UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A SINGLE DEGREE OF FREEDOM HAPTIC SYSTEM HANDLE

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By

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DEDICATION

Specially dedicated to my family and friends.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Sense of touch is one of the most important senses for human. Human feels and interacts with the environment through their sense of touch. This thesis describes the design and development of a single degree of freedom handle with force feedback. The interaction between the handle and the user is achieved through the usage of a DC servomotor. The servomotor provides the resistive force to the manipulator. To control the servomotor, electronics circuit is constructed. The electronics circuit controls the force provided by the motor by using the Pulse Width Modulation technique. A computer is used to provide graphical interface to the user. The computer is also used to control the force provided by the motor by sending data through its parallel port to the controlling electronics circuit. At the end of the project, a single degree of freedom handle has been constructed and its characteristics have been tested. From the tests conducted, the system built managed to provide resistive torque up to 1.6Nm

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PEMBINAAN PENGAWAL DENGAN KUASA SUAP-BALIK BERKEBEBASAN SATU DARJAH

Oleh

KWA CHIN KOK

Januari 2004

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Deria sentuh merupakan salah satu deria yang penting kepada manusia. Manusia berinteraksi dengan persekitaran melalui deria sentuh mereka. Tesis ini menerangkan rekabentuk and pembinaan satu pengawal dengan kuasa suap-balik berkebebasan satu darjah. Interaksi antara penguna dengan pengawal dicapai melalui penggunaan motor arus terus 24V. Kuasa penentang oleh pengawal adalah diperoleh daripada motor ini. Untuk mengawal motor ini, litar elektronik direka. Litar elektronik ini mengawal kuasa yang dibekalkan oleh motor dengan menggunakan teknik modulasi lebar denyut. Komputer digunakan untuk memberikan interaksi grafik kepada penguna. Komputer juga digunakan untuk mengawal kuasa yang dibekalkan oleh motor dengan menghantar data melalui pengkalan selarinya kepada litar elektronik. Pada akhir projek, satu pengawal dengan kuasa suap-balik berkebebasan satu darjah telah dibina dan ciri-cirinya diuji. Daripada ujian-ujian yang telah dilakukan, sistem yang telah dibina berkeupayaan menjana kuasa tentangan 1.6Nm telah dibina.

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It is a pleasure to acknowledge my family. Their love and support have always been my source of inspiration and aspiration.

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LIST OF ABBREVIATIONS

Abbreviation	
AC	Alternating Current
CAD	Computer Aided Design
DC	Direct Current
EMF	Electromotive Force
GUI	Graphical User Interface
JSF	Joint Strike Fighter
LVDT	Linear Variable Differential Transformer
MIT	Massachusetts Institute of Technology
PCB	Printed Circuit Board
RVDT	Rotary Variable Differential Transformer

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CHAPTER 1

INTRODUCTION

1.1 Haptic System

The term haptics was derived from the Greek word *haptikos*, which brings the meaning of "able to touch" [1]. This was first coined by the psychologists who were studying active touch in the early part of the 20th century.

Sense of touch has enabled human to feel the environment around them. Simple everyday tasks such as brushing one's teeth, typing, writing, or pressing a button would all become great difficulties to human without the sense of touch.

Sense of touch is different from the sense of hearing as well as visual. This is because in audio and graphics, the user is just receiving energy from the environment. But in touch, the user is interacting, which means that the user is exchanging energy with the environment.

Development in human-machine systems such as teleoperation and interactive human-computer systems such as virtual reality has increased the interest in haptics study. In virtual reality for example, besides audio and graphical display, the user must also be able to feel, touch and manipulate the virtual environments as it should be in the real environment, which can be achieved through haptic display.

Figure 1.1 shows a block diagram for a haptic interface to a computer-simulated environment. In this system, human will interact with the haptic interface through motion. The motion signal from haptic interface will be inputted to a computer simulation of a virtual environment. The computer will computes the desired reaction forces back to the user through the haptic interface.

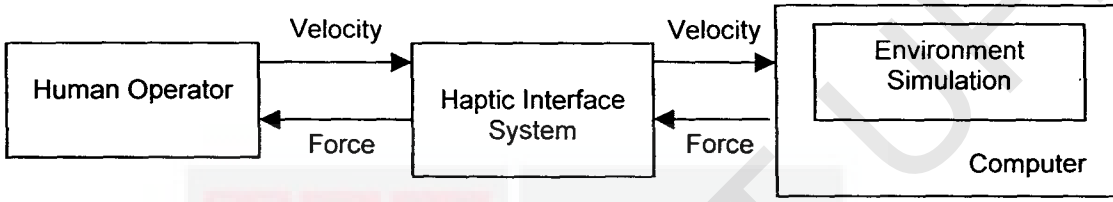

Figure 1.1: System for Haptic Interaction with Computer Simulation

1.2 Problem Statement

This thesis is intended to design a basic single degree of freedom haptic interface system. The primary challenges to this effort are development of haptic interface mechanisms, development of software simulations and the communication between the software, the user and the haptic system. The purpose of this thesis is to build the basic knowledge to the design of the haptic interface system as foundation to future device design.

