Haptic Technology

University Physics II Honors Project Paper

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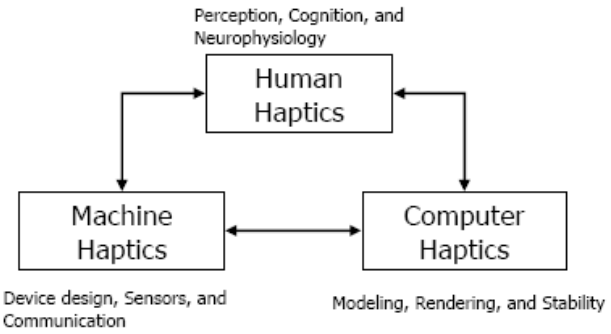
Introduction

Haptic technology is created from the word “haptein” which means to hold. It is specifically the interaction of humans and the world around them, specifically by touch. This can be through the use of their sense of touch or through the use of some kind of machine in a virtual world that replicates a certain situation. Haptics became its own study in the early 90’s as a result of other studies such as robotics, communication, virtual reality, and more. Soon, so many breakthroughs and discoveries were being made in each of these fields in the way of virtual reality mixed with communication and robotics that it became its own field of study. The majority of the haptic studies can be broken into three main categories which are: human haptics, machine haptics, and computer haptics. Human haptics is specifically the study of how humans themselves interact with their environment through touch without the aid of a machine or computer. This is just the average touch that is felt through the nerves in the skin. Machine haptics is the area that pertains to the study and creation of machines that will replicate physical attributes in the real world such as magnetic fields, friction, and viscosity. Lastly, computer haptics is the field that studies the ways these virtual worlds can be created and interact with the machines that are created to accomplish these tasks. All three of these fields are closely related and affect each other as shown in the diagram below.



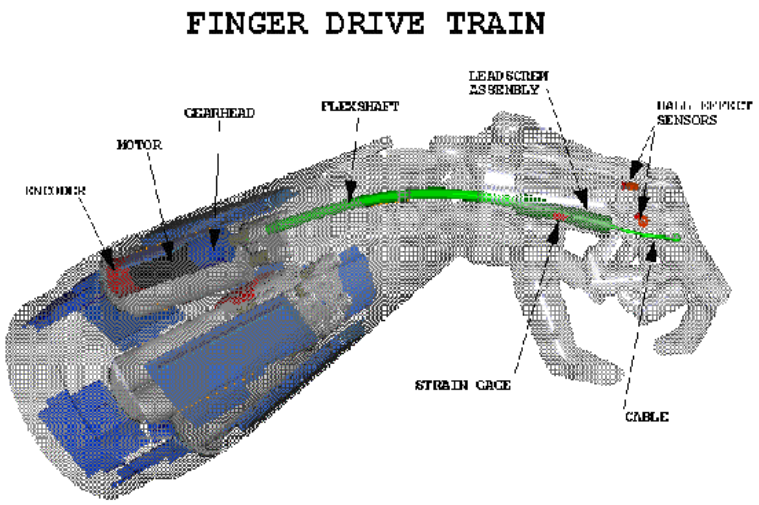
Applications of Haptic Technology

Haptic technology is being applied to many areas of learning and training. This is because of the haptic technology's ability to create an extremely realistic world by replicating all the physical forces that are surrounding us. Haptics can be used to teach visually impaired students important aspects of science such as magnetic fields, viscosity, molecular structure, and other forces. All of these would be difficult for a blind student to learn since most other students learn these aspects in the lab visually. Now, studies are being done to use haptic technology with different machines to teach visually impaired students these different scientific subjects. One of the machines that are subject to testing right now is the Novint Falcon. It was originally created for the purpose of replacing a mouse or a joystick when playing computer games. Now, certain games are being programmed using this device to teach blind students science subjects. As seen in the image, the Novint Falcon is a simple device with a large circular hub in the center with three extensions coming out that converge again on a smaller orb. This smaller orb is what is held by the student and can be moved in every direction. One such program that is being written and tested at the University of Arkansas has a student hold the orb and move it around a virtual object that is created on the screen. This object can have many different surfaces such as a rough, coarse sand paper or smooth ice. The extensions coming out of the Falcon then resist motion accordingly so that the student can feel the force of friction that is on the surface on these objects. Also, the virtual object can be

made of different materials such as molasses so the student can test out viscosity. This program can also represent pulling forces such as centripetal force. It does this by creating a virtual system where the circular orb is attached by a string to a heavier ball. Then when the students move the orb around he will feel the pull of the object attached by the string. All of this is done by the motors that are being run in the large hub of the falcon. Each individual arm has its own motor that can apply any force in any direction. The computer that the machine is connected to gives an update to the Falcon every $1/1000^{th}$ of a second. This updates the cursor's position and whether or not there is a force that needs to be applied and in what direction it needs to be applied in. Also, some haptic units can give tactile feedback. This is not forceful feedback but the feedback that is generated by the nervous system such as heat. This is done by sending a small electric current into the user's skin that will cause them to sense heat. This will allow students to learn about chemical reactions and thermodynamics of a system and friction.

