reFLEX : A HAPTIC INTERFACE FOR CONTACT LOCATION FEEDBACK OF HAND IN A VIRTUAL ENVIRONMENT

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

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IN

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COIMBATORE – 641 006.

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BONAFIDE CERTIFICATE

Certified that this project report **"reFLEX – A HAPTIC INTERFACE FOR CONTACT LOCATION FEEDBACK OF HAND IN A VIRTUAL ENVIRONMENT"** is the bonafide work of **"AMIRTHA RAMAN and AISHWARRYA PRAKASH "**, who carried out the project work under my supervision.

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declare that the project entitled **"reFLEX – A HAPTIC INTERFACE FOR CONTACT LOCATION FEEDBACK OF HAND IN A VIRTUAL ENVIRONMENT"**, submitted in partial fulfillment to Anna University as the project work for Bachelor Of Technology (Information Technology) Degree, is a record of original work done by us under the supervision and guidance of **Dr.S.Thangasamy, Professor**, Department of Computer Science and Engineering, Kumaraguru College of Technology, Coimbatore.

Place : Coimbatore

Date : 16.04.2005

[Amirtha Raman]

[Aishwarrya Prakash]

ACKNOWLEDGEMENTS

Doing this project has instilled new confidence in us by making us overcome many hurdles in the path, which tested us in many ways. The path has been illuminated by the support and timely ideas from many people. We are indebted to all of them.

We would like to begin by thanking our Department Head and our project guide, Dr.S.Thangasamy. He has made us understand that a project is a never ending one and that we have to define our boundaries. His critical eye on details has been instrumental in making us think through the process.

We are grateful to Mr.K.R.Baskaran, our Assistant Professor who has patiently reviewed our project and has given us timely suggestions. We particularly thank Mr.Thiagarajan, Mr.C.V.Subramaniam, various staffs and technicians who have shared their time to help us in different stages of the project.

Though indirectly involved, we are extremely thankful for the Maya community for their tutorials and discussions. They have helped us in rushing through the essentials of 3d world and Maya itself, in this short span.

And to Professor Kenneth.J.Salisbury, "Father of Haptics", whose quotes we have very often used to prove a point that tactile sensation is as important as other senses in Human Machine Interface, we are very grateful.

Our thanks can never match the involvement of our parents who form the user community of the reFLEX, who played "a devil's advocate" and been our greatest strength as well in completing the project, to what it is today and to make it to what it will be tomorrow.

ABSTRACT

Haptic interfaces aims at incorporating the sense of touch as an important faculty to enhance the Human-Machine Interface. The goal of the project is to provide a seamless interaction of the user with the virtual objects. For now the objective is a step in that direction-to provide user feedback as to where in the virtual environment they have placed their hand.

The challenges associated with providing tactile stimulations are formidable, requiring the proper depiction of visual entities, identifying the position of hand, relative positioning of hand, way to manipulate the objects, conveying the effective information through the sensory modalities and designing the information and its impact.

In our project reFLEX, essential and possible haptics is included. The user manipulates the object in the virtual environment through a virtual hand model. Based on the orientation and placement of the fingers, the object gets influenced providing visual cues. Which part of the finger comes into contact with the object is identified, and the actuator gets activated providing signals to the vibrators which imparts the feeling to the user. The number and position of the vibrators are static and is based on the most sensitive areas in the hand, but the impact is dynamic, based on the manipulation.

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LIST OF ABBREVIATIONS, SYMBOLS

Abbreviations

mll	– Maya Linked Library
API	– Application Programming Interface
DC	– Direct Current
HCI	– Human Computer Interface
IK	– Inverse Kinematics
JND	– Just Noticeable Difference
MEL	– Maya Embedded Language
MEMS	– Micro Electro Mechanical System
SDK	– Software Development Kit

Symbols

™	- TradeMark
®	- Registered

1

INTRODUCTION

Anyone [redacted] *dreaming*

has'nt tried haptics

We use our hands everyday to assess the size, shape and texture of objects. We sense and interpret tactile stimuli from our environment and perform tasks with our hand in a nearly instinctual manner. The ability to discriminate among texture surfaces, sense incipient slip and roll the object between fingers without dropping it can be attributed to the specialized mechanoreceptors in the hand. These touch receptors possess unrivaled range and acuity. They respond to both static and dynamic stimuli as well as temperature and pain. We are also equipped with reflexes and automatic responses that allow us to make use of tactile information without expending cognitive efforts. Despite the obvious importance of tactile cues in our everyday life, the subject of tactile display for teleoperation, virtual reality and more generally human-machine interfaces, has only recently received significant attention.

In our attempt to use the tactile feedback for graphical applications, we have begun by providing a scenario where the user interacts with the object on the screen with the virtual hand. It is implicit that the user is not aware of where exactly their fingers contact the object. Some information is received through visual feedback regarding their contact position. We provide vibratory stimuli to augment the information base. The user will be able to manipulate the object through the keys that pose the hand.

Various methods are followed to provide such tactile feedback and finding better ones itself form an important research area. Apart from identifying them, incorporating them effectively is essential.

1.1 Existing System

*T*o date, most human-computer interactive systems have focused primarily on the graphical rendering of visual information and, to a lesser extent, on the display of auditory information. Among all senses, the human haptic system provides unique bidirectional communication between human and their physical environment. Current systems are seemingly handicapped as of now, since a tactile feedback is absent in them, which if present will be an important enhancement.

*T*otal information is not conveyed to the users from the current systems and the real potential of computers in providing dexterous manipulation of objects is not tapped as it lacks the tactile element. This obviously relates to the bottle-necks in remote handling and teleoperations of objects, apart from 'virtual reality' applications which will form a major portion of computer needs in the near future.

1.2 Haptic Interfaces – Adding value to existing system

Extending the frontier of Human-Computer Interaction, haptic interfaces or force feedback devices increases the quality and capability of HCI by exploiting our sense of touch and ability to skillfully manipulate objects. The direct physical interaction with the computer generated objects enabled by haptic interfaces provides an intuitive augmentation to visual display and enhances the understanding of, and interaction with complex data sets.

*S*everal novel applications that could use haptic technologies include molecular docking, nanomaterial manipulation, surgical training, virtual prototyping, and digital sculpting. [Ming Lin et al. 2004]

1.3 Motivation and Contributions of reFLEX

*F*or virtual reality, when advanced graphics and sound is augmented by vibration and force feedback, one's perception is altered and one becomes immersed in artificial reality. [Burdea 1996]

*S*imilarly, telemanipulation systems have heavily relied on vision feedback and have required experienced operators. It has been shown, however, that adding the sense of touch to these systems connects the operator to the remote environment, making the system more intuitive. [Dennerlein et al.1997]

*P*erhaps even more important than the sense of realism that tactile feedback creates is, its ability to leverage innate human tactile ability. With tactile sensation at their fingertips human can bring their extensive experience in handling the objects. In areas where touch is extremely important as in medicine, we create the ability for telesurgeons to palpate and probe the biological tissue as if they where touching the objects with their own hands. The new appeal of such interfaces, the amount of effort going around and the interesting challenges it poses, to create a rich interface, is a strong motivating factor to pursue this project.

The major contributions of the project reFLEX are:

- A new framework that gives contact feedback through vibrations
- A visual modeling of hand and an API interface to manipulate it
- An extension to the modeling software by allowing it to communicate to the hardware through the new customized reFLEX plug-in
- Evaluation and manipulation of objects being touched and providing textual, visual and tactile cues
- A prototype that can be extended to provide better information if other means of force feedback is chosen

1.4 Report Outline

This report is organized into seven chapters. This chapter provides a bird's eye view of the project, its primary motivation and the contributions.

Chapter 2 introduces the architecture and design goals of this project. It will consist of discussions of the overall design.

Chapter 3 discusses various approaches that can be used to provide force feedback and the method this project will use. The characteristics of hand that are of importance are discussed.

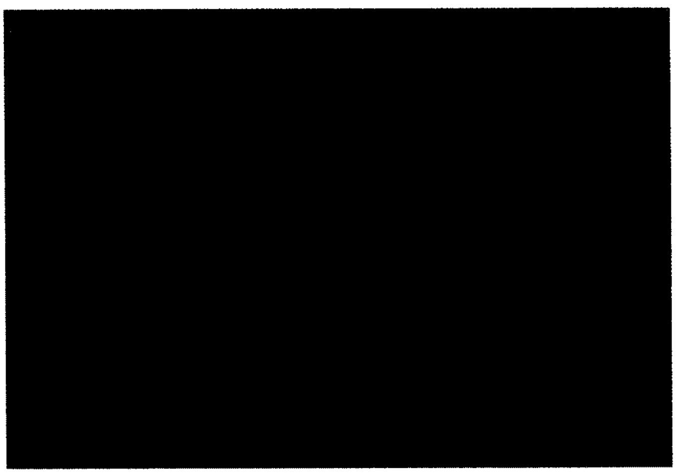
Chapter 4 reveals the platform that is used for developing this project. It familiarizes the readers with the software that is used and the reasons for choosing it.

