Haptico-A Haptic Enabled Robotic Interface

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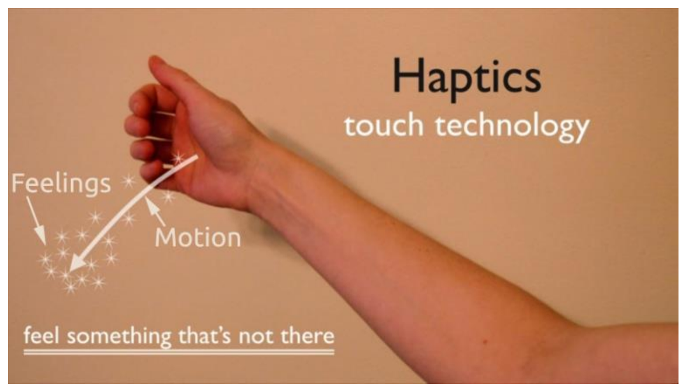
Abstract: Robots are playing a very important role in all our day to day life. The main intention behind making any robot is to reduce human effort. Depending upon the requirements, various types of automated and self-controlled robots are being implemented. As many robots which are already existing in the market are suffering from controlling issues and to overcome this, one of the nascent technology named Haptics Technology is discussed in this paper. This paper also discusses an approach for demonstration of a robotic arm for physically disabled people who cannot walk. For those people who cannot easily lift simple things (e.g. lifting a bottle filled with water). The development of a Robotic Arm which is controlled by a wireless medium is the theme of the paper and haptics technology is going to play a crucial role as far as implementation is concerned. Basically, our project setup is divided into two parts i.e. Haptic glove and robot arm. The area in which robot arm moves, depends upon the range of Zig-bee module and robot arm is controlled by the haptic glove. So by keeping all constraint and limitations this paper is going to discuss a review on the implementation of a low-cost robot arm using Haptic technology which performs multiple tasks using less number of resources and it is easy to use.

Index Terms: Haptic interface, Sense of Touch, Touch in Machines, Robotic Arm

1 Introduction

The word 'Haptic', is derived from the Greek term, Haptikos, which means "to touch". It is defined as the "science of applying tactile sensation and motion to human interaction with computer systems". It enables a manual interaction of the user with real, virtual and remote environment. Haptic technology permits users to sense, recreate and manipulate three-dimensional virtual objects with help of parameters such as shape, weight, surface textures, and temperature of their real-life counterparts. In our paper, we explain the basic ideas and implementation of Haptic Technology in various fields such as Surgical Simulation, Medical Training, Military operations, etc. Military operations often include many different areas; in one large scale military operation involved could be strategic, logistical, medical, communication, combat and maintenance areas. As new advances are being made in technical and electronic products and their applications, there is a need in the field of military to research and introduce new technologies, which could help in training and operating in different military areas. The using of new and advanced technologies can bring along advantages that can lead to large scale improvements in performance and exponential reduction in risks involved. In this paper we have discussed the fundamentals of Haptics technology, previous usage of haptic technology and how these touch-enabled devices are created to induce the sense of touch. We have also discussed the implementation of this technology by means of haptic rendering and contact detection. The use of haptics has the potential to drastically enhance the feeling of immersion in any training scenario, whether it is performed in a virtual reality simulator or in a real-life training situation. Thus, haptic technology can be widely used in training and simulations to create a better workforce while using minimal resources.



Feelings and Motion

2 Haptics

Haptics refers to any interaction that involves the sense of touch, and Haptic technology is the technology that interfaces with the user through the sense of touch. Haptics is the digitization of the biological sense of touch. Scientists and engineers all around the world have intensively worked on the

senses of audio and vision, but the research in the touch domain is still in its nascent stage. Even if we understand the biological aspects of touch to a much larger sense now, digitizing touch is still a long way to go. Inculcating haptics into traditional robotic interfaces can exponentially increase the accuracy, responsiveness and thus efficiency of the entire system. This is especially important in controlling remotely operated systems as distance and force applied cannot be easily determined by simply relying on individual sense of vision or audio. Combining senses of vision and audio along with touch feedback can drastically change the experience of a system user and thus provide the required output for any operation.

3 Biological Touch

Touch is the only human sense which is uniformly distributed throughout the body, unlike other senses which are concentrated in a specific region. The vast stretch of skin that wraps the human body is widely responsible for the sense of touch. Sensation of touch can be explained with two primary parameters – Feelings and Motions.