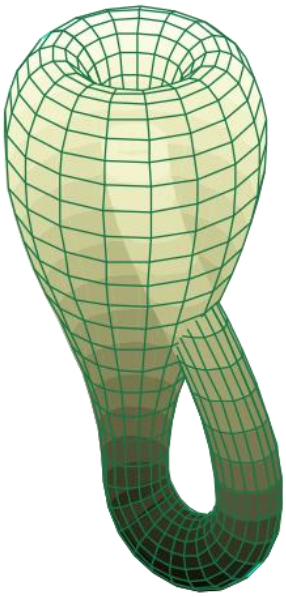
Education is not the only thing that haptic technology can be used for. It can also be used for training and simulation in areas that require very little error. One example would be surgery. A haptic machine connected to a computer can replicate the inside of a human body exactly. It would be bad if a surgeon practiced by trial and error on real people, there is not much room for the doctor to make mistakes when a life is on the line. Because of this, doctors need to rigorously train in hands-on experience but not many people are going to volunteer to let a new doctor cut into them and play around. However, all of this can be avoided with the use of haptic technology. The doctor can

run through many scenarios in the operating room on a virtual human with haptic machines. Another job with little room for error is that of an astronaut. NASA is in the process of developing a robot that uses tactile feedback of haptic technology to commit certain actions called Robonaut. NASA has been trying to develop a completely automated system in space that could do experiments and such without the need of human operators. Although, researchers are realizing that there are just some tasks that cannot be automated. These tasks will always be done by humans. This situation can be aided with the use of haptic technology in robots such as Robonaut. Robonaut is essentially a robotic astronaut that is controlled by an operator that is wearing a pair of gloves or suit that has sensors on it which are transmitted to the robot. These gloves and suit use some tactile feedback and force feedback from the robot to simulate its surroundings, however, visual feedback is still typically necessary to the operator's success. Below are images of the Robonaut (on the left) and an example of the glove that is used to control the robot (on the right).



Haptic research is, however, not only focusing on the possible but the impossible. Situations are being proposed such as what would it be like to pick up an airplane on an asteroid, or play with a yo-yo on a different planet? These questions would be impossible to answer without extreme amounts of funding, a lot of time, and a lot of personnel. All of this should not be necessary to answer such simple questions that can be answered with mathematics but can't be experienced firsthand…until now.

Dr. W. S. Harwin is a professor of Interactive systems. He teaches and leads research teams at the University of Reading in Reading, Berkshire in England. The college has been regarded as one of the top research universities in the world. Dr. Harwin and his team in the Department of Cybernetics are working on creating haptic environments that allow users to touch, manipulate, and move objects in a virtual environment that can replicate anywhere in the universe. His team has already created the first real Klein bottle, which can only be recognized in the fourth dimension because it must pass through itself without the presence of a hole, in a haptic environment where it can be held and recognized. A replica of this object in the third dimension can be seen on the left. The team has also created a virtual drum kit where the drummer is able to play on both sides of the drum one side being a snare drum, and the other a bongo. Other instruments can be positioned around them where it is most convenient and do not have any limit of how big or small they can be but still produce their necessary sound. Dr. Harwin commented



on haptic technology by saying, "The ability to provide computer synthesized illusions of touch sensations has been very limited prior to the development of haptic interfaces. Until now, the technology has been limited to simulations of single point or probe contact, whereas tactile exploration is often multi-fingered and relies heavily on vision to support the perception. Our latest project has seen significant steps toward creating the hardware, software and control foundations for a high-fidelity, multi-finger haptic interface device. This gives a high degree of realism, and because we can model free-floating three-dimensional objects the user can explore all sides – top, bottom, front and back."

The Physics of Haptic Technology

Haptic technology would not be successful without a complete understanding of physics and the application of physics on the virtual environment being created. For optimal realism in the virtual environments, the physics must be solid and in sync with the machine and computer that is creating the environment and reading the feedback from the user. The main physical law that is used is the concept of force. It is difficult to recreate mechanical energy and other concepts like that. According to the International Society for Haptics, the three main reasons they chose force specifically to replicate real life in a virtual environment are:

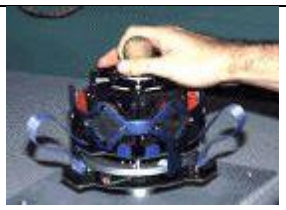
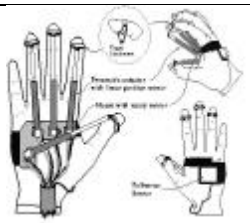
1. Force is a concept that is readily related to everyday experience. Its intuitive meaning provides a good approximation to its precise physical meaning. As a

result, using the concept of force allows for a simple, accessible introduction to the workings of haptic technology.