Chapter 5 details the development of reFLEX in relation to its technical details and modules. It reviews the possible and necessary position locations of placing the vibrators in the fingers.

Chapter 6 and 7 summarizes what reFLEX has achieved, its test results, and suggests possible future enhancements.

2

DESIGN ARCHITECTURE



Energy lost in one form is regained in another form

The architecture of project reFLEX shown below (Figure 2-1), depicts the information flow belt across the various blocks that form the elements of reFLEX.

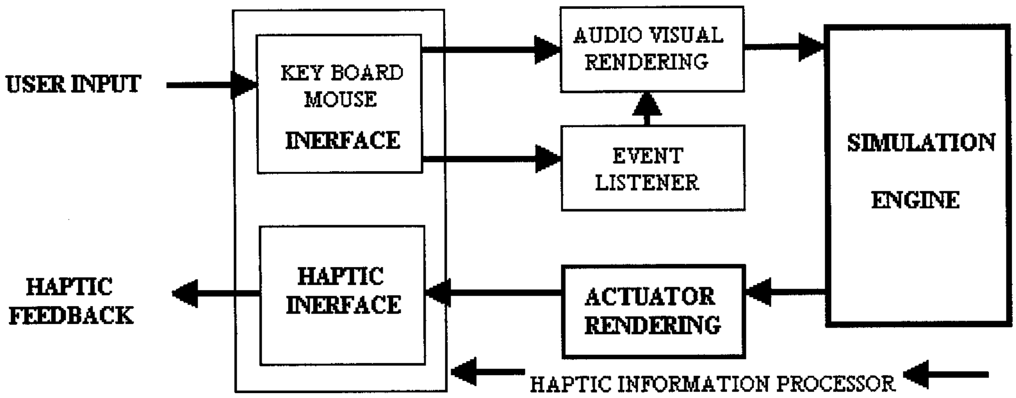


Figure 2-1. Architecture of reFLEX

In this, the user interacts with the system through the interface. Using the keyboard and mouse, the user provides input to the system. The inputs are primarily of selection and keying type which actually manipulates the API interface. These events are handled which in turn manipulates the virtual hand. Audio – visual rendering is the default action taken upon these inputs. Apart from these, the events result in notable changes in the environment in terms of textual and visual cues.

The simulation engine evaluates the changes to the hand and influences the objects on the screen accordingly. Based on the analysis of contact locations, the actuator is activated. The actuator assembly converts the signals into vibrations and the user feels the haptic response corresponding to the virtual region their input has affected. This conveys more information than the visual representation alone.

2.1 Design Goals

*S*ince user interaction is the most important aspect and the application is more of virtual reality type, care has to be taken in striking a balance between reality and representation. In short the interface has to be smooth.

- A good API design for the user to interact with
- Realistic depiction of hand and finger movements as per inputs
- Proper visual feedback of manipulated objects
- Textual feedback to show the history of operations
- Limited load of vibrations on the hand through vibrators
- Correct placement of vibrator motors on the hand
- Co-ordination of visual and tactile feedback to give a realistic experience, with limited rendering needs for a quick response

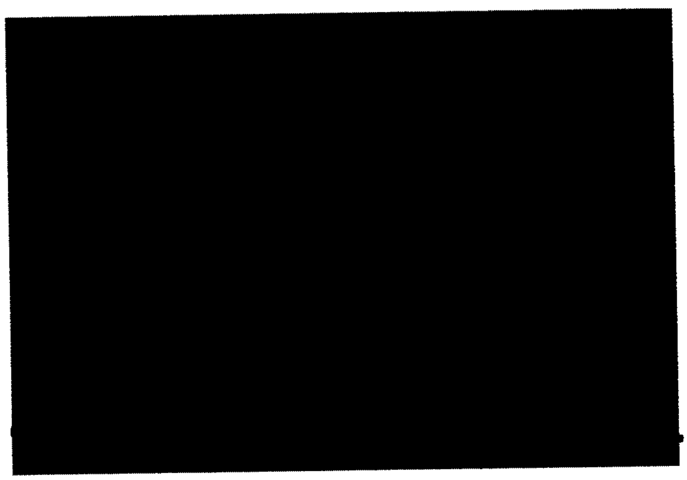
2.2 Discussions

*O*utput to the user is not purely haptic in nature; it is implicit that visual feedback and to a lesser extent audio feedback is also used. But co-ordination of all these faculties is an important consideration.

*T*o convert the inputs into effective changes, some methodology has to be used. The software interface should be self-explanatory and the user should be able to get immersed in the environment. The vibratory feedback should vary in amplitude and position relatively quickly and the change should be clear enough to convey the information. The information itself has to be designed.

3

UNDERSTANDING DESIGNING CHALLENGES AND DESIGN CHOICES



The transition is through design!

Designing hardware meant to convey artificial touch to human hand is a significant challenge. The primary reason is that our hand is incredibly sensitive to even the slightest vibrations over a range from 10-100 Hz. To help define the design requirements of such hardware, it is crucial to understand the underlying tactile sensing mechanisms. Not only will this serve as a source of inspiration for improving tactile sensor designs, it will also help focus on which signals are important to communicate and how to communicate them. Although this is requisite knowledge, there is more to consider than simply the neurophysiology of touch. Our sense of touch is a fusion of tactile and kinesthetic information. The combination of cutaneous and kinesthetic sensing is referred to as haptic perception. At high level, it is the perception or interpretation of these signals that ultimately interests us. For this, rest of the chapter would be a good start.

3.1 Human Mechanoreception

The human hand contains a complex array of specialized receptors that are rugged enough to survive repeated impacts, while retaining the ability to detect faint vibrations and softest touch. Neurophysiologists have identified four main types of tactile mechanoreceptors. Each is specialized to isolate specific sensations such as pressure, shear, vibration or texture [Provancher, 2003].

Psychophysics, which is a subfield of cognitive psychology, arose out of the desire to quantify the relationship between "sensations in the psychological domain and the stimuli in the physical domain" [Gescheider

1997]. Tremendous work has been done by scientists in determining the sensory thresholds for human perception.

Researchers in this field have measured both absolute and relative thresholds for every imaginable sensory modality. Absolute threshold refers to the minimum stimulus necessary to be registered as a perceptible sensation, whereas a relative threshold (JND: Just Noticeable Difference), represents the minimum difference required to distinguish between the two signals.

The most sensitive response of the human skin occurs at about 200Hz at amplitudes greater than 1μm, while additional sensations occur at about 250Hz. The linear displacement of amplitude must be greater than 0.015 inches (380 microns). The adaptation time lies between 100-200 microseconds. When human skin is exposed to constant forces over sustained periods, the ability of the fingers to sense magnitude and direction of forces being applied deteriorates temporarily. Furthermore, human fingers cannot sense forces below 0.2 N/cm^2 with a resolution limit of 2mm spacing. Yet, human fingers get fatigued when exposed to large pressure for long periods. In all tactile feedback systems, as the number of skin contact elements per unit area decreases, so does the effectiveness of the touch feedback. At the other extreme, as the contact points increases beyond a point, no further useful information is received by the fingers. The threshold point is where the spacing between two skin contact points is equal to the minimum distance between two points that the human skin can discriminate at that location. This is referred to as ***the two point discrimination ability*** of the human skin. Thus contact areas should be carefully designed considering all these factors.

3.2 Approaches to Tactile Feedback

There are a variety of methods that provide the user with the touch feedback in a synthetic environment. Some of the prevalent ones are discussed below:

I. **Visual Display System**: It is an indirect method of providing feedback. Here the status of the slave finger is indicated by the appearance of an icon or by the display of the slave fingertip forces. One approach displays the location of the two – fingers and the object boundary as two icons which help to relate them easily. But this method limits the user to slow finger movements and has limited use.

II. **Pneumatic Stimulation:** Three versions of this method is available – air jets, air pockets and air rings. Here an array of say, air jets force air against the ventral surfaces of the operator's finger which provide touch feedback. This can be made complex to vary pressure and direction to provide better feedback. But the system has inherently slow response.

III. **Electro Tactile Stimulation:** Here mini electrodes are attached to the operator's hand, which provide electrical pulses of appropriate width and frequency. The resulting trickling sensation gives an impression that the slave fingers are touching something. But this method gives a raw feeling to the user.

IV. **Magnetized Vibrating Voice Coils:** The vibrating voice coils are placed beneath the user's hand. The voice coil utilizes the internal moving electromagnet with a fixed external magnet. This makes the voice coil transmit low amplitude, high frequency vibrations to the user. It consumes comparatively higher power and will be complex.

