology. When a user presses the button, he or she feels movement in and movement out. He also hears an audible click. It is accomplished by placing two small piezoelectric sensor pads under the screen and designing the screen so it could move slightly when pressed. Everything, movement and sound is synchronized perfectly to simulate real button manipulation.

5.2 Surgical Simulation and Medical Training

Various haptic interfaces for medical simulation may prove especially useful for training of minimally invasive procedures and remote surgery using teleoperators. In the future, expert surgeons may work from a central workstation, performing operations in various locations, with machine setup and patient preparation performed by local nursing staff. Rather than traveling to an operating room, the surgeon instead becomes a *telepresence*. It is well documented that a surgeon who performs more procedures of a given kind will have statistically better outcomes for his patients. Haptic interfaces are also used in rehabilitation robotics.

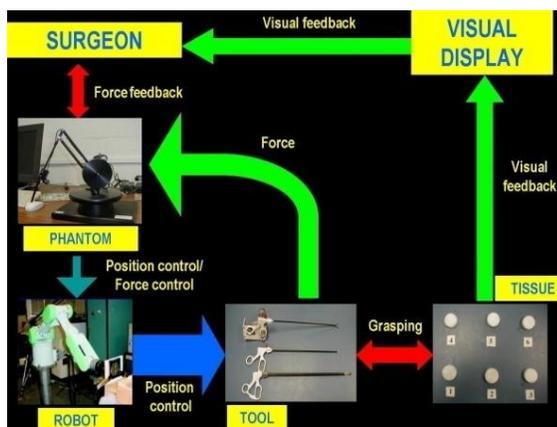


Fig. 8 Showing surgical simulation

The potential benefits of simulation-based training and preoperative planning have attracted significant research interest and commercial investment. Systems under development are moving toward use in training and certification in several surgical specialties. For example, in machine haptic, surgical tele-robots already help humans perform cardiac and abdominal surgery. And it is easy to imagine the convergence of bio-simulation and tele-surgery in the near future.

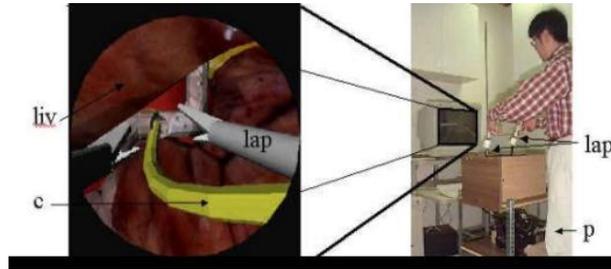


Fig. 9 Developing device for medical uses

Research indicates that 'Virtual Haptic Back' (VHB) is a significant teaching aid in palpatory diagnosis (detection of medical problems via touch). The VHB simulates the contour and compliance (reciprocal of stiffness) properties of human backs, which are palpated with two haptic interfaces. Reality-based modeling for surgical simulation consists of a continuous cycle. In the figure given above, the surgeon receives visual and haptic (force and tactile) feedback and interacts with the haptic interface to control the surgical robot and instrument. The robot with instrument then operates on the patient at the surgical site per the commands given by the surgeon. Visual and force feedback is then obtained through endoscopic cameras and force sensors that are located on the surgical tools and are displayed back to the surgeon.

5.3 Military Training in virtual environment

Virtual environments work well in military applications. When well designed, they provide the user with an accurate simulation of real events in a safe, controlled environment. Specialized military training can be very expensive, particularly for vehicle pilots.

Flight Simulators: The Air Force and Navy use flight simulators to train pilots. Training missions may include how to fly in battle, how to recover in an emergency, or how to coordinate air support with ground operations. The simulator sits on top of either an electronic motion base or a hydraulic lift system that reacts to user input and events within the simulation. As the pilot steers the aircraft, the module he sits in twists and tilts, giving the user haptic feedback.

Ground Vehicle Simulators: Although not as high profile as flight simulators, VR simulators for ground vehicles is an important part of the military's strategy. In fact, simulators are a key part of the Future Combat System (FCS) -- the foundation of the armed forces' future. The FCS consists of a networked battle command system and advanced vehicles and weapons platforms. Computer scientists designed FCS simulators to link together in a network, facilitating complex training missions involving multiple participants acting in various roles.



