Applications of Haptics Technology in Advance Robotics

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Abstract— **Haptic interaction with the world is manipulation using our sense of touch. The term "haptics" arises from the Greek root haptikos, meaning "able to grasp or perceive." Haptic interaction with computers implies the ability to use our natural sense of touch to feel and manipulate computed quantities. Haptic computer interaction is a relatively new field that has generated considerable interest over the past decade. Initially, computers could deal only with numbers. It took many years to realize the importance of operating with text. The introduction of CRT display technologies allowed graphics to be displayed, giving us a new way to interact with computers. As processing power increased over time, three-dimensional (3D) graphics became more common and we may now peer into synthetic worlds that seem solid and almost real. Likewise, until recently, the notion of carrying on a "conversation" with our computer was far-fetched. Now, speech technology has progressed to the point that many interesting applications are being considered. Just over the horizon, computer vision is destined to play a role in face and gesture recognition. It seems clear that as the art of computing progresses, even more of the human sensory palette will become engaged. It is likely that the sense of touch (haptics) will be the next sense to play an important role in this evolution. We use touch pervasively in our everyday lives, and are accustomed to easy manipulation of objects in three dimensions. 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**

Keywords- Haptics, teleoperated, sense of touch

I. INTRODUCTION

A. *What is 'Haptics'?*

Haptics refers to sensing and manipulation through touch. Since the early part of twentieth Century, the term haptics has been used by psychologists for studies on the active touch of real objects by humans.

Haptic technology refers to technology that interfaces the user with a virtual environment via the sense of touch by applying forces, vibrations, and/or motions to the user. This mechanical stimulation may be used to assist in the creation of virtual objects (objects existing only in a computer simulation), for control of such virtual objects, and to enhance the remote control of machines and devices . This emerging technology promises to have wide-reaching applications as it already has in some fields. For example, haptic technology has made it possible to investigate in detail how the human sense of touch works by allowing the creation of carefully controlled haptic virtual objects. These objects are used to systematically probe human haptic capabilities, which would otherwise be difficult to achieve. These new research tools contribute to our understanding of how touch and its underlying brain functions work. Although haptic devices are capable of measuring bulk or reactive forces that are applied by the user, it should not to be confused with touch or tactile sensors that measure the pressure or force exerted by the user to the interface.

The term haptic originated from the Greek word ἁ πτικός (haptikos), meaning pertaining to the sense of touch and comes from the Greek verb ἅ πτεσθαι (haptesthai) meaning to "contact" or "touch".

B. *Basic System configuration*

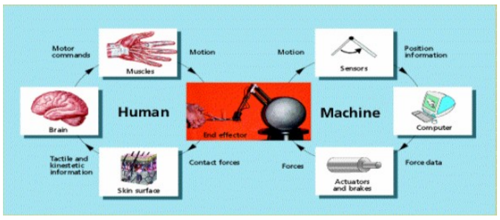

Figure 1.Basic Haptic Configuration

Basically a haptic system consist of two parts namely the human part and the machine part. In the figure shown above, the human part (left) senses and controls the position of the hand, while the machine part (right) exerts forces from the hand to simulate contact with a virtual object. Also both the

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systems will be provided with necessary sensors, processors and actuators. In the case of the human system, nerve receptors performs sensing, brain performs processing and muscles performs actuation of the motion performed by the hand while in the case of the machine system, the above mentioned functions are performed by the encoders, computer and motors respectively.

C. Haptic Information

Basically the haptic information provided by the system will be the combination of (i) Tactile information and (ii) Kinesthetic information.

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 informations.

II. CREATION OF VIRTUAL ENVIRONMENT (VIRTUAL REALITY).

Virtual reality is the technology which allows a user to interact with a computer-simulated environment, whether that environment is a simulation of the real world or an imaginary world. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special or stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced, haptic systems now include tactile information, generally known as force feedback, in medical and gaming applications. Users can interact with a virtual environment or a virtual artifact (VA) either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, the Polhemus boom arm, and omnidirectional treadmill. The simulated environment can be similar to the real world, for example, simulations for pilot or combat training, or it can differ significantly from reality, as in VR games. In practice, it is currently very difficult to create a high-fidelity virtual reality experience, due largely to technical limitations on processing power, image resolution and communication bandwidth. However, those limitations are expected to eventually be overcome as processor, imaging and data communication technologies become more powerful and cost-effective over time.

Virtual Reality is often used to describe a wide variety of applications, commonly associated with its immersive, highly visual, 3D environments. The development of CAD software, graphics hardware acceleration, head mounted displays; database gloves and miniaturization have helped popularize the motion. The most successful use of virtual reality is the computer generated 3-D simulators. The pilots use flight simulators. These flight simulators have designed just like cockpit of the airplanes or the helicopter. The screen in front of the pilot creates virtual environment and the trainers outside the simulators commands the simulator for adopt different modes. The pilots are trained to control the planes in different difficult situations and emergency landing. The simulator provides the environment. These simulators cost millions of dollars. The virtual reality games are also used almost in the same fashion. The player has to wear special gloves, headphones, goggles, full body wearing and special sensory input devices. The player feels that he is in the real environment. The special goggles have monitors to see. The environment changes according to the moments of the player. These games are very expensive.

