Immersive Simulations and Engineering Environment

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Research and Development of the immersive Simulations and Engineering Environment

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Nomenclature

iSEE	=	immersive Simulations and Engineering Environment
Mocap Orb	=	Silver spherical ball coated with special material designed to be visible by motion capture camera
Jack	=	Analysis and task simulation software
Vicon	=	Motion Capture Vendor
Jack Script	=	Proprietary scripting language used in the Jack software

I. Introduction

A. Abstract

March of 2018 marked the conclusion of the primary updates to the immersive Simulations and Engineering Environment (iSEE) at Kennedy Space Center (KSC). Many of the problems that had arisen during the previous semester have been addressed and rectified. These included the malfunction to one of the lab's primary routers, the inefficiency of the capture environment, and various interface issues in the analysis software, Jack. This semester was primarily research and development oriented with some focus on implementation of the new hardware and software that was received last semester. The new computers and cameras that arrived sometime during the winter were installed, and the lab received its second operation opportunity. The second operation was a major milestone for the lab, both in terms of what the abilities were and what can be learned from its use. The operation performed was a virtual simulation of a critical task that would occur, if it should be needed, in the Multi Payload Processing Facility. It was done to gather human factors data on its safety and process controls. The technicians were able to come to a number of conclusions about how to perform their task as a result of utilizing iSEE. Another key breakthrough this semester was the introduction to Jack Script, a scripting language built into our analysis software that further extend Jack capabilities.

In addition to the aforementioned, many preparations were made for family day, an exposition for KSC families to come out and tour the spaceport. Due to family day being moved to the spring, the video made last fall had to be updated with recent environment changes in preparation for the Family Day demonstrations.

B. Introduction

The iSEE is designed to explore the uses of virtual reality and motion capture technology for the purpose of Human Factors evaluation and testing. The primary goal of iSEE is to assist NASA's human factors groups in ensuring that the standards, set for worksite analysis and safety of all operations on site, are maintained. The advantages of using the lab versus traditional full-scale mockups with human in the loop testing of an actual operational environment became clearer during the first iSEE operation. Some of these advantages include the ability to come to conclusions about an operation before any significant amount of money or time is spent on them; perform live analysis that determine long term effects of different postures; and work routines without the arduous task of actually performing such routines.

This semester, the progression tasks include planned upgrades as well as remaining optimization assignments. These tasks were designed with the idea of improving the integrity of the lab such that it would operate with all the abilities of its predecessor, the Human Engineering Modeling And Performance Lab. Continuing from the previous semester, a lot of the optimizations and modernizations were already complete, and the remaining tasks included primarily hardware that needed to be installed or modified in a subtle way for performance improvement. When not troubleshooting or upgrading parts of the lab, the focus was on operations and select research and development projects. These tasks consistently increased the popularity of the iSEE, and expanded its range of uses for clients.

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C. Overview

While the overall renovation was incomplete, a majority of the updates that were scheduled for last semester were finished. Much useful data was gathered on daily operations of the lab. This part of the research served primarily as a continuation of the modernization that had commenced previously. Another primary subject of interest, aside from the modernization, was the establishment of normal operations such as training, worksite analysis, and task analysis. The lab was able to finally demonstrate its potential by hosting a demo of a contingency operation. This illustrated the lab's strengths and weaknesses and provided a clear course for future optimizations. The main goal for iSEE this semester was to conclude any incomplete modernizations with a final optimization of the lab. After the modernization of the lab, the next step is to apply the technology. This semester will include hosting operations and determining how many will be completed each month. The last component of the project was the research and development, and their upgrades. With these R&D activities, progress was made to go beyond the original lab's capabilities. Each of these three goals will be explained in detail in the following sections.

iSEE Modernization

D. iSEE, How it works

What makes the iSEE unique is its ability to use live motion capture data to visualize and perform analysis on tasks without the need for expensive props. Twenty-nine visible red and infrared cameras are interspaced throughout the lab. These cameras are designed to capture the live position of objects by tracking small silver motion-capture orbs attached to them. This data is then sent through Ethernet cables to four high speed router units that package the information into a format that the motion capture software can understand. This information is then translated into positions of objects in 3D space. Some of the major strengths of the system include its ability to virtualize up to 3 people performing a particular task accurately and store this data with the ability to rerun the operation at any time. The physical layout of the lab is designed to optimize performance by having the newer cameras closer to the top of the capture volume to take advantage of their stronger and more robust view range.

Since the conclusion of the modernization, the lab has changed quite a bit. Both of the new computers are running the latest version of the analysis software and motion capture software. The system follows a simple layout involving the two computers. One of these computers is tasked with handling the data acquisition with the motion capture software, and the other is tasked primarily with the analysis of the data. This is done to split the processing power between the two for increased performance. Although this is relatively similar to the original configuration it has been greatly optimized to improve performance.

E. Installation of New Computers

The final parts of the renovation began in late January. The new computers for the lab arrived in December and were slated for installation in early February. All of the old calibration methods remained relatively the same during this time due to a delay in scheduling for the next operation. However, it was decided that general modernization activities would continue. The new computers were installed over the course of two days, one per day so that the lab would remain in a relatively light construction stage. The hardware installation went well. The major problems pertained to issues with the network cards and network card configurations. The original computers had two network ports while the newer ones only came with one. The only workaround for this was to acquire unused network cards from some of the older computers.

The hardware side of the new computer installation went smoothly, however a number of driver updates seemed necessary to get the required software to work efficiently. As soon as the new computers were online and ready to go, the motion capture software was installed. There were no immediate problems at first; however, an issue preventing the motion capture system from coming online was discovered and had to be promptly addressed. The problem was attributed to a setting in the Windows firewall configuration. The program was designed to work with a specific configuration. Due to how the new Windows operating system saves its firewall settings, the procedure for this setup had to be modified.