V. **Functional Neuromuscular Stimulation:** This method is based on embedding signaling chips underneath the skin which is studied in the area of MEMS (Micro Electro Mechanical System). It is only in future that this method can be established as it is still in its starting stages.

3.3 Approach followed in 'reFLEX'

A variation of vibrating voice coil method is used in reFLEX. A vibrator is used to provide the vibrations unlike the voice coil used by its counterpart.

The vibrator is a DC motor capable of varying the number of rotations per second proportional to the power supply. At one of its end is a load purposefully mounted asymmetrically, off the motor shaft's center. As the motor rotates the load too does so but in an unstable manner causing strong vibrations.

This method is the most suitable one for it is compact, requiring voltage in the range of 1 to 3 V. Moreover, its commercial availability, cheaper cost and ease of incorporating for reFLEX have made it the choice for the project.

4

DEVELOPMENT PLATFORM

Whe [redacted] *hand*

Give it the nothing but the best

One of the world's most powerful integrated 3D modeling, rendering, animation and visual effects solution, Maya, is used for the visual representation of the virtual environment in this project reFLEX. This section provides the readers with a first hand notion of Maya and its features with respect to this project.

4.1 About Alias|***wavefront***

Maya® is from the house of Alias|Wavefront, a division of Silicon Graphics Limited. For 20 years, Alias has been the world's leading innovator of 3D graphics technology. Today we will find them delivering award winning software solutions for the film, video game, interactive media, industrial design, corporate communication and visualization markets. In addition to Maya, now in its 8th major release, other graphics application the company develops include the design visualization suite, StudioTools®, and the newly released 2D stylus-based application, Alias SketchBook Pro™. The Academy of Motion Picture Arts and Science awarded Alias|Wavefront an Oscar for scientific and technical achievement for the development of Maya in 2003.Its products cater to a wide range of companies like BMW, CNN, Disney, Nintendo, Weta digital, Industrial Light & Magic, etc.,

4.2 Introduction to Maya and its Features

3D graphics and animation can take the projects to a higher level and Maya is the solution that most software professionals turn to. It is the most comprehensive package for creating 3D and 2D graphics and its intuitive, customizable user interface and artist friendly brush based tools makes its industry standard features easy to learn and use.

Maya commercially is packed into two options with lots of features which include:

- **Intuitive User Interface** – It has an array of ease-of-use tools such as marking menus and interactive manipulators. Also it has self-learning tutorials with Instant Maya which has practical lessons support quick learning by briefing on fundamentals.
- **3D Modeling** – It has an entire suite of **polygonal** modeling and UV editing tool that focused on games, interactive media. Also a wide range of advanced curve and surface modeling through **NURBS** technology, and **Subdivision Surface** modeling which provides choice of hierarchical subdivision surface and polygonal meshes.
- **General and Character Animation** – A comprehensive set of keyframe and non-linear animation editing tools along with advanced tools for creating, animating and editing realistic digital characters, and adapting and reusing animation data.
- **Deformers** – A range of sophisticated deformation tools for modeling and animation. They help to create realistic character setup.
- **Dynamics** – High speed precision manipulation of hard and organic objects determined by physical rules helps representing rigid and soft body dynamics. It also has fully integrated particle effects controlled by forces based on real world physics.

- **Maya Artisan** – It is a highly intuitive pressure sensitive brush interface for digital sculpting, component selection and attribute painting.
- **Multiple Integrated Rendering** – It includes Maya native software renderer, the hardware renderer (proper graphics card required), vector renderer - capable of producing bitmap and vector outputs including Macromedia Flash. A unified rendering workflow provides easy and consistent access to all four renderers through a common interface.
- **MEL™** - The Maya Embedded Language is a scripting tool allows the programmers to extend Maya's capabilities, add in-house and fully customize the Maya user interface.
- **Maya API/SDK** – A full Application Programmer's interface opens up Maya's architecture for the development of plug-ins and translators that extend the range of Maya's functionality and enable the software to interface with other systems. It has an integrated set of plug-in resources.
- **Maya Cloth and Fur** – It provides the most accurate, production proven software solution for simulating a wide range of clothing and fabric. Fur enables realistic styling and rendering of short hair /fur with Maya Artisan interface.
- **Maya Live** – It enables precise match moving of 3D elements in Maya with original live action footage.

- **Online Documentation and Tutorials** – This helps the artists hone their skills and take full advantage of what the software offers. Extensive task-based, online help and comprehensive reference material search capabilities are provided.

Apart from these, there are many innate features that are available in Maya which is now in its eighth release as Maya 6.

4.3 Maya Options

Commercially Maya is available in two options:

1. **Maya Complete** - This integrates the world's foremost animation, visual effects, modeling, rendering into one complete workflow solution. It includes modeling, animation, dynamics, rendering, brush based technologies, connectivity and integration, Maya API/SDK and MEL, tutorials and documentation.

2. **Maya Unlimited -** It has all the functionalities of Maya Complete and provides artists and animators with additional industry leading-leading innovations for superior digital content. Apart from the basic tools of Maya Complete, it also has Maya Fur, Maya Cloth, Maya Live, and Maya Fluid Effects.

Alias provides a free Personal Learning Edition of the latest version of Maya.

4.4 Requirements posed by Maya

Different from contemporary non-graphical software, this high end 3D package requires more processing power and graphical support. Since it has to carry out precise graphical processing like rendering which takes a lot of time, it is implicit that a good hardware support is a vital.

- **Hardware Requirement**

  Processor - Intel Pentium® II or higher; AMD Athlon™ equivalent;
  Minimum 200 MHz

  RAM - 512 MB or more for good quality; a min of 128 MB

  Graphics Card - Hardware accelerated OpenGL® graphics card

  Mouse - 3 button mouse with associated driver

  Disk Space - 450 MB or more

- **Software Requirement**

  Operating System - Microsoft® Windows XP/ 2000 or higher
  Or SGI® IRIX 6.2.15
  Or RedHat™ Linux 7.3 or higher
  Or Apple® Mac OS X 10.2.4 or higher

  Interface Software - Microsoft Visual C++ or C++

  Browser - Internet Explorer® 4.0 or higher / Netscape® 7.0 or higher

Apart from Maya, Microsoft Visual C++ is also used to develop plug-ins for the project reFLEX. Maya Complete 4.0 is the edition used for the development of the virtual environment of reFLEX.

5

IMPLEMENTATION WORKFLOW

feasibility makes no sense

The reFLEX workflow is organized modularly. Initially the scene elements are created, followed by modeling the impact of interaction visually by deformation of objects and motion of hand. An API interface is created for the user to manipulate those elements. This information is communicated to the actuator through the plug-in. The actuator hardware is integrated separately and interfaced with the software through the printer port (Refer Figure 2-1). The process is detailed below.

5.1 Modeling the Virtual Environment

The virtual environment is chiefly a visual representation. The scene consists of a soft ball and a virtual hand. The hand will be capable of manipulating the ball and is flexibly.

5.1.1 Creating the Soft Ball

The soft ball is a polygonal sphere and is assigned a fur material over it. Some considerations while creating the ball are fur density, lighting direction, opacity attributes of fur, etc., These are important because the soft ball is central to visual representation. By 'soft' we mean the ball can be pressed, crushed and deformed as per pressure applied on it. How such deformation is achieved will be discussed in section 5.1.3.

5.1.2 Creating the Virtual Hand

The hand is a complex structure even in 3D modeling but not as complex as the real hand.

- First, the hand like proxy is created using polygonal and subdivision surface modeling methods. Now, it is a dummy structure. (See Figure 5-1)

- In order to make the hand move and react naturally, skeletons are to be added to the proxy, similar to the real hand. But, the placements of skeletons and joints depend on our required movements and they do not correspond to their real world counterparts.