III. HAPTICS DEVICES:

A haptic device is the one that provides a physical interface between the user and the virtual environment by means of a computer. This can be done through an input/output device that senses the body's movement, such as joystick or data glove. By using haptic devices, the user can not only feed information to the computer but can also receive information from the computer in the form of a felt sensation on some part of the body. This is referred to as a haptic interface.

Haptic devices can be broadly classified as

A. Virtual reality/ Telerobotics based devices

1) *Exoskeletons and Stationary device*
2) *Gloves and wearable devices*
3) *Point-sources and Specific task devices*

1) Exoskeletons and Stationary devices

The term exoskeleton refers to the hard outer shell that exists on many creatures. In a technical sense, the word refers to a system that covers the user or the user has to wear. Current haptic devices that are classified as exoskeletons are large and immobile systems attach that the user must him or herself.

2) Gloves and wearable devices

These devices are smaller exoskeleton-like devices that are often, but not always, take the down by a large exoskeleton or other immobile devices. Since the goal of building a haptic system is to be able to immerse a user in the virtual or remote environment and it is important to provide a small remainder of the user's actual environment as possible. The drawback of the wearable systems is that since weight and size of the devices are a concern, the systems will have more limited sets of capabilities.

3) Locomotion interfaces

An interesting application of haptic feedback is in the form of full body Force Feedback called locomotion interfaces. Locomotion interfaces are movement of force restriction devices in a confined space, simulating unrestrained mobility such as walking and running for virtual reality. These interfaces overcomes the limitations of using joysticks for maneuvering or whole body motion platforms, in which the user is seated and does not expend energy, and of room environments, where only short distances can be traversed.

IV. HAPTICS RENDERING

A. *Principle of haptic interface*

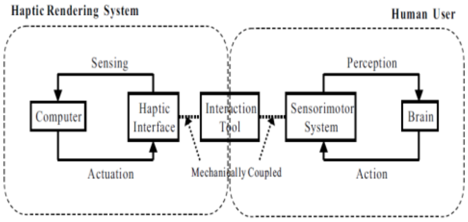

Figure 2.Block diagram for human computer interface

As illustrated in Fig. given above, haptic interaction occurs at an interaction tool of a haptic interface that mechanically couples two controlled dynamical systems: the haptic interface with a computer and the human user with a central nervous system. The two systems are exactly symmetrical in structure and information and they sense the environments, make decisions about control actions, and provide mechanical energies to the interaction tool through motions.

B. *Creation of an AVATAR*

An avatar is the virtual representation of the haptic through which the user physically interacts with the virtual environment. Clearly the choice of avatar depends on what's being simulated and on the haptic device's capabilities. The operator controls the avatar's position inside the virtual environment. Contact between the interface avatar and the virtual environment sets off action and reaction forces. The avatar's geometry and the type of contact it supports regulate these forces.Within a given application the user might choose among different avatars

C. *System architecture for 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. Several components compose typical haptic rendering algorithms. We identify three main blocks, illustrated in Figure shown above.

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.

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. Force-response algorithms typically operate on the avatars' positions, the positions of all objects in the virtual environment, and the collision state between avatars and virtual objects. Their return values are normally force and torque vectors that are applied at the device-body interface. Hardware limitations prevent haptic devices from applying the exact force computed by the force-response algorithms to the user.

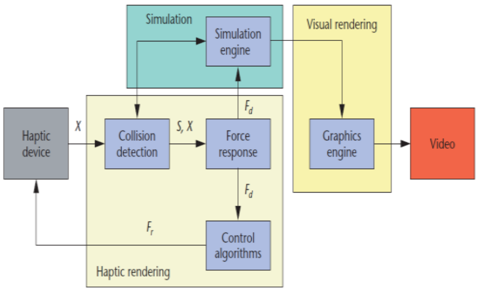

Figure3. Haptic Rendering Architecture

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; as we explain further later in the article. Desired force and torque vectors computed by force response algorithms feed the control algorithms. The algorithms' return values are the actual force and torque vectors that will be commanded to the haptic device.

The simulation engine then uses the same interaction forces to compute their effect on objects in the virtual environment. Although there are no firm rules about how frequently the algorithms must repeat these computations, a 1-KHz servo rate is common. This rate seems to be a subjectively acceptable compromise permitting presentation of reasonably complex objects with reasonable stiffness. Higher servo rates can provide crisper contact and texture sensations, but only at the expense of reduced scene complexity (or more capable computers).