The Feelings describe the sensations that are experienced when the skin comes in direct or indirect contact with another body. The feeling helps the brain differentiate between cold, colder & coldest and warm, warmer & warmest. You can differentiate between glass, leather and a paper by simply running your fingers through the surface. The brain saves and links certain feelings with objects which you can feel even if you are not physically touching an object. That's why you can feel the hardness of a glass and the textures on a paper sheet, even if you just think about them and not actually touch them.

Motions are the forces that are applied either in the direction of the action or against it. A motion is the mixture of movement and resistance. When you touch an object with your fingers, your finger-tips, specifically skin, applies a force on the object. The object, obeying Newton's Third law of motion, applies a reactive force on skin.
Depending upon the magnitude of these forces and many other external forces, the two bodies may move in a specific direction at a relative speed. This movements or motions are very important in determining the actual location of the object in space relative to the human arm.

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4 Digital Touch

While the brain is perfectly able to sense and save touch feelings to some extent, we are still not able to do that in a digital format. Even after years of experimentation and research, man is not yet able to reproduce the feelings experienced while touching or the magnitude of the motions that follow the touch, in a manner that can be shared or stored. We can save what we hear in the form of .mp3 files and we can share what we see in the form of .jpeg or

.png files. But to store the sensations, a new type of container is required. We cannot simply listen to the rhythms of music and feel the exact feelings of the gentle touch of the pianist's fingers on the piano. We cannot feel the textures or smoothness of a wooden surface by rubbing our fingers on the pictures. We need something more than just these. We need a new set of containers that can define touch.

5 Understanding Touch

Touch is the physiological sense by which we perceive external objects or forces through contacts with the body. Our body is covered by a layer of skin which protects the inner, delicate organs from changing outer conditions such as temperature, pressure, humidity, radiations, etc. The skin acts as a filter allowing permitted amounts of the above-mentioned conditions to interact with the body. The skin is made up of a large number of pressure receptors, or sensory receptors that are all linked with the brains via neurons. Whenever the skin comes in contact with any external body, the pressure, acting on the area of skin in contact, changes. This change is calculated, compared, compressed and sent to the brain for processing. The brain processes the data that it receives from these receptors and sends a signal back to the skin. This signal contains the instructions that the body must follow to adapt to the change experienced by the body.

The brain is divided into different parts; each part controls a specific organ or system of organs. This division is represented using a representation system known as a cortical homunculus. It is the neurological "map" of the anatomical divisions of the body. When the body receives a touch sensation from a location, the receptors send the data to the part of the brain controlling that specific location and appropriately send the actions to be performed to react to the sensation.

6 Understanding Haptcs

Haptics is the science that deals with understanding various sensations experienced during touch and storing it in such a manner that can be reproduced later in the exact same manner in which it was originally experienced. When we touch something, our hands give us 2 types of feedback – Tactile and Kinesthetic. The tactile feedback has information such as contact location, pressure, shear, slip, vibration and the temperature. The kinesthetic feed-back has the information regarding the position, orientation, and the force.

By merging and syncing the tactile and kinesthetic feedback, various feelings and motions can be recorded. When this feedback is sent back to the body at some other location, the exact same sensations experienced at the original location of contact will be felt at the new location, although the original external object that was causing the sensations is not present in the new location. Thus, we will be able to transfer feelings from one body to another

Touch Feedback

6.1 Haptico Bot

Haptico Robot is a robotic interface which can provide haptic feedback to the user. In our project, we are building a robotic arm that will imitate the users hand motions and gestures, and will be providing real time 'feelings' to the user. The user will be wearing a glove, set up with sensors and actuators, which will be continu-ously and wirelessly transmitting the users hand movements to the robot and receiving information such as surface texture of the object, temperature, hardness and other similar data from the interface to the user.

The main difference between Haptico robotic interface and the traditional robotic interface is the lack of touch feedback in the latter. In traditional systems, the user relies only on his vision and audio sense. The problem here is if the user misses a single visual or audio signal from the system, there is a chance of inducing an error in the process. The benefit of using touch feedback is that the body is continuously observing the touch sensations. The us-er's body will be instantly alerted with even a slight feedback The current version of Haptico consists of a 3D printed arm, that is actuated using servo motors. The flexing of the fingers is con-trolled by the rotation of the servo motors. Each finger has a force detecting sensor attached to the tip that calculates the intensity of force being applied on the fingertip.