Fig. 10 Simulator

Trainees can learn how the real vehicle handles in treacherous weather conditions or difficult terrain. Networked simulators allow users to participate in complex war games.

5.4 Telerobotics

In a telerobotic system, a human operator controls the movements of a robot that is located some distance away. Some teleoperated robots are limited to very simple tasks, such as aiming a camera and sending back visual images. In a more sophisticated form of teleoperation known as telepresence, the human operator has a sense of being located in the robot's environment. Haptics now makes it possible to include touch cues in addition to audio and visual cues in telepresence models. It won't be long before astronomers and planet scientists actually hold and manipulate a Martian rock through an advanced haptics-enabled telerobot, a high-touch version of the Mars Exploration Rover.

5.5 Virtual Education

Research indicates that a considerable portion of people are kinesthetic or tactile learners—they understand better and remember more when education involves movement and touch. Because formal education has traditionally focused on visual (reading) and auditory (hearing) learning, these learners have been at a disadvantage. Haptics opens the door to an entirely different learning method and style, one that for many students provides the best opportunity to learn. Moreover, even for visual and auditory learners, haptics can improve learning[8]. For a broad range of subject matter, incorporating sensory data and feedback allows for a richer understanding of the concepts at hand. 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.

5.6 For the Visually Impaired

The haptic display device, will include an integrated touch-screen so that users can push on areas of the screen to activate menus and other graphical icons that they feel there. With the ability to display graphical images and activate them by touch, the wide world of graphical information displays available on computers today can finally be accessed by the blind.

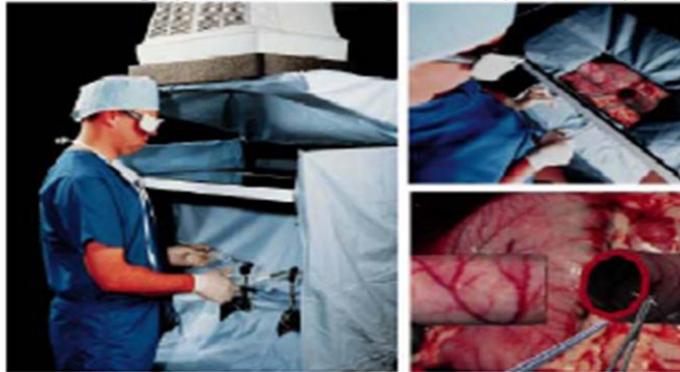


Fig. 11 Simulation of Blood Vessels

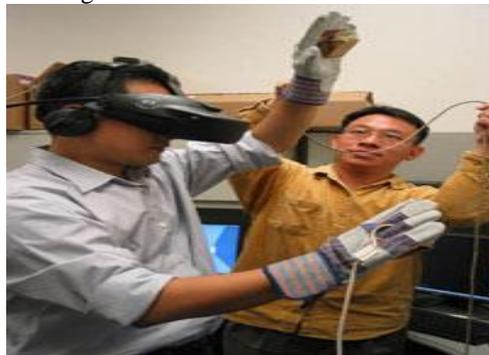


Fig. 12 Using Haptic Interface

A multimodal tool allows blind people to create virtual graphs independently. Multimodal interactions in the process of graph creation and exploration are provided by using a low-cost haptic device. Haptic technology can be incorporated into touchable maps for the blind. To create a map, a video is shot of a real-world location, either an architectural model of a building or a city block. Software evaluates the video frame by frame to determine the shape and location of every object. The data results in a three-dimensional grid of force fields for each structure. Using a haptic interface device, a blind person can feel these forces and, along with audio cues, get a much better feel of a city’s or building’s layout.

VI. CONCLUSION

For early primates to survive in a physical world, as Frank Wilson suggested, “a new physics would eventually have to come into their brain, a new way of registering and representing the behavior of objects moving and changing under the control of the hand. It is precisely such a representational system—a syntax of cause and effect, of stories, and of experiments, each having a beginning, a middle, and an end—that one finds at the deepest levels of the organization of human language.” This is true on developmental and evolutionary level. Our efforts to communicate information by rendering how objects feel through haptic technology, and the excitement in our pursuit, might reflect a deeper desire to speak with an inner, physically based language that has yet to be given a true voice.

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