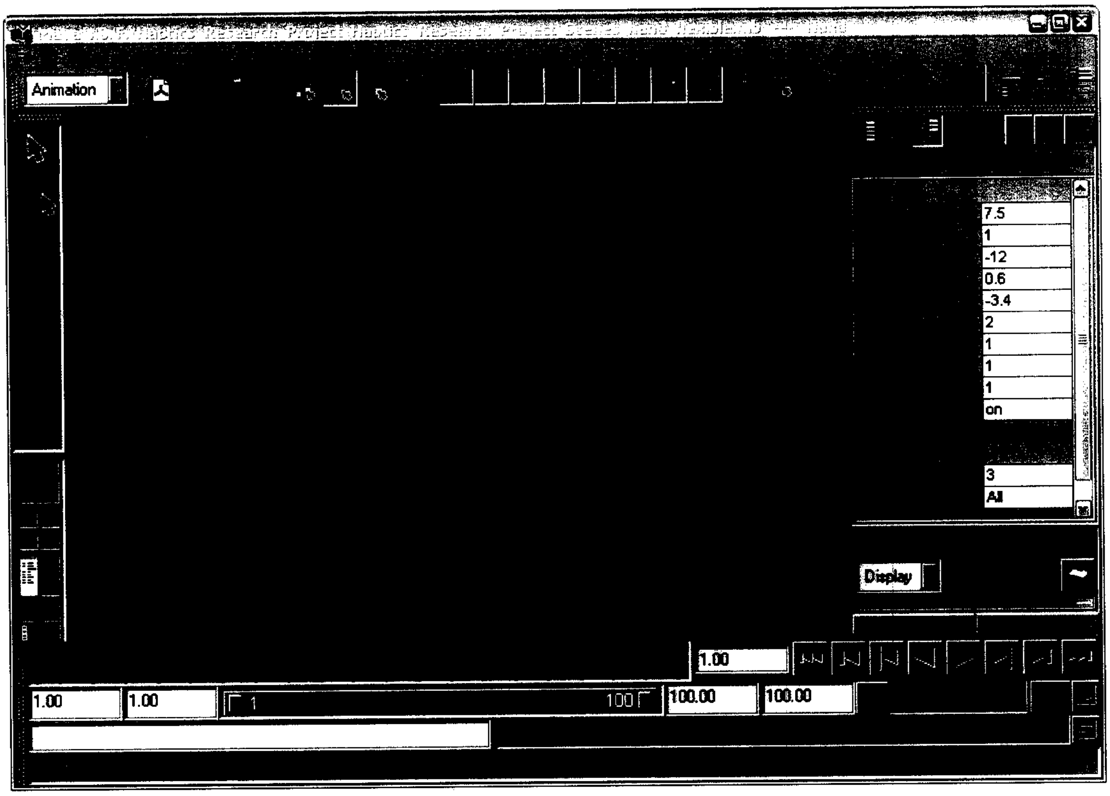


Figure 5-1. 'The virtual hand' dummy – for reFLEX. A hand modeled from the scratch, using polygonal modeling. It is a non-functional proxy structure and needs more modeling for making it flexible, i.e to act like a real hand.

- The skeletal joints begin at one point and are linked to each other in a hierarchical manner. Whether moving one joint, affects the other or not is determined by this hierarchy. This sort of arrangement can be seen in the hypergraph provided by Maya. (See Figure 5-2)

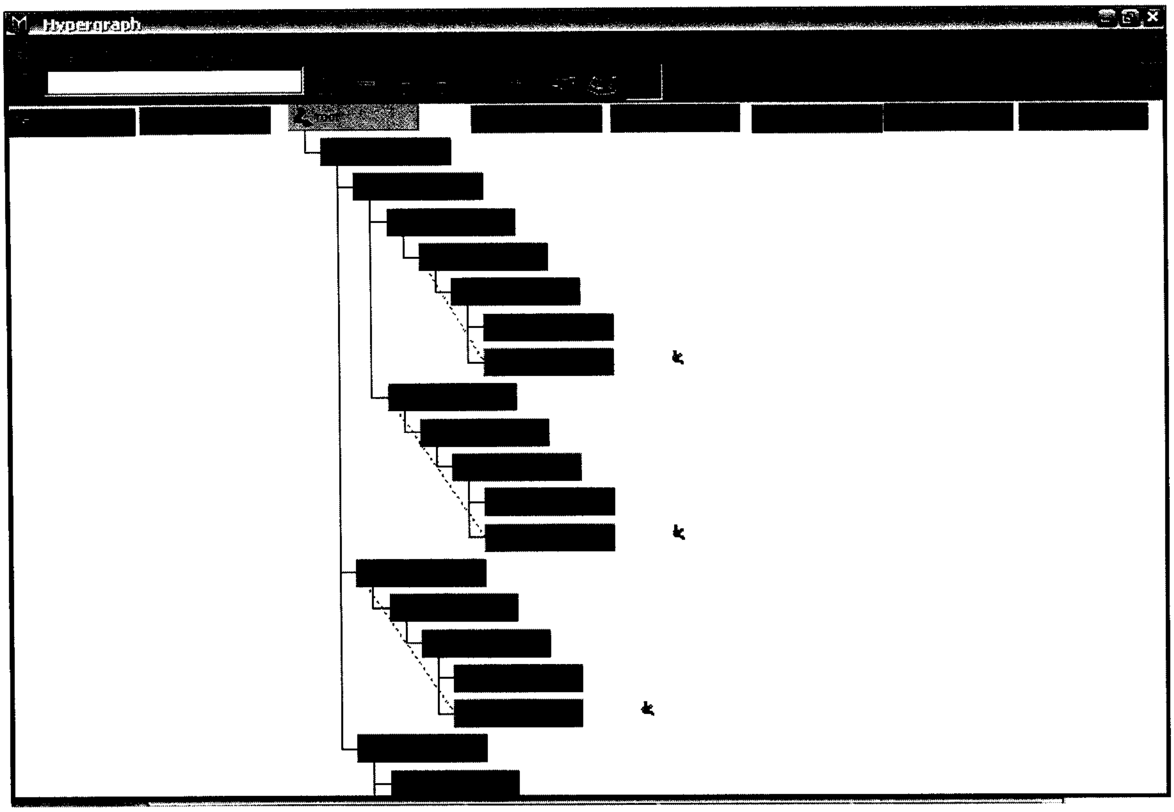


Figure 5-2. Maya's Hypergraph for reFLEX- showing the hierarchical relation of different joints of the hand and the skeleton modeled for reFLEX. It also shows other objects on the scene. Each box in the Hypergraph is a node and is influenced by elements above it in the hierarchy.

- Now, various movements of the skeleton with its restrictions are to be effected. For individual finger bending movements to be realistic, IK (Inverse Kinematics [Maya Tutorials, Using IK Spline Handles]) handles are added as a chain from the knuckles of the finger to its tip.
- If we try to move the skeleton, now the skin also moves along. But certain undesired bulging and disproportionate alignment of skin occurs in the process. To avoid this, the skin weights are to be painted. The joint affecting the skin and how much it affects each skin area is

decided and painted. The results can be verified and the skin movements can be fine tuned.

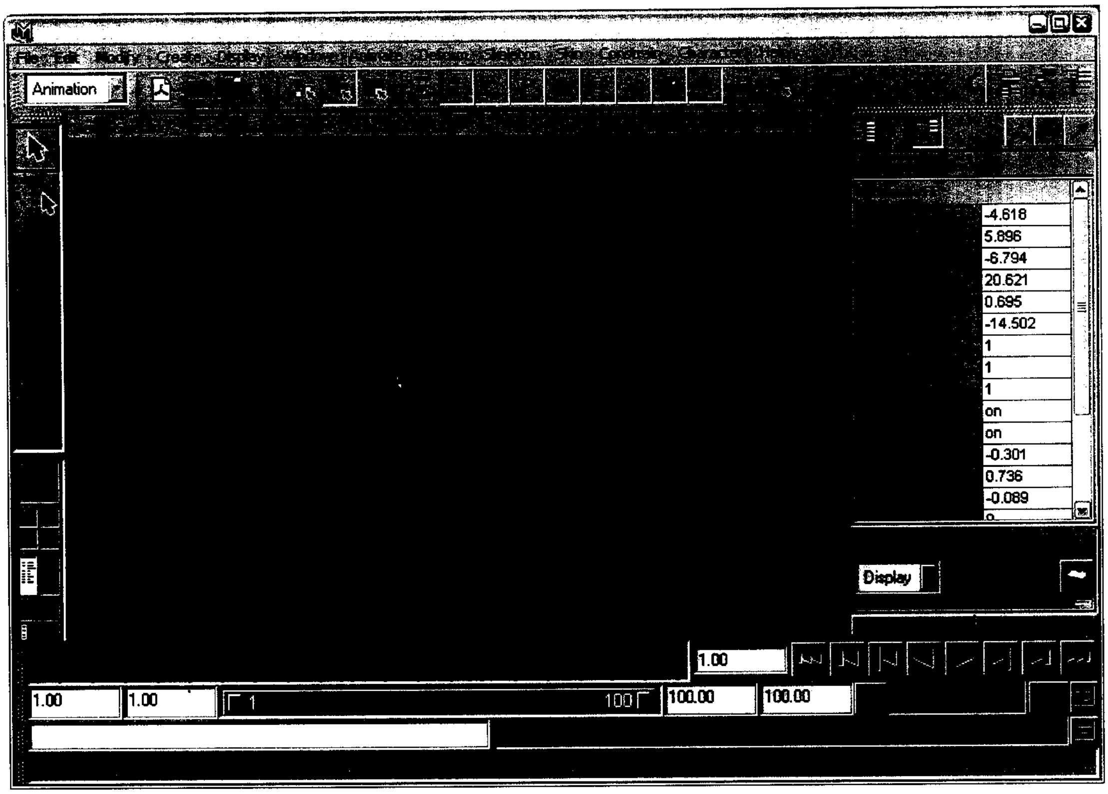


Figure 5-3. 'The virtual hand' functional – for reFLEX. The figure shows the virtual hand shaded in the X-Ray mode, depicting the internal structure of the hand with the skeleton and joints. The skin is bound to the skeleton (skinning process). The green lines notify that the IK handle of the forefinger is selected. The related IK chain is marked in pink color. This chain helps in moving the skeleton of that chain move as per the rules defined for it. This IK handle is created for all the fingers.

