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Engineering Internship Program Report

by

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Introduction

Prior to my participation in the Engineering Internship Program (EIP) at the Massachusetts Institute of Technology (MIT), I had completed my fifth year of undergraduate studies in the Aerospace Engineering and Electrical Engineering departments. Through EIP, an internship was established between MIT and the National Aeronautics and Space Administration (NASA) at the Johnson Space Center (JSC) in Houston, Texas. This internship was intended for two students from each MIT class year, after their sophomore year, to spend three summers and the first semester of their graduate work at JSC. Due to a variety of reasons, the program was limited to sending two students in the summer of 1993, and a proposal was approved to send two more students in the summer of 1994. A total of four students participated in this program. Lisa Cohen and Lynetta Frasure participated in the summer of 1993, and Deborah Gustafson and myself participated in the summer of 1994.

This was my first tour at NASA JSC. My tour began on May 31st and lasted until August 26th. I worked in Building 9, in the Mockup and Trainer Section, in the Experimental Facilities Development Branch. My supervisor was David Ray.

Mockup and Trainer Section Overview

The Experimental Facilities Development Branch consists of the Weightless Environmental Training Facility (WETF) and the Mockup and Integration Laboratory (MAIL). The WETF is a large pool used to simulate a weightless environment with neutral buoyancy, and is used to train astronauts for extra-vehicular activities (EVAs). I worked in the MAIL which is maintained by the Mockup and Trainer Section. It consists of full scale mockups of the Space Shuttle Orbiter and the International Space Station Alpha, and trainers for micro-gravity simulation. The MAIL is required to provide correctly configured mockups to support shuttle missions, space station development, engineering evaluations, and astronaut training. The MAIL supports various activities for a number of organizations or customers across the center as well as other centers and prime contractors.

The MAIL consists of the building 9A and 9B complex located on site at JSC. Here is located the full fuselage trainer (FFT), the two crew compartment trainers (CCT and CCTII), the Precision Air Bearing Floor (PABF), and the Partial-Gravity Simulator (known as the POGO). The CCTII is currently being built, while the FFT and CCT have been in service since the beginning of the shuttle program.

The FFT includes the flight deck, middeck, airlock, and payload bay of the space shuttle, and it's function is to familiarize astronauts with the location and appearance of the control panels and storage lockers, and it helps the astronauts get used to the size of the middeck and flight deck. It is a static mockup with no functioning systems.

The CCT is a mockup of the flight deck, middeck, and airlock. The CCT is a high fidelity mockup used to train astronauts on the orbiter's audio and video systems. The astronauts also use the CCT to practice ingress, egress, and airlock EVA procedures. The CCT has the ability to be tilted from the horizontal position to the vertical position to simulate prelaunch conditions. The CCTII will be similar to the CCT. The CCTII will be equipped with a new tilt and rotating system, allowing it to be positioned at various angles and rotated, from a nose down position to being positioned on its side.

The PABF simulates a planar microgravity environment, and is used to train astronauts for EVAs, to evaluate engineering designs for EVA tools and external structures, and for biomechanical studies. Individuals and equipment are supported on sleds that glide over a floor on cushions of air, which provides for minimal resistance to motion in x and y translation and yaw.

The POGO can be used to simulate various gravity environments such as lunar gravity ($^1/_6$g), Martian gravity ($^3/_8$g), or zero gravity. A subject is strapped into a harness which a pneumatic system lifts up on by a certain fraction of their entire weight, allowing them to move about as if they were in a different gravity environment. The POGO was developed during the Apollo program, so astronauts could see what walking on the moon might be like. An object can also be attached to the harness and suspended in a zero gravity condition so that astronauts can gain mass handling skills.

Virtual Reality Work

As a summer student intern, I worked with the PABF and POGO, under the guidance of David Ray. I was offered a number of projects to work on, and the one that occupied most of my summer was research on virtual reality (VR) systems. My job was to investigate hardware issues in the implementation of a VR system onto each of these trainers. Other work I did was to gather information on device level communication networks, and to integrate LabView software with the POGO.

Virtual reality is a technique which allows an individual to interact with a real or simulated environment which would usually be impossible due to distance, hazards, cost, etc. The key idea is immersion, the virtual reality system provides enough sensory input so that the user has a convincing perspective of the real or simulated world. The main sense that is involved is visual, but there is also 3-D sound and force feedback which further enhance the immersion. The actual physical setup of a VR system has a limited working volume, such as an aircraft cockpit, in front of a workstation, or on a mounted seat or stationary bike. But while the subject is immersed in a virtual environment, they can be moving through a whole architectural floor plan, flying over the Martian or Venusian landscape, seeing a 3-D view of the airflow over the surface of an aircraft, flying through the airspace surrounding an airport or battlefield, or maneuvering around the space shuttle's payload bay while training for a mission, as with the repair mission for the Hubble Space Telescope.

There are three primary hardware issues in choosing a virtual reality system. There is the choice of a graphics platform, a head-mounted display, and a position and orientation tracking system. There can also be a choice of peripherals such as 3-D sound, voice-activated control, and gloves. In developing a VR system for the POGO and PABF, the head mounted display and the graphics platform were both available on site through the PLAD Lab, and the single most challenging issue was choosing a position and orientation tracking system, which is what I worked on.

The tracking system is necessary in providing accurate data on the position of the subject in the working volume, and also the orientation of the viewer's head or hands, and this information is used by the computer graphics platform to update the view in the head-mounted display. This gives the subject a realistic view of the virtual world, and allows for the user to accurately manipulate their perceived environment, real or simulated. The POGO and PABF are rather unique applications of virtual reality by the fact that they both have a very large working volume. As mentioned before, most VR applications have limited working volumes. The POGO allows a subject to move along a 15 foot linear track, and the PABF allows for motion on a 32 foot x 16 foot floor. These trainers, coupled with a VR system and with the freedom to move around a larger area while feeling the reduced gravity or the lack of resistance to motion, add unique enhancements to the subject's level of immersion.