7 Review Of Literature

A. Five-Fingered Haptic Interface Robot: HIRO III
[Takahiro Endo, Member, IEEE, Haruhisa Kawasaki, Member, IEEE, Tetsuya Mouri, Yasuhiko Ishigure, Hisayuki Shimomura, Masato Matsumura, and Kazumi Koketsu]

7.1 ABSTRACT

The paper presents the idea, design, implementation and characteristics of a five-fingered haptic-enabled robotic interface called HIRO III. The aim of the HIRO III interface is to provide a highly precise three-directional force on the five human fingertips. The experimental system of HIRO III includes a 15-degrees-of-freedom haptic-enabled hand, a 6-DOF user interface arm, and a wireless control system. The interface, which consists of a robotic arm and a hand, can be implemented in a large workspace and can provide precise multipoint contact between the main user and a virtual environment & objects. However, a few problems that are peculiar to a multi-DOF robot have arisen during the experiment: a significantly large amount of friction backlash, and the presence of a large number of wires to control all the motors and sensors involved. Several experiments have also been carried out in different environments to investigate the performance and working of the HIRO III interface.

7 .2 CONTENT

We have described a newly developed five-fingered haptic inter-face robot known as HIRO III. A new design mechanism for a haptic hand and interface arm was introduced and the following functionality requirements of the haptic interface were achieved: a reduction of the static friction at the joint, a change in the connect position between the human and haptic fingertips to enable better grasping of a virtual object, greater compactness in size, and lighter weight. Furthermore, we have developed a compact wire-saving control system for the haptic hand and the interface arm. These systems are installed in the space inside the haptic inter-face. The force sensor, encoder, motor, brake for the motor, and zero-seeking sensor signals are input into the system and com-municate to the main control PC on a LAN. This eventually reduces the number of wires in the control system, thus increases the compactness, and enhances the portability of the interface. Finally, we carried out several experiments, the results of which showed the high-precision force presentation and the high potential of HIRO III.

Although the reduction of static friction at the joints was accom-plished by changing the transmission mechanism by incorporat-ing asymmetric differential gears, reducing the weight of the in-terface, and so on, we were not able to reduce the backlash at the joints. At the present stage, we consider that the motor's gearhead has the largest influence, and changing the gearhead is one of our future tasks. In addition, the inertia of the arm influences the performance of the force control of the haptic interface in the experiments. In this paper, we did not consider compensating for the inertia of the arm, but we will need to devise a dynamic control law that compensates for the interface arm's inertia as the next problem to be tackled. Furthermore, as an application of HIRO III, we have researched and developed bimanual haptic interface that can present three-directional force at the ten human fingertips of both hands.

HIRO at Japan Robotics 2005

B. FlexTorque: Exoskeleton Interface for Haptic Interaction with the Digital World
[Dzmitry Tsetserukou, Katsunari Sato, and Susumu Tachi - Toyohashi University of Technology, Japan]

8 FLEX TORQUE

The paper discusses a novel haptic interface named FlexTorque that allows realistic physical user interaction with real and Virtual Environments. The core idea behind FlexTorque interface is to recreate human muscle structure in the robot, which allows us to perform manipulations and interactions with the real and virtual environment in daily life. It also suggests new and promising possibilities for highly realistic, natural physical interaction in different virtual environments. There are no range or physical restrictions on the arm movement, and there is no need to hold a physical object or a controller during user's interaction with the objects in virtual reality environment. The system can easily generate required forces, even though it is light-weight, easily wearable, and intuitive, which enables the users to experience a new level of reality as they interact with virtual environments

8.1 ABSTRACT

The main highlighted features of FlexTorque interface are: (1) it presents a highly precise sensation to the user according to the interactive forces at play; (2) it does not, in any way, restrict or limit the natural motion of the arm; (3) it has wearable and easily manageable design; (4) it is extremely safe in operation; (5) it is highly portable and can be easily stored. These advantages allow for a wide range of applications in virtual reality systems and also improve game playing as we know it.

FlexTorque interface enables possibilities for extremely realistic, natural physical interaction of the user in different virtual environments.

In order to achieve human-friendly and wearable design of haptic display, we analyzed the amount of torque to be presented to the operator arm. Generally, there are three cases when torque feed-back is needed. The first case takes place when haptic communi-cation with remote human needs to be realized. For example, the user performs a handshake with the slave robot and torques at multiple joints are presented to the operator. Such interaction results in torques of very small magnitude. The second interaction takes place when robot transports heavy object. Here, the torque values are much higher as compared to the previous case.