Now, the virtual hand is ready to be moved, bent or stretched as per the wishes of user. reFLEX has taken care that a realistic model of hand is created, and that the fingers can be moved or bent as in the real world. The soft ball is also in the place. (See Figure 5-3 above)

5.1.3 Modeling the Deformation Effects on the Soft Ball

To change the shape of the objects, here the soft ball, Maya deformers can be used. A deformer is an object, which has some attributes set as per need, and they deform the object when they are placed within it or when they move over the object. The requirement of reFLEX is dynamic deformation and with accordance to pressure applied.

Of many deformers like blend shape deformers, lattice deformers, jiggle, cluster deformer, etc., sculpt deformer caters to our needs. Sculpt deformer is has an influence object called sculpt sphere, which when placed inside the object, affects it according to the attributes of the deformer. Several manipulations are done on it to suit our needs by varying its attributes in trial-and-error fashion, viz, the size of sculpt sphere, its mode, drop off distance, envelope, maximum displacement,etc.,

Five deformers in the stretch mode and of same type are created for each finger. The movement of the finger should in turn move the deformer over the soft ball which changes its shape. For this a point constraint is set on the deformer with respect to the IK handles at each fingertip. Constraints are a set of rules that affect one object with respect to the position, orientation, size or geometry of the other. The result is the desired action of the soft ball deformation as the fingers contact the soft ball and tries to penetrate it. The synthetic environment is modeled for interaction of the hand and the soft ball. (See Figure 5-4)

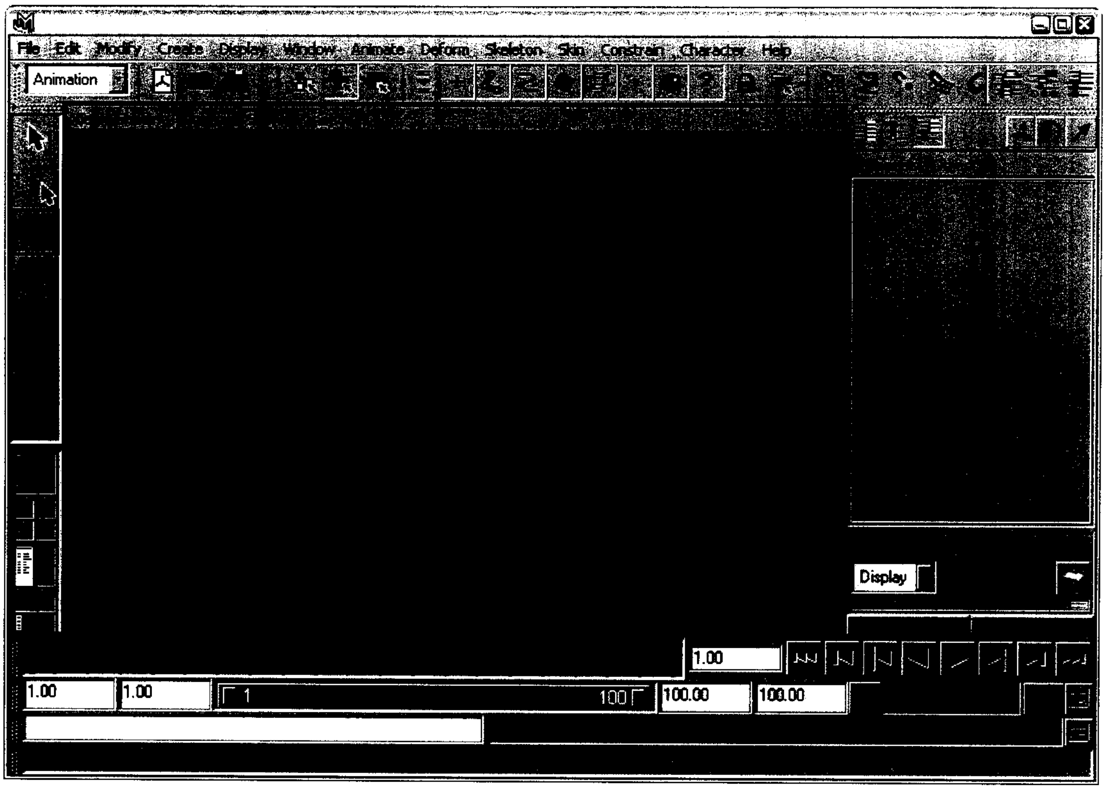


Figure 5-4. 'The visual synthetic environment' of reFLEX. The figure shows a soft fur ball, capable of deforming, in the modeling - perspective view, before rendering. At the tip of each finger is a sculpt sphere, which will cause the deformation on the ball when it comes in contact. For a rendered view see section 8-3

5.2 The Software Interface for Hand Manipulation

*S*ome means has to be provided for the user to manipulate the virtual hand. Using Maya Embedded Language (MEL), a simple user friendly interface has been created that can manipulate all the nodes that form the hand. This interface is shown in Figure 5-5. Also a text of history of operations will be recorded in the output window (See Figure 5-6), as the user starts working with the interface.

The MEL script is written in the Script Editor window of Maya. MEL is an interpreted language and is procedural. The entire script for creating this interface is available in the sample code section. (See Appendix)

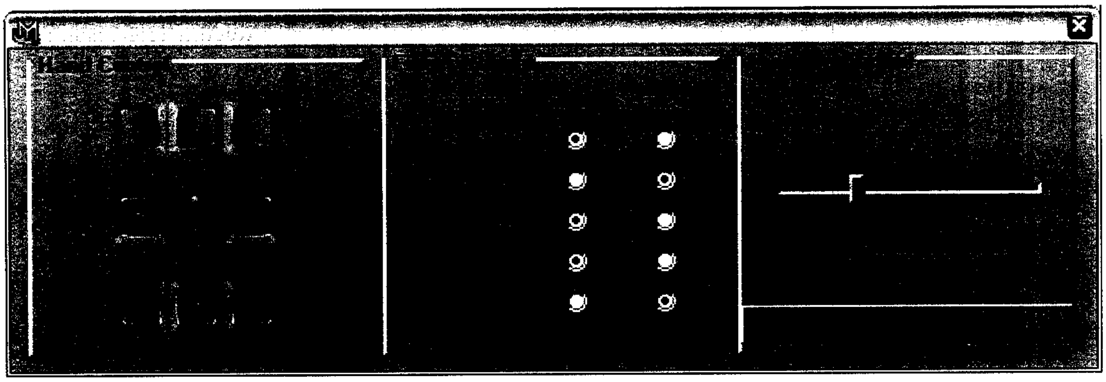


Figure 5-5. 'The Manipulator Window' of reFLEX. This shows a 1*3 row-column layout. The Hand Control buttons enable the movement of the hand as a whole in various directions. The Finger Control radio buttons enables the stretching or bending of individual fingers in a coordinated manner. The pressure control slider allows exertion of pressure on the ball when the fingertip comes in contact. The features are self-explanatory.

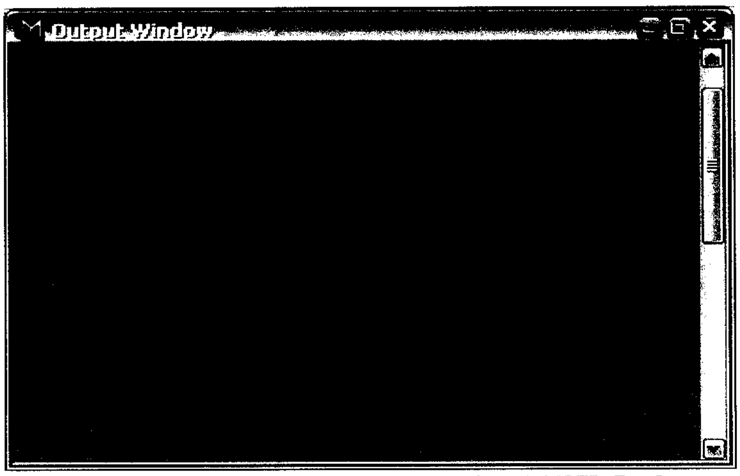


Figure 5-6. 'The Output Window' of reFLEX. It shows the trace of actions performed on the Manipulator Window and opens automatically with the Manipulator Window.