As it turns out, the physical environments of the PABF and POGO are fairly hostile towards the four technologies that current tracking systems are based on. The major challenges these trainers present are range, the presence of conducting and ferromagnetic materials, and line of sight problems. These trainers required VR systems that worked beyond the abilities of a single technology on the market, and it took a combination of these technologies to accomplish the task. This is explained after a general background is given on these technologies.

The four main technologies for position and orientation tracking systems are electromechanical, electromagnetic, acoustic, and optical. Electromechanical systems are based on a series of linked mechanical assemblies, with potentiometers at each assembly joint measuring its relative angle and position. There are two types of electromagnetic systems, those based on alternating current magnetic fields (AC) and those based on pulsed waveforms (DC). Both systems use a three-axis magnetic dipole source and three-axis magnetic sensors. Acoustic systems generate inaudible sound frequencies and employs triangulation methods to calculate position. As with the EM, there are two types - phase-coherent and time of flight. Optical systems can be broken up into fixed transducer or image processing. Fixed transducer systems have cameras which view a set pattern of LEDs. Either the cameras or the LEDs are placed on the head-mounted display with the other somewhere in the working volume, such as the ceiling. Image processing relies on ambient light to illuminate a specially designed image placed on the subject, with a camera to capture the image.

Two of these technologies were immediately discarded, those being the electromechanical and acoustic systems. The electromechanical systems rely on a centrally mounted, linked mechanical assemblage that restricted the working volume. The acoustic systems are hampered either by an inherent phase lag (time of flight) or by an accumulated spatial error (phase coherent). These characteristics were unacceptable in the large working volumes of the POGO and PABF. Also discarded was the image processing option. The required computing power and expense of these systems, plus the line of sight problems, made these undesirable.

The most promising technologies were electromagnetic and optical. The keys issues were range, tracking a number of body parts, line of sight obstructions, cost, and the presence of conducting and electromagnetic materials. The optical systems have good range, but tracking a number of body parts given the range of motion on these trainers and the line of sight problems would be difficult, and the systems were expensive. The electromagnetic systems have good close range tracking without interference from line-of-sight obstructions, long range tracking is poor, they are adversely affected by the presence of conducting and ferromagnetic materials, and they are the least expensive of the devices.

A number of commercially available products and one university research project were considered. For electromagnetic systems, the products that were considered were FastTrak (Polhemus), Flock of Birds and Extended Range Transmitter (Ascension Technologies). The Walkthrough Project at the University of North Carolina and OPTOTRAK were optical systems we considered. Some of the key characteristics of these systems are as follows. FastTrak is a lightweight, AC system, with a range of 5 feet, inexpensive, and can track up to 4 receivers. Flock of Birds is a lightweight, DC system, with a range of 3 feet, inexpensive, is less affected by the presence of conducting materials than the AC FastTrak, and can track up to 30 different points. The Extended Range Transmitter has similar features as the Flock of Birds, but is bulky (one cubic foot, fifty pounds) and has a range of 10 feet. The OPTOTRAK has a range of up to 20 feet, is expensive, can track up to 256 points, and is affected by line of sight obstructions. The Walkthrough Project is an expandable setup, and has effectively an undefined floor area, as long as a ceiling superstructure can be constructed above the working volume. Other characteristics are excessive headborne weight and limited head rotation range, and is expensive.

A number of possibilities were considered, with different arrangements of single technologies or coupled technologies. The Extended Range Transmitter was too bulky to place several above each trainer's working volume. The Walkthrough Project was too expensive for this phase of the project. This left the Flock of Birds, FastTrak, and OPTOTRAK. For the POGO and PABF, using an electromagnetic system alone would be impractical, given the ranges and the presence of conducting and ferromagnetic materials. It was also impractical to use an optical system alone, using several OPTOTRAKs for full coverage would be too expensive.

The final solution for the POGO was to locate an OPTOTRAK above the working volume and track the harness, and use a Flock of Birds located on the harness to track the head and hands. For the PABF, the same solution applies with an OPTOTRAK tracking the sled and a Flock of Birds located on the sled tracking the head and hands, but a human operator would need to be in the loop, to keep the OPTOTRAK oriented toward the subject.

Conclusion

Towards the end of the summer, I prepared for a presentation to the chief of the Flight Crew Support Division to obtain funding for Phase I of the project. I presented information on the tracking systems, David Ray presented on the POGO and PABF and the integration of the virtual reality systems, and Mike Van Chau talked about other hardware issues such as head-mounted display, 3-D sound, gloves, graphics platforms, and other peripherals. The funding was approved, and work was to begin at the end of August in evaluating a couple of the tracking systems, to integrate the graphics platform and video equipment with the POGO, and to build a larger gantry for the POGO.

This tour I learned how to effectively gather information and present them in a convincible form to gain funding. I explored a entirely new area of technology, that being virtual reality from the most general form down to finer details in its tracking systems. The experiences over the summer have added a lot of detail to work at the Johnson Space Center, life within NASA, and to the many possibilities for becoming involved with the space program.

Again, my internship was extremely rewarding. I am extremely fortunate to be working for NASA JSC as an intern. I consider the engineering experience gained during this tour as a valuable part of my education. I plan to return to NASA Johnson Space Center in the fall of 1994. During that tour I will be working in Building 4S, with the Russian teaching program.