8.2 OUTCOME

FlexTorque provides an amazing revolution in the way we interact with the digital world. In a constantly changing world, augmented and virtual reality are soon going to be an integral part of day to day human life and in such a scenario, it is very important to utilize the sense of touch to the maximum.

The paper helps in understanding the development and working of an interface which can directly affect the user's interaction with the digital reality. This technology can be implemented in our project to improve the process of remote operations and digital learning. Using a haptic based interface to teach or learn a skill can increase the memory retention rate and increase the learning speed by manifold.

9 Experimental Setup

9.1 Robotic Arm

The Robotic arm is 3D printed and is designed by French designer Gael Langevin. Multiple parts of the arm structure have been in-dividually printed and assembled. The arm has 5 Degrees of free-dom and can easily hold an object either by using all the fingers simultaneously or by just using the thumb & the index finger. Five servo motors are used to control the motion of each finger. The servo motor heads are connected to the fingers using fishing line. This is to ensure constant tension and no extension of the line on application of load.

The servo motors are controlled by Arduino Uno microcontroller. Using Xbee adapters, the Arduino will be continuously transmit-ting and receiving data from the user's glove. The Arduino will change the servo motor positions based on the inputs received from the user's glove.

Force sensitive sensors are attached to the tip of the robotic arm. The reading from this sensor is transmitted to the user's glove. Force sensor readings are also used to ensure the force exerted by the robotic arm on the object does not exceed the max permissible force.

9.2 User's Glove

The user can control the robotic arm by using the glove. The glove is fixed with flex sensors on each finger. These flex sensors are used to determine the amount of bending in the fingers. This val-ue is then sent to the robotic arm to proportionally bend the ro-botic arm's fingers.

Vibrating motors are attached on the glove. These motors will vibrate at intensities proportional to the value received from the force sensors on the robotic arm.

9.2 Arduino Uno

Arduino Uno is the brains behind the entire experiment. It is a microcontroller that accepts inputs, processes them and generate the required outputs. Two Arduino uno boards will be used on each interface ie. One on the robotic arm and one on the user's glove. The Arduino boards will communicate with each other using Zigbee protocol on Xbee adapters.

9.3 Xbee Adapter

Xbee is used to allow serial communication between two or more interfaces within a specified distance range. The xbees communi-cate on a widely popular Zigbee protocol. They will be used to transfer information simultaneously between the robotic arm and the user's glove.

10 Methodology

10.1 Design of Arm and Components

The design of the arm is the most crucial step since each part is individually created and then assembled together to form an en-tire arm. The design consists of the forearm, wrist, palm and five fingers. The design is inspired by the open source Inmoov project led by French designer and sculptor Gael Langevin.

The design files consist of 29 main parts which further contain many more sub parts. The design is edited and reworked on Solidworks 2016. The files are then saved as .stl files to ease the process of 3D printing.

The design helps to generate 5 Degrees of freedom in each arm and 16 Degrees of freedom in each hand. Each finger can be bent and flexed in a similar way as a human finger. The wrist can be easily rotated and twisted to provide better flexibility. The thumb acts as a human thumb and can be used for gripping and picking objects.

The design is made to ensure the electrical components fit perfect-ly in the space provided. 5 servo motors can be placed inside the forearm space. This ensures precise and concise use of space, thus improving the aesthetics of the interface without any loss to func-tionality.

The fingers are connected via fishing lines to the servo motors. This is to provide enough tension and strength in the fingers to perform in an optimum manner.

10.2 Fabrication of Arm and Components

3D Printers are used for fabrication as rapid prototyping can be done and to keep the fabrication cost of the system at minimum. PLA (Poly Lactic Acid) material is used for printing as it gives optimum hardness at room temperature and does not break easi-ly.

Use of 3D printers allow the possibility to make instant changes in the designs and prototypes and are very accurate. They also pro-vide a good surface finish. 3D printing cuts down the cost of building a dye and thus is the best fabrication method for making a single product prototype.

10.3 Design of Electrical Interface

The robotic arm is made to dimensions as per an average human arm. Thus, very less free space is available in the interface. The electrical components are placed such that they are easy to con-nect with the main Arduino boards, and can perform their func-tion efficiently.

The main electrical components on the robot's arm are servo mo- tors, force dependent sensors, servo controller and the Arduino Uno board with Xbee adapter.

The main electrical components on the user's gloves are flex sen- sors, vibrating motors, and the Arduino Uno board with Xbee adapters.

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