5.3 The Communicator Plug-in

*M*aya provides an important extensibility mechanism to help the programmers. Additional functions can be created and integrated manually for increasing its functionality. In reFLEX, the deformation data has to be sent to the actuator hardware. In order to establish a communication between the hardware and Maya, a plug-in has been developed in VC++.

*W*e have created and named it portCommand whose code is available in the sample code section. The program written in VC++ is converted to an mll file (Maya Linked Library). This is imported to Maya environment through Maya plug-in manager. Now the function can be called as any other Maya command for writing data to the parallel port.

5.4 The Actuator Electronics

*T*he hardware related to providing the tactile sensation forms the actuator assembly. Data from the parallel port is conveyed to the vibrators as voltage signals at the appropriate level.

*T*he vibrators (discussed in section 3.3) are assembled in the outer cover of the glove that forms the ventral surface of the hand. Each vibrator receives the signal, which is actually stepped down/up proportional to the actual data from the parallel port.

*S*ome functional requirements are considered relating to cross-sectional area of the skin contacts. For a given functional frequency, the minimum amplitude of vibration the fingers can sense decreases with increase in cross-sectional area. A decrease by about 1000 times will scale the minimum sensible amplitude high by 30 times. But in the case of reFLEX six vibrators are placed in the key sensitive areas like the fingertips and the palm region. These provide the basic location feedback. This can be further extended for betterment.

A sample vibrator is shown below (Figure 5.7). For extensive study of placement of contact devices and its effectiveness refer studies by Karun. B. Shimoga. [Fearing and Binford 1991]

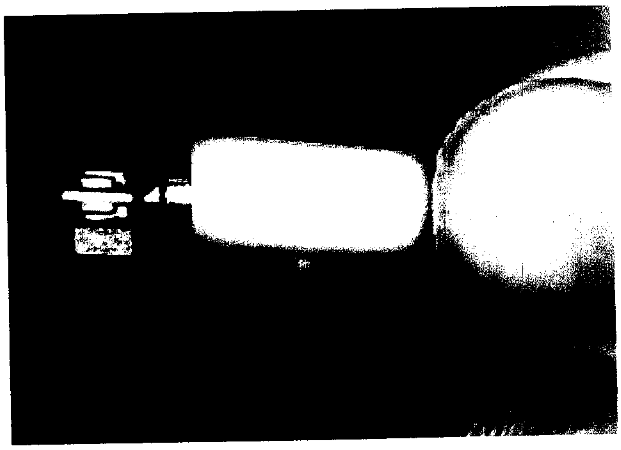
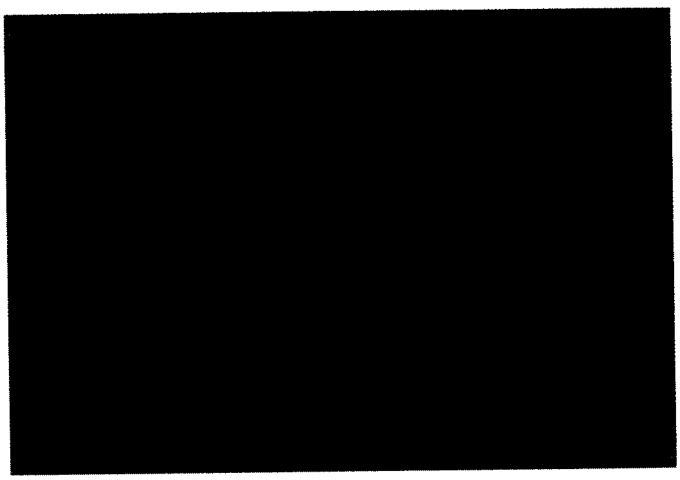


Figure 5.7. The vibrator used for reFLEX. The figure shows the load at the end of the DC motor which is sheathed in plastic.

6

SIMPLE TESTING



And so for machines too!

For all is fair in ware

*E*very module introduces new challenges which are to be well designed to provide realistic feeling. Sample test experiments were conducted on reFLEX at every stage. Also the overall coordination was verified by few users.

6.1 Test Experiments

The experiments are not recorded as in real software testing phase, but most of the viable cases are verified so that the impact is good.

6.1.1 Test on the Synthetic Environment

Visual impact is key for retrieving the basic information from the environment. Some factors that were tested are:

- The impact of deformer at various locations of the object
- Dynamicity of the deformation
- Deformation extent (the object should not be over manipulated, and pressed beyond and extent)
- Finger penetration depth on the object.

6.1.2 Test on the Data Transfer

The data sent through the port is verified for correctness, continuity, and transition time, etc., LED's are used before actually connecting to the printer cable. The data is changed randomly at frequent intervals to learn its adaptability.

6.1.3 Load Test on the Vibrator and Renderer

The vibrator has input voltage minimum at 1 V. There on, the vibrations due to spinning increases proportionately. We verified that the spinning speed is too high to cause any vibrations after 12 V. Also the vibrator cannot withstand a voltage higher than 15V.

Rendering is an important aspect with respect to processor load. This process consumes a large amount of memory and CPU time. Rendering of a scene in reFLEX takes about 26 sec. even with 256MB RAM. When three rendering jobs are posted in quick intervals, the first one gets cancelled before completion or the system hangs for a minute and shows runtime error. So enough memory and CPU cycles must be free for better response time.

Constantly changing the data at the port sometimes has not produced noticeable changes.

6.1.4 Testing with the Users for Conformance

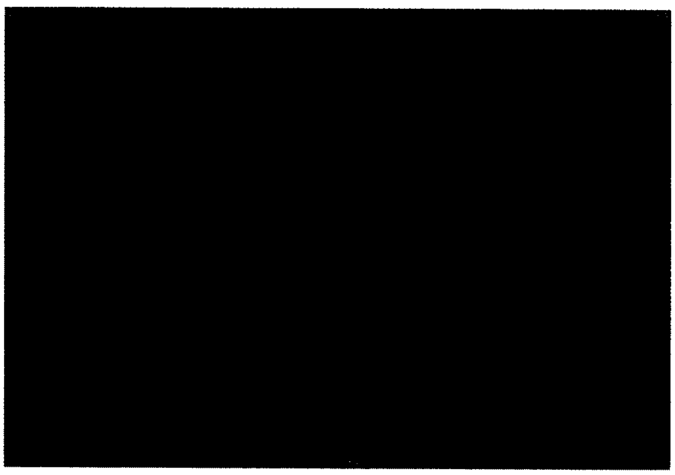
Few users have used and tested the reFLEX on these aspects.

- How comfortable they are with the gloves?
- Does constant vibration create fatigue?
- Is the change in vibration noticeable?
- Is the virtual environment immersive enough?
- Does the contact location match properly and provide useful cues?
- Is the coordination level satisfactory?

By means of interacting with the users fine-tuning has been possible. The users feel comfortable with what reFLEX has offered them now. But it will be enhanced to meet the goal of a full-fledged haptic interface.

7

EXTENSIONS AND CONCLUSION



As a new beginning

7.1 Extensions

*H*aptic Interface Designing is a creative area and is very interesting too. The user feedback and the development process have provided ideas of where the entire setup of reFLEX can be enhanced. Through the work done in this project, one only begins to understand what an exquisite instrument human hand is and is a significant achievement of nature that man may never succeed is replicating. However the work makes some contribution and as stated in the introduction, the project is only a first step towards reaching the goal of creating a seamless tactile interface.

*T*he project can be enhanced to provide the exact feeling as if the object is being touched really. At present reFLEX provides feedback of the contact locations alone. But lot of work will be concentrated on finding a device that could reproduce that effect.

*T*he virtual environment is predefined and demonstrates a small area though it reacts to dynamic changes. This could be converted to a larger framework for real time application, which could be more useful.

*A*n inherent challenge is posed in providing the visual output immediately, since there is an intermediate rendering process that is tedious. In reFLEX, the operations are carried out in modeling view for better response time and rendered at regular intervals to get a hand on visual data. This problem has to be solved.

The placement of vibrator and the glove design can be modified for better feedback. A mathematical model for the location mapping will greatly enhance the reality of information.

7.2 Conclusion

As with most work one can understand a great deal from each generation of prototypes. What is done through reFLEX can reach a better destination and the path has to be a long one, at least with the available knowledge and technology. reFLEX has introduced a new method of obtaining the touch feedback and a fresh manipulation plan. With debates on haptic interfaces being put to rest, their end use will definitely change the way interfaces will look. With a small demonstration of how haptics will do, reFLEX will steer a new set of methods for manipulation in teleoperations and virtual reality applications.