V. APPLICATIONS OF HAPTICS TECHNOLOGY

A. *Surgical Simulation and Medical Training.*

Various haptic interfaces for medical simulation may prove especially useful for training of minimally invasive procedures (laparoscopy/interventional radiology) 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*. 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. Haptic interfaces are also used in rehabilitation robotics. In ophthalmology, "haptic" refers to a supporting spring, two of which hold an artificial lens within the lens capsule (after surgical removal of cataracts).

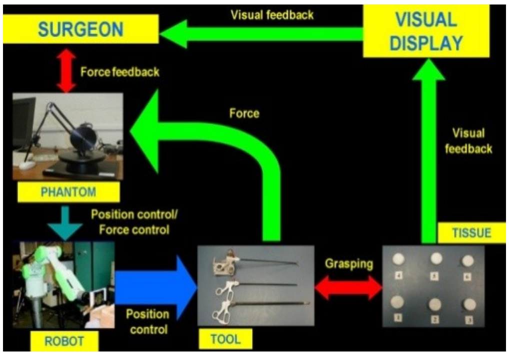

Figure 4. Surgical Simulation and Medical

A 'Virtual Haptic Back' (VHB) is being successfully integrated in the curriculum of students at the Ohio University College of Osteopathic Medicine. Research indicates that 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 (Sensable Technologies, Phantom 3.0). 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.

B. *Military Training in virtual environment.*

From the earliest moments in the history of virtual reality (VR), the United States military forces have been a driving factor in developing and applying new VR technologies. Along with the entertainment industry, the military is responsible for the most dramatic evolutionary leaps in the VR field.

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. Some training procedures have an element of danger when using real situations. While the initial development of VR gear and software is expensive, in the long run it's much more cost effective than putting soldiers into real vehicles or physically simulated situations. VR technology also has other potential applications that can make military activities safer.

Today, the military uses VR techniques not only for training and safety enhancement, but also to analyze military maneuvers and battle field positions. In the next section, we'll look at the various simulators commonly used in military training. Out of all the earliest VR technology applications, military vehicle simulations have probably been the most successful. Simulators use sophisticated computer models to replicate a vehicle's capabilities and limitations within a stationary -- and safe -- computer station.

Possibly the most well-known of all the simulators in the military are the flight simulators. The Air Force, Army and Navy all 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.

Although flight simulators may vary from one model to another, most of them have a similar basic setup. 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**. The word "haptic" refers to the sense of touch, so a haptic system is one that gives the user feedback he can feel. A joystick with force-feedback is an example of a haptic device.

Some flight simulators include a completely enclosed module, while others just have a series of computer monitors arranged to cover the pilot's field of view. Ideally, the flight simulator will be designed so that when the pilot looks around, he sees the same controls and layout as he would in a real aircraft. Because one aircraft can have a very different cockpit layout than another, there isn't a perfect simulator choice that can accurately represent every vehicle. Some training centers invest in multiple simulators, while others sacrifice accuracy for convenience and cost by sticking to one simulator model.

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.

The FCS simulators include three computer monitors and a pair of joystick controllers attached to a console. The modules can simulate several different ground vehicles, including non-line-of-sight mortar vehicles, reconnaissance vehicles or an infantry carrier vehicle

The Army uses several specific devices to train soldiers to drive specialized vehicles like tanks or the heavily-armored Stryker vehicle. Some of these look like long-lost twins to flight simulators. They not only accurately recreate the handling and feel of the vehicle they represent, but also can replicate just about any environment you can imagine. 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.

*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.

VI. LIMITATIONS OF HAPTICS SYSTEM

Limitations of haptic device systems have sometimes made applying the force's exact value as computed by force-rendering algorithms impossible.

Various issues contribute to limiting a haptic device's capability to render a desired force or, more often, desired impedance are given below.

1) Haptic interfaces can only exert forces with limited magnitude and not equally well in all directions, thus rendering algorithms must ensure that no output components saturate, as this would lead to erroneous or discontinuous application of forces to the user. In addition, haptic devices aren't ideal force transducers.

2) 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.

4) Finally, haptic device position sensors have finite resolution. Consequently, attempting to determine where and when contact occurs always results in a quantization error. Although users might not easily perceive this error, it can create stability problems.

VII. CONCLUSION

Finally we shouldn't forget that touch and physical interaction are among the fundamental ways in which we come to understand our world and to effect changes in it. This is true on a developmental as well as an evolutionary level. For early primates to survive in a physical world, as Frank Wilson suggested, "a new physics would eventually have to come into this 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."

VIII. FUTURE VISION

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. We're only beginning to understand the psychophysical and cognitive details needed to enable successful multimodality interactions. For example, how do we encode and render an object so there is a seamless consistency and congruence across sensory modalities—that is, does it look like it feels? Are the object's densities, compliance, motion, and appearance familiar and unconsciously consistent with context? Are sensory events predictable enough that we consider objects to be persistent, and can we make correct inference about properties? Hopefully we could get bright solutions for all the queries in the near future itself.

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