2. The most commonly available haptic interfaces can be defined as force-producing devices, and they are used and programmed accordingly.
3. For many practical uses of haptic technology, the concept of force allows expressing haptic interaction in simple, convenient terms.

Also, an understanding of physics is necessary in the creation of haptic machines, not just the virtual environment. Haptic machines can be run by several different methods whether it is with electric motors, a hydraulic system, or a complex system using magnets. The Novint Falcon, as mentioned earlier in this paper, is an example of a machine that uses electric circuits to run each of its motors. Below is a table of different haptic machines and what technology they used to create said machine.

Name	**Technology**	**Picture**
Sidewinder Force Feedback Pro Created by Microsoft	DC Motors Low Bandwidth/Resolution	
MouseCAT Created by Haptic Technologies	DC Motors	

Magnetic Levitation **Haptic Interface** Created by Berkelman	Magnetic Levitation	
RMII Created by Burdea	Pneumatic	

One of the haptic machines mentioned above uses magnetic levitation. Many new machines are being created using magnetic levitation. The advantage to using magnets is that with electrical motors there have to be multiple different motors to include all directions along the x, y, and z axis. With magnets, there is only one moving part. This means, the machine can represent a single point in space that is just floating with the power of the magnets being regulated by a computer that is connected to the machine. Also, when the use of motors comes into play so does friction. Each motor, even though it runs smoothly, will have different degrees of friction because of all the parts grinding together. Since there is essentially no friction, this provides the machine to have the ability to be extremely accurate. This degree of accuracy gives the user the exact feel of the environment because of such high bandwidth and resolution with the machine. The main aspect of physics that the magnetic levitation relies upon is the use of Lorentz force on the floating object the user holds. Since Lorentz forces are so powerful the user has a wide range of how much force is applied to their hand. This gives the virtual environment the ability to apply a slight push or pull or have the effect

of hitting a solid object and not giving the slightest bit. Also, since the part the user holds is floating it offers six degrees of freedom of movement and sometimes seven if the machine is configured to have the ability to grasp a hold of something. One of the top machines on the forefront of magnetic levitation for haptic machines is the Maglev 200, produced by Butterfly Haptics, LLC (left). This machine is the candidate for advanced applications such as remote robot control, microsurgery, computer aided design, virtual dentistry, character animation, and surgical training.

What's next for Haptics?

Haptic technology is quickly becoming more complex and intricate. However, the questions stand, what future products can we expect and how will this affect our society? One type of haptic machine we can expect soon is the full body haptic suit. This suit will cover the whole body from head to feet able to represent any type of touch whether it be a soft breeze or a full on hit. However, as with any research, as questions are answered, more questions arise. The new question for this suit is what will it be used for? One type of activity being discussed is for entertainment purposes such as playing in a video game. If someone pushes you in an online virtual environment you will feel the push in real life. This will provide any gamer with the full submersion into the video game that so many desire. This will probably used for sport games, role-playing

strategy based games, and first person shooter military games. Another activity that is being discussed (but probably shouldn't be) is the idea of cybersex. This is still only to be found as rumors with no real research done on it but with these full body suits

covering the whole body the idea is becoming more and more of a possibility. Also, these full body haptic suits could be used to aid in military or local force training. The Office of Naval Research's VIRTE program is working to create a full virtual environment that will be used to simulate close quarter's combat for Marines in urban areas. The environment needs to able to do anything, creating environments that could be on fire, filled with gas or smoke, having marines maneuver around rubble, through doors, clear rooms, and even have them firing their weapons at virtual enemies. As in real life, the marines need to be able to have anything happen. The full body haptic suit is just one of the machines that we can expect to see coming in the near future. This suit is predicted to be fully operational and out by 2020.

Overview

Overall, haptic technology is extremely useful and will soon be in many aspects of our daily life whether it be training, education, or entertainment. And none of these machines or applications would be possible without the creators' full understanding of the laws of physics in the world. Physics is used in every aspect from the use of Lorentz force with magnets and electrical circuits to create motors to run the haptic machine to

the created virtual environment and how forces are applied in there to the user that is in control of the environment. Haptic technology is used also to complete the impossible. Since any world can be created and so can any object, haptic technology is proving to be one of the most useful tools in research. Haptic technology is still largely underdeveloped even though it has come very far in the past 20 or so years that it has been developed. Soon, haptic technology will be an average everyday use by the masses.

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