8

APPENDIX

[redacted]

Whe[redacted]*ens is*

It appends

8.1.1 Code for Manipulator Window

```
//Manipulator Window
string $window = `window -title "Manipulator Window"
                        -sizeable false
                        -topEdge 360
                        -leftEdge 170
                        -width 620
                        -height 210`;
trace "Manipulator Window Opened\n";

//2.create 1*3 row Layout which will hold the frames
    rowLayout -numberOfColumns 3
          -columnWidth3 200 200 200
          -columnAttach3 "left" "left" "left"
          -columnOffset3 10 10 10;

//3.Create the three frames with the necessary components
    frameLayout -label " Hand Control"
           -labelAlign "top"
           -borderStyle "out"
           -width 190
           -height 175
           -marginHeight 5
           -marginWidth 45;

         rowColumnLayout -numberOfColumns 3
     -columnWidth 1 30
     -columnWidth 2 30
     -columnWidth 3 30
          -columnSpacing 1 1
          -columnSpacing 2 1
          -columnSpacing 3 1;

    iconTextButton -style "iconOnly" -image1 "lftup.bmp" -label "-Z" -command up_l;
    iconTextButton -style "iconOnly" -image1 "up.bmp" -label "+Y" -command up;
    iconTextButton -style "iconOnly" -image1 "rtup.bmp" -label "+Z" -command up_r;
    iconTextButton -style "iconOnly" -image1 "left.bmp" -label "-X" -command left;
    iconTextStaticLabel -style "iconOnly" -image1 "center.bmp" -label "NIL";
    iconTextButton -style "iconOnly" -image1 "right.bmp" -label "+X" -command right;
    iconTextButton -style "iconOnly" -image1 "lftdwn.bmp" -label "-Z" -command down_l;
    iconTextButton -style "iconOnly" -image1 "down.bmp" -label "-Y" -command down;
    iconTextButton -style "iconOnly" -image1 "rtdwn.bmp" -label "+Z" -command down_r;


          setParent ..;
    setParent ..;
```

//The control for relaxing hand positions

```
        frameLayout -label " Finger Control"
                -labelAlign "top"
                -borderStyle "out"
                -width 190
                -height 175;
        columnLayout -rowSpacing 7;

            text -width 200
                -font "smallFixedWidthFont"
          -label "Finger  Bend  Stretch"
                -align "center";

            radioButtonGrp -numberOfRadioButtons 2
                        -label "Thumb"
                        -columnWidth3 100 50 50
                        -columnAlign3 "center" "center" "right"
                        -labelArray2 "" ""
                        -onCommand1 bend_T
                        -onCommand stretch_T ;
            radioButtonGrp -numberOfRadioButtons 2
                        -label "ForeFinger"
                        -columnWidth3 100 50 50
                        -columnAlign3 "center" "center" "right"
                        -labelArray2 "" ""
                        -onCommand1 bend_FF
                        -onCommand stretch_FF;
            radioButtonGrp -numberOfRadioButtons 2
                        -label "MiddleFinger"
                        -columnWidth3 100 50 50
                        -columnAlign3 "center" "center" "right"
                        -labelArray2 "" ""
                        -onCommand1 bend_MF
                        -onCommand stretch_MF;
            radioButtonGrp -numberOfRadioButtons 2
                        -label "RingFinger"
                        -columnWidth3 100 50 50
                        -columnAlign3 "center" "center" "right"
                        -labelArray2 "" ""
                        -onCommand1 bend_RF
                        -onCommand stretch_RF;
            radioButtonGrp -numberOfRadioButtons 2
                        -label "LittleFinger"
                        -columnWidth3 100 50 50
                        -columnAlign3 "center" "center" "right"
                        -labelArray2 "" ""
```

```
                                -onCommand1 bend_LF
                                -onCommand stretch_LF;
                    setParent ..;
    setParent ..;
```

//The pressure control frame with the slider to control the attribute t finger tip

```
        frameLayout -label " Pressure Control"
                    -labelAlign "top"
                    -borderStyle "out"
                    -width 190
                    -height 175;

                columnLayout -columnWidth 200 -rowSpacing 20;
                text -font "smallFixedWidthFont"-width 200 -label "Pressure" -align "center";
                floatSliderGrp -field false
                                -label " "
                                -columnWidth2 15 150
                        -minValue 0
                                -maxValue 20
                                -dragCommand pressure;
                text -width 190
                    -font "smallFixedWidthFont"
                    -label "Min-----------------Max" -align "center";
        button -width 187 -label "Reset All" -command reset;
                        setParent ..;

    setParent ..;

showWindow $window;
```

//4.procedures for handling each control to position the hand

```
global proc up()
{
select -r root;
move -r 0 0.3 0;
trace "Hand moved - upwards\n";
}
global proc left()
{select -r root;
move -r 0 0 -0.3;
trace "Hand moved - left\n";
}
global proc right()
{select -r root;
move -r 0 0 0.3;
trace "Hand moved - right\n";
}
```

```
global proc down()
{select -r root;
move -r 0 -0.3 0;
trace "Hand moved - downwards\n";
}
global proc up_l()
{select -r root;
move -r 0.3 0 -0.3;
trace "Hand moved - away along left\n";
}
global proc up_r()
{select -r root;
move -r 0.3 0 0.3;
trace "Hand moved - away along right\n";
}
global proc down_l()
{select -r root;
move -r -0.3 0 -0.3;
trace "Hand moved - towards user along left\n";
}
global proc down_r()
{select -r root;
move -r -0.3 0 0.3;
trace "Hand moved - towards user along right\n";
}
global proc reset()
{select -r root;
move -4.2 6.4 -20;
rotate 0.6 -3.4 2;
}
//to bend or stretch the fingers
global proc bend_LF()
{
select -r ikHandleLF ;
move -r 0 -2.019682 0 ;
move -r 0 0 -1.923406 ;
trace "Little finger bent\n";
}
global proc bend_RF()
{
select -r ikHandleRF ;
move -r 0 -2.339005 0 ;
move -r 0 0 -2.172227 ;
trace "Ring finger bent\n";
}
```

```
global proc bend_MF()
{
select -r ikHandleMF ;
move -r 0 -2.661549 0 ;
move -r 0 0 -2.342856 ;
trace "Middle finger bent\n";
}
global proc bend_FF()
{
select -r ikHandleFF ;
move -r 0 -3.37982 0 ;
move -r 0 0 -2.100683 ;
trace "ForeFinger bent\n";
}
global proc bend_T()
{
select -r ikHandleT ;
move -r 0 -1.793932 0 ;
move -r 0.684914 0 0 ;
trace "Thumb bent\n";
}
global proc stretch_LF()
{
select -r ikHandleLF ;
move -r 0 2.019682 0 ;
move -r 0 0 1.923406 ;
trace "Little finger stretched\n";
}
global proc stretch_RF()
{
select -r ikHandleRF ;
move -r 0 2.339005 0 ;
move -r 0 0 2.172227 ;
trace "Ring finger stretched\n";
}
global proc stretch_MF()
{
select -r ikHandleMF ;
move -r 0 2.661549 0 ;
move -r 0 0 2.342856 ;
trace "Middle finger stretched\n";
}
global proc stretch_FF()
{
select -r ikHandleFF ;
move -r 0 0 2.100683 ;
move -r 0 3.37982 0 ;
trace "ForeFinger stretched\n"; }
```

```
global proc stretch_T()
{
select -r ikHandleT ;
move -r 0 1.793932 0 ;
move -r -0.684914 0 0 ;
trace "Thumb stretched\n";
}

global proc pressure()
{
float $i =`getAttr root.translateZ`;
if ($i < -14) trace "pressure on free space non traceable";
else
{ select -r root;
move -r 0 0 0.1;
sendCommand 10;
render;
}
}
```

8.1.2 Code for the plug-in 'sendCommand'

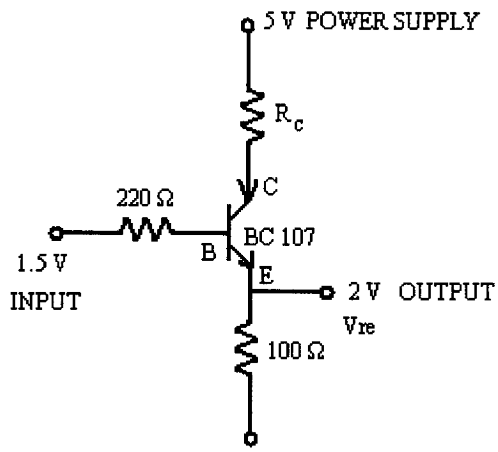
```
/// sendData.mll
//      Arguments:
//              args - the argument list that was passes to the command from MEL
//
//      Return Value:
//              MS::kSuccess - command succeeded
//              MS::kFailure - command failed (returning this value will cause the
//            MEL script that is being run to terminate unless the
//            error is caught using a "catch" statement.
//
{
        int i,j;
        i=args.asInt(0);
        j= _outp(888,i);
        MStatus stat = MS::kSuccess;
```

```
    // Since this class is derived off of MPxCommand, you can use the
    // inherited methods to return values and set error messages
    setResult( "sendData command executed,port 888!");
    appendToResult(j);
    return stat;
}
```

8.2 Hardware Design and Data

8.2.1 Power Supply Step Up/Down Circuit

The circuit below is used in reFLEX for converting the voltage from 1.5 V to higher or lower levels.



