CHAPTER I

Introduction

1.1 Classifications of Haptic Devices

As we approach the 21’st century, programmable and intelligent mechanical systems are becoming more prevalent in our lives. One particular area of interest are mechanical systems intended for use directly with humans; such systems share desired workspace and interact with humans to complete specific tasks. More explicitly, many of these devices consist of a mechanism an operator physically manipulates to position a particular part of the device or “end point”. The mechanical system may merely record the “end point’s” location and path it took to get there. In addition, the device may restrict an operator’s movements to a preprogrammed path, possibly assisting the operator’s effort.

The first classification of devices is completely passive and intended to only record and compare information. A computer interface may be utilized to assist an operator in maneuvering the device through graphically showing where the “end point” is in comparison to a desired position. The device’s “end point” may hold a specific tool, part, or mechanical jig to be held in place, while built in brakes lock the system once it is in proper position. Such a device acts as a holder, allowing the operator to perform a desired job without worrying about keeping the tool, part, or jig steady. Potential applications are assembly, medical, or machining processes. Such examples are surgical operations where a needle must be held constant while being inserted in the patient or machining where a template is held in position as the tool performs its task along the guide. Furthermore, such a device may be used as a joystick for tele-operating another machine, similar to existing joy sticks except that the device is tailored to match the remote machine's configuration or task's natural motion. As can be seen these systems are entirely passive and rely solely on the operator to move and restrict motion of the device, making a safe human machine interface by nature.

The next step is for the system to work with the operator to restrict or aid in the device's motion, feeding back tactile information to the user. Devices (joy stick, mouse, or large scale mechanism) that relay tactile information back to the user with regards to position, machine being tele-operated, or virtual environment being simulated are referred to as Synergistic Systems or Haptic Interfaces [Troccaz and Delnondedieu, 1996]. These devices may be used to restrict the user's motion of the mechanism to within a programmed region or on a programmed path. In addition, haptic interfaces may relay back force information based on the programmed virtual environment or actuator limitations and environment of the remote tele-operated machine. This may be accomplished through restricting the device's motion with active compliant motors, creating an active haptic display. Due to the size or nature of specific applications it may not be desirable to use a haptic interface with capabilities of unpredictable self initiated motion, potentially overpowering the human's input. Alternatively, passive haptic interfaces do not use actuators capable of adding energy to the system, but rather utilize actuators that dissipate, store, or redirect user-supplied energy. This can be accomplished through modulating clutches / brakes, continuous variable transmissions, or fluid systems.

A third classification is when a device supplies most of the required force for movement, but only travels in the direction guided by the operator and at a rate proportional to the operators input force. Because the required force to impart motion is shared by the operator and the device’s actuators, the operator feels tactile information from the performed task. Again, such a device may be preprogrammed, restricting motion to a set path or region. Such machines can act as force multipliers allowing an operator to maneuver tools & objects much heavier then ordinarily possible, while still feeling tactile information based on the operation or programmed restrictions.

1.2 Applications for Haptic Interfaces

Haptic interfaces have various applications ranging from training devices to super joysticks for remotely operated robots. As the global economy becomes more competitive and existing companies begin to clean up muda (manufacturing waste), it is apparent that manufacturers are completing more of the product and manufacturing process design in virtual reality. Therefore, it is now imperative that companies must be flexible for quick implementation of product design changes to stay ahead of the competition. Programmable constraint devices are tools that can add flexibility to the design and manufacturing process. For manufacturing, a haptic interface can be used with a virtual factory simulation to study ergonomics of an assembly process. Such a process could be picking up a part and placing it on an assembly. In this example, the device may be used to restrict operator's motion to that required by the assembly process. Much information regarding execution time of the process and operator comfort may be determined allowing various iterations to be studied before one is chosen for implementation. Another application for haptic interfaces is as an actual assembly tool. Here the haptic interface might be a mechanism that holds an assembly part either too heavy or delicate for the line worker to handle. The worker can now manipulate the haptic mechanism to correctly position the assembly part, but because the haptic interface has a pre-programmable path, the worker is restricted to moving the part into the correct location and orientation. This haptic device may be reprogrammed for changes in assembly part or processes making it more versatile than a dedicated assembly machine.

As briefly mentioned previously, another application of haptic interfaces are as "super joysticks" for tele-operation of remote devices in a different room or building then the operator; useful for situations where the active working device is in an environment dangerous to the operator. In this example a haptic interface acts as a super joystick relaying information about the remote device to the teleoperator. Such information might be the remote device has reached its limits of allowable movement or has hit an obstacle and can not continue any further without causing damage to itself or the environment. One such application might be operation of earth excavation equipment. For example, the controls of a Backhoe would relay information to the user about hardness of earth being excavated. The user would know when a rock or immobile obstacles is encountered and further excavation would result in equipment damage. Alternatively, it may be desirable to restrict the slave / remote device to within a specific region by programming this restriction in the operator’s haptic interface.