In the mechanical design, a force transmission system has to be designed that will provide the force interaction between the user and the haptic system. The design of the power transmission system will the primary objective in the mechanical design in order to achieve the desirable torque.

In the electronics design, there are few things that have to be considered. The type of motor driving circuit that has to be used and the method of driving the motor, either using Pulse Width Modulation technique, or any other methods that is more suitable for the circuit. Besides that, the selection of communication protocol with the computer has to be put into consideration.

In the software, the important part in the design is to consider the interaction of the computer with the haptic system. The design of the Graphical User Interface to display the position of the handle and the communication with the haptic system will be given primary priorities.

The single degree of freedom haptic system handle can be used as a foundation for future research in understanding haptic system. Amongst the many applications that can be achieved by the proposed system is in arm physiotherapy sessions. Conventional physiotherapy method is to do exercise with various objects that will have different weights. By using this system, together with the implementation of the computer system, the doctors will have the flexibility to monitor and control the patients physiotherapy sessions development.

Besides that, the system can be further developed into a teleoperation system. The advent of the internet and more sophisticated digital gadgets, a system that will allow a user in Europe to control or touch an object located in Malaysia seems to be achievable and not intangible.

1.3 Objectives of the Project

The proposed system will have the following basic features:

- The system should have a feedback to the user as though he or she is interacting with the real world.

- Under no load simulation, the user should have force-free control, which means the user should be able to move the handle freely without feeling any resistive force.

- The handle should remain at one place when the operator stops pushing it.

The objectives of the project are listed as follows.

1. Design of mechanical setup. This includes the design of the handle and the power transmission from the motor to the handle.

2. Design of electronics circuitry. Electronics is used to control the torque and direction of the force applied by the motor.

3. Design of graphical interface. Graphical interface is important for the interaction between user and the system. Computer is used to control the force and direction provided by the motor. Besides that, computer provides the graphical presentation of the movement of handle.

1.4 Thesis Layout

Chapters 1 and 2 are introductory. Chapter 1 presents objectives and the basic construction of this project. Chapter 2 reviews the on-going and available research on haptics technology. Besides that Chapter 2 also presents various types of mechanisms and parts that are available that could be used in the design. Chapter 3 gives detail design methodology of the proposed project. In Chapter 4, results and discussion of experiment and tests will be highlighted. The last chapter, Chapter 5, summarises the project and gives further recommendation to continue the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Haptic Technology

A haptic system can be defined as a force feedback interface that lets the user touches, feels and manipulates the virtual environments. In the future there will be more and more surprising and eye-opening inventions emerging, as the potential of haptic application is still vast.

2.1.1 Application in Virtual Reality

The most obvious application of haptics is in the computer applications. Perhaps the earliest haptics devices for computers were those meant for the Braille readers. These devices enable the blind user to read the text on the computer screen by moving their finger along a line of metal pins that form a Braille representation of the text displayed on the screen.

Playing computer games will be more engaging by touch interactions. This objective is achieved with the emergence of the force-feedback joysticks and force-feedback mouse [2]. Immersion began licensing its TouchSense software in 1995 for usage in joysticks and steering wheels. This technology is quickly absorbed by the game producers such as Microsoft, Electronic Arts, Acclaim and LucasArts in their game applications. Black & White has won major awards including the Best Show at E3, the world largest video games trade gathering. The game that was created by Black & White, "god

simulator" allows the game player to feel the fish nibbling, heartbeat of the worshippers, the tug of uprooting a tree and the pulsing power of casting a spell [3]. The Immersion's tactile feedback technology also works well with the Windows 98 compatible software. Hence it will automatically adds touch feedback to many of the basic Windows controls, such as the icons, menus and buttons. Besides that, it will also add sense of touch to internet application such as the hyperlinks, check boxes and the menus.