The voltage step up circuit. From 1.5V input to 2V output

Re = 100Ω , Vre = 2 V, Vcc =5

Ie = Vre / Re = 2 /100 = 20 mA

Ic = Ie (approx). Hence, Ic = 20 mA

Ic = Vcc / (Rc + Re)

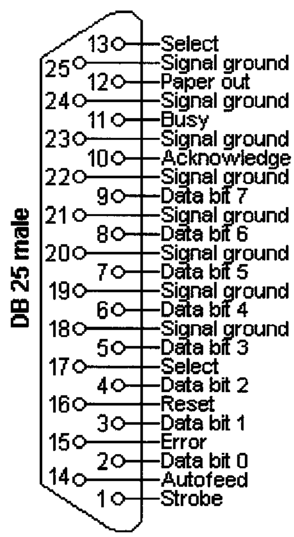
5/(Rc+100) = 20 mA

Hence Rc = 150 Ω

Similarly, the required output level can be calculated by varying the resistance.

8.2.1 Parallel Port Configuration

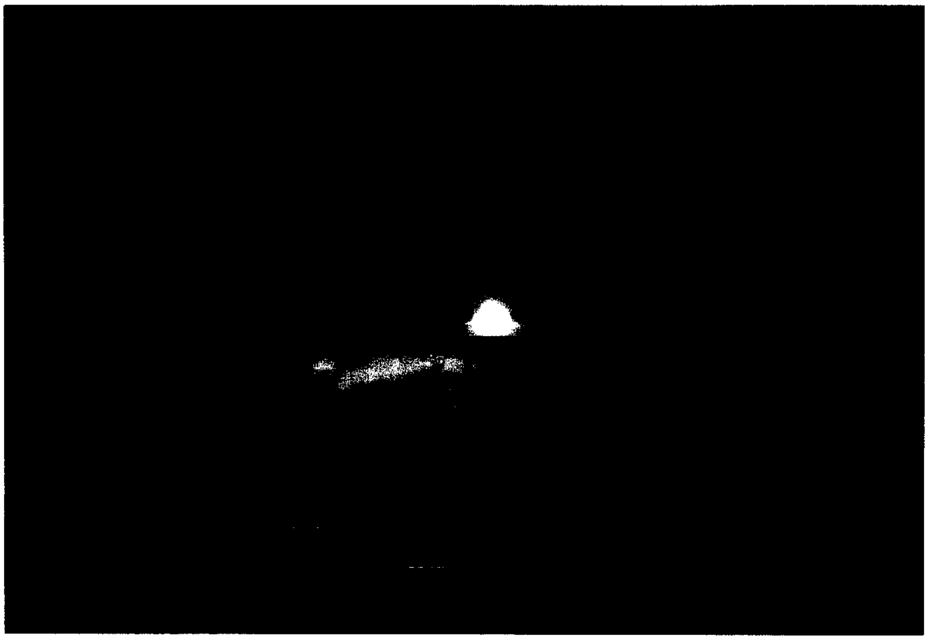
The figure shown below is the configuration of 25 pin parallel printer port of male connector. Pins 2 to 9 are used to transmit the data and pins 18 to 24 serve as ground.



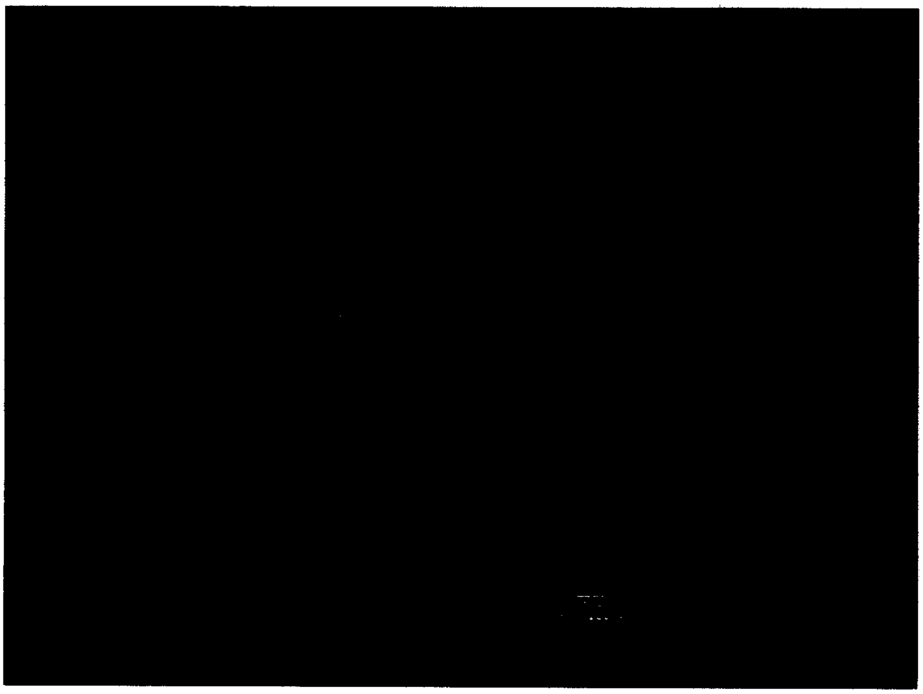
DB 25 male parallel port

The female connector is soldered to a set of single stranded wires to transfer the data.

8.3 reFLEX Working Scenario



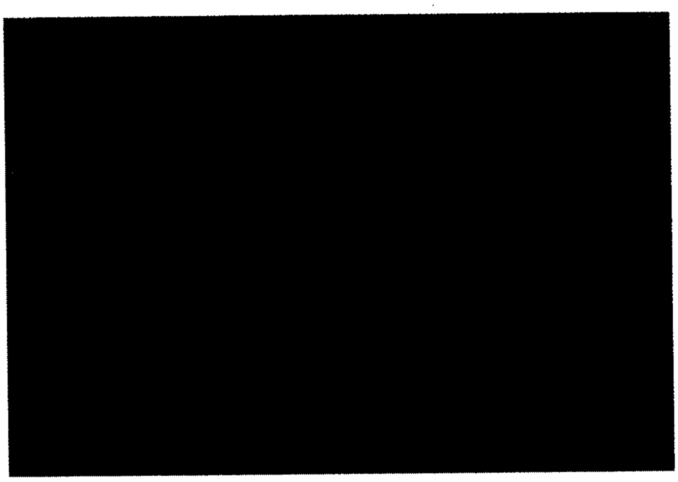
As the hand in the virtual environment touches the ball the vibrator in the hand vibrates. The vibrator selection is based on the contact position.



The figure above shows the glove fitted with the vibrators for two fingers

9

BIBLIOGRAPHY



But the past experiences are always references

1. Burdea, G.C. (1996) 'Force and Touch Feedback for Virtual Reality', New York: J. Wiley & Sons.
2. Dennerlein, J.T., Millman P.A., and Howe R.D. (1997) 'Vibrotactile Feedback for Industrial Telemanipulators.', Proceedings of the ASME Dynamic Systems and Control Division,Dallas, TX, USA.
3. Fearing, R.S. and Binford T.O. (1991) 'Using a Cylindrical Tactile Sensor for Determining Curvature',IEEE Transactions on Robotics and Automation, vol. 7, 1991, pp. 806-817
4. Gescheider, G.A. (1997) 'Psychophysics: The Fundamentals.' 3rd ed: Lawrence Erlbaum Associates.
5. Hale, K.S and Stanney, K.M. (2004) 'Deriving Haptic Design GuideLines from Human Physiological, Psychophysical, and Neurological Foundations', IEEE Transactions on Computer Graphics and Applications, March/April 2004 Edition.
6. Ming Lin, Salisbury, K.J. (2004) 'Haptic Rendering – Beyond Visual Computing', IEEE Transactions on Computer Graphics and Applications, March/April 2004 Edition.
7. Provancher, W.R. (2003) 'On tactile sensing and display', TouchLab, Stanford University.
8. www.news-service.stanford.edu/news/ - Salisbury, K.J. (2003) 'Haptic Technology Simulates the sense of touch'
9. Shimoga , K.B. (1993) ' A survey of Perceptual Feedback Issues in Dextrous Telemanipulaions: Part II. Finger Touch Feedback', IEEE Proc. Virtual Reality Annual International Symposium, Seattle, Washington.

Technical References

1. 'Maya Online Documentation and Tutorials' integrated in Maya Environment
2. Spadaro Jo, Kim Don. (2003) 'Maya 4.5 Bible', Wiley Publishing, Inc.
3. www.aliaswavefront.com/
4. www.alias.com/
5. www.highend3d.com/ and its Maya User Community
6. www.lammertbies.nl/ for information on port and configuration