1.3 Georgia Tech Haptic Interface Test Beds

The Intelligent Machine Dynamics Laboratory (IMDL) has implemented two Haptic Interface test beds. The first is HURBIRT (Human Robot Bilateral Research Tool), designed and implemented by Lonnie Love. [Love, 1995] The Second is PTER (Passive Trajectory Enhancing Robot), designed and built by Robert Andrew Charles. [Charles, 1994]

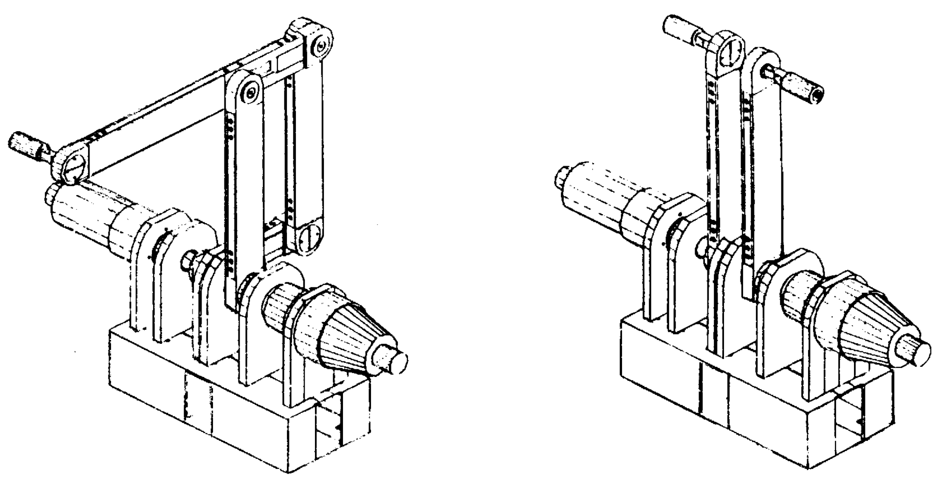

Figure 1.1: HURBIRT in Two Configurations [Love and Book, 1994]

HURBIRT is an active Haptic Interface designed to be reconfigured between a 2 DOF device and two 1 DOF devices. The 2 DOF configuration utilizes a closed kinematics chain in the form of a parallelogram, eliminating coriolis and centrifugal terms from the dynamic equations of motion. In addition, the actuators are located at the base and do not move with the links. HURBIRT has been used as an active master for bilateral teleopertion of RALPH (Robot Arm Long and Flexible) a long reach manipulator. Impedance control, an algorithm intended to force the robot to behave like a target dynamic system when encountering virtual boundaries, was implemented and tested. For example, this target system may take the form of a simple mass-spring-damper.

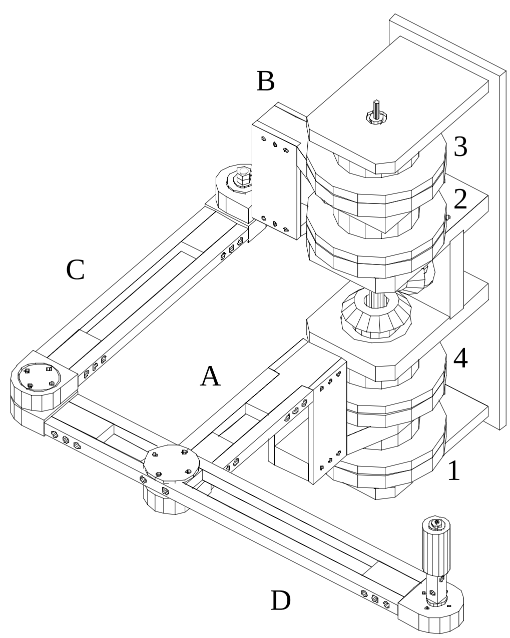

Figure 1.2: PTER

PTER is a passive Haptic Interface based on the kinematics of HURBIRT therefore utilizing the same dynamic benefits. Instead of geared electrical motors, PTER uses 4 electromagnetic friction clutches (labled 1,2,3, &4 in Figure 2) to redirect or dissipate user supplied energy. Similar to HURBIRT ‘s motors, these clutches are located at the base and do not move with the links. Impedance controllers were programmed by past students to simulate haptic features. [Charles, 1994] [Davis, 1996] [Gomes, 1997] Such Haptic features that PTER has simulated in past research are virtual walls, circular paths, and corridors. Though it is in future plans, to this date PTER has not been used as a master in bilateral tele-operation. Several students have worked on implementing different haptic control algorithms, all realizing several mechanical deficiencies in the hardware of PTER. Because of these deficiencies, improvements to PTER is the focus of this research; primarily improvements to the 4 actuators.