In December year 2000, Logitech, a renowned mouse maker, began offering its latest mouse technology that made use of haptic technology, the WingMan. Working alongside with Immersion's software, WingMan has microprocessor and motors that will vibrate, recoil, stiffen and loosen the mouse accordingly. Besides that, the latest version of Logitech's mouse, iFeel would enable user to feel the tactile sensations linked to the features on the site [4]. This mouse made use of the Inertial Harmonic Drive. The mismatch number of tooth of its meshed gears will generate the vibration and motion needed to provide the haptics sensation.

As pointed out by by the author in [5], learning 3-D modeling packages has always been time consuming and torturous. With the emergence of the a device called FreeForm Phantom's 3-D modeling system by SensAble Technologies, the learning curve of the 3-D modeling has been greatly reduced. One of the best examples of using the haptics devices in 3-D modeling is in the movie, Chicken Run.

A group of researchers in MIT is developing the World Wide Web with the touch of haptic [6]. Using Phantom haptic interface, the user will be asked to differentiate the stiffness of two different coils across the web and send their responses via e-mail. They are trying to embed the haptics into Virtual Reality Modelling Language (VRML) through its extension mechanism. Another group of researchers, led by Professor Hardwick, foresees the application of VRML and haptics in helping the blind to 'feel' over the net [7]. Using the Immersion's Impulse 3000 force-feedback probe and the VRML language, they are able to provide some sense of touch over the internet.

2.1.2 Application in Medical Field

The usage of haptic technology has greatly help the doctors to have the better tools in order to reduce the risk when performing surgery procedures [8, 9, 10, 11]. In endosurgery procedures, there are great amount of loss in the sense of touch compared to the open surgery. This is due to the mechanical design and construction of the endoscopic devices that will create a lot of friction, backlash and stiffness in these long devices. In the papers presented by a group of researchers [8, 9], they have presented on a system named 'Computerized Force Feedback Endoscopic Surgical Grasper' was developed by using the computer control and haptic interface. The system developed has been able to differentiate the difference between the live tissue and the artificial tissue. The application of haptic in the endoscopic system, as presented in these papers, has proved that it will greatly help the doctors in performing their surgical procedures compared to the normal conventional endoscopic graspers by restoring the lost of the sense of touch.

Application of haptic in the endosurgery will restore the sensation of touch that is much needed by the doctors during the surgery procedures, especially in handling delicate and soft tissue. Hence, the use of haptics endoscopic grasper has greatly reduces the trauma to the tissues, reduces the pain of patient, and increases the rate of recovery of the patient. In a very well written journal written by Stoianovici [10], the author has pointed out a few robots and applications that utilize haptic technology. For example, the daVinci system developed by Intuitive Surgical Inc. that perform totally endoscopic coronary artery bypass procedures on a beating heart, and the Zeus system developed by Computer Motion, Inc. that also enable the surgeon to operate the system from the remotely located haptic interface.

Doctors or medical students rarely have a chance to practice their technique before performing any surgery on a live patient. With the emergence of simulation programmes that have incorporated the haptics technology, doctors and medical students will be able to do training before performing any surgical operation [8, 11, 12, 13, 14, 15, 17]. Paper written by Issenber [14] has quoted the Medical School Objectives Project, sponsored by the Association of American Medical Colleges, stated in their Medical Informatics Objectives that the medical students should be proficient in various computer-based instructional tools, including the electronic tutorials and patient simulations. There are many medical training simulators available in the market nowadays. One of the most popular simulators is CathSim, the product of Immersion Medical [13]. This simulator allows the medical students to get a feel for the basics of snipping a tissue sample from inside a

lung or inspecting a colon without touching a patient. There are also Harvey, the Cardiology Patient Simulator [14], laparoscopic surgical skill simulator [15], Iowa Dental Surgical Simulator developed by colleges of Dentistry and Engineering of University of Iowa [16], and endoscopic sinus surgery simulation [17].

For the visually impaired people, they 'see' the world mostly by touching. VisuAide [18] has shown how the MouseCAT, a two-button mouse that provide haptic sensation, helped the blind people to feel their way through the computer. The paper written by Gunnar Jansson [19] has emphasised how the haptic could help the blind by improving their recognition ability through their sense of touch.

In the future, haptic may also help restoring the feel of touch of the prosthetics from their artificial limbs and arms [1]. One day in the future, the doctors and patients will not have to meet. The patient will consult the doctor through Internet and the doctor could perform surgery on the patient even they are parted by the Pacific Ocean. This is what Grobkopf and friends foresee [20].

2.1.3 Application in Manufacturing

Haptic is widely applied in product designing. The application of haptic device in the product design, prototyping and testing will greatly reduce the time and cost of manufacturing and designing [21, 22].