The final part of the computer upgrades was the installation of the new Jack software that came less than a few weeks before the low point drain operation. The software had to be acquired from the vendor's website and transferred to the computers. Coordination with the vendor was needed in effort to procure the right license files and procedures to get the software to run. Due to the new security features of Windows, a new method had to be devised to install the new license software on both the license computer and client computers. While arduous, this task did result in the lab being able to simultaneously run two separate editions of the software and analyze them side by side for comparison.

F. Installation of New Cameras

It was decided that installation of the new cameras should begin immediately after the lab's first demonstration in late February. This was done in order to provide enough time to prepare should there be another operation. The lab had received four new cameras late last semester, as well as the new router to install them. In order for the installation to take place, new fast-track aluminum tubing had to be prepared to provide stable unobstructed locations in which to mount the new cameras. After they were successfully unboxed, positioned, and mounted on the lab scaffolding, the wires were routed and then connected in the server. A massive improvement in performance of the system was noticed with little setbacks. The full efficiency was unable to be achieved from this new system configuration until the Vicon optimization which wouldn't occur until the end of March. While the cameras were able to provide much needed coverage to the volume, there were a number of configuration settings that appeared to inhibit the maximum amount of data that the cameras would be able to stream. One final result of the updates was a change in the procedures on how to calibrate the volume. Originally, the calibration process was three steps and required three different calibration objects for each respectively. Due to the improvements and the results of the new system requirements, only one calibration object is now required.[i]

Important Milestones: Low Point Drain

G. Low Point Drain

On the week of January 29th, iSEE experienced its first fully functional operation, and second operation to date of the Low Point Drain worksite analysis and contingency operation. The main purpose of the lab is to provide a means to test human factors designed and modeled performance solutions. The lab is essentially another way to verify the human system interfaces of a particular task performed by NASA contractual technicians and engineering personnel. This operation involved a worksite analysis and safety plan for two technicians who would be tasked with accessing a hatch in a hard to reach crawlspace beneath a very sensitive piece of equipment. For this particular operation, the lab was not providing just the environment, but also the necessary tools to complete the task that they would be expected to perform in the environment. For the scenario described above, technicians were not limited to just moving around in the crawlspace, but they had to actually carry and navigate a piece of equipment. In the case of this operation, the technicians had to move a step platform, out of a confined space and to a particular location in the environment to perform the actual activity.

The goals for the operation on behalf of iSEE were to provide two products. For technicians, this would be a good overall feel for the environment where they would have to work via head mounted displays, as well as a sense of how they would have to move around in it during the operation. The lab would also provide a way for the technicians to formulate a methodology on how to perform the operation while taking into account the visible obstacles in both the environment and the task they are trying to perform. As far as the Human Factors personnel, the product the lab would be providing is an in-depth analysis on the physical ergonomics and safety of the operation, utilizing our analysis software. iSEE would be able to provide a detailed analysis of the forces on each of the technician's bodies as they maneuvered the platform, determine how much stress is present and asses health hazards if there are any.

For this operation, most of these milestones were able to be met with overwhelming success, not necessarily in the way expected.

H. Low Point Drain: Conclusions Drawn

With the aid of iSEE, the technicians were able to come to a number of conclusions as well as get a better understanding of how difficult it was to move around in the virtual Low Point Drain environment. One of the first conclusions that they made was the need to reduce the size of the steps. The original model included a step that was unnecessary given the height of both the tallest technician and shortest technician. Both were able to access the area of interest without this additional step. Trimming off this extra step would also allow them to more easily handle the step platform in the small environment.

Another conclusion was a possible request of having a smaller set of technicians, given that one of the technicians who was a bit taller had trouble moving around. They kept colliding with various obstructions as evidenced by our software's collision detection system.

The more interesting conclusion from this operation was that the technicians were able to get a better sense of how cramped and confined the work area was designed. This led to them requesting that a physical mockup be built for testing. While they were able to gain an understanding of how they would have to move around the environment, they often collided with equipment that was deemed too sensitive to ensure continued safety of both the work area and the hardware. Given this was a contingency operation and could not afford failure, they decided that a full-scale mockup would have to be constructed. These results, while extremely informative and on par to iSEE's purpose, were unexpected.

Overall the operation was a good preview of iSEE's abilities. Since the Low Point Drain operation, the environment's abilities have expanded.

I. Lessons Learned –Requested upgrades

While the Low Point Drain Demonstration was a success for iSEE, there were some setbacks and numerous points of improvement.

During setup for the operation, we learned that we would only have one Head Mounted Display (HMD) available for use for a two person operation. This did not severely impact the result of the simulation, however it did highlight our need for continued upgrades as our other technician had to use one of the monitors to get a sense of where they were in the environment.

There were other drawbacks pertaining to how exactly we utilized the displays as well. Most of them related to the reoccurring problem of simply not having enough transmitters and receivers. Due to our limited supply, we were only able to utilize one extra monitor to broadcast to both of the individual displays on the HMD, as opposed to two. The results were fairly noticeable as the technician who wore the HMD, visibly had trouble with depth perception. As a result of this, the lab has since upgraded our transmitters and receivers to a much more reasonable, lower cost variant.

When this operation was done, we were still experiencing issues with the newer computer and we had to run it on the older motion capture PC. Surprisingly, one of the high points of the simulation came from the use of the older pc for the Low Point Drain operation. From the technical standpoint, we were able to capture two actors with relative accuracy as well as an object with little to no prop merging. Prop merging is when the system is unable to tell which physical objects correspond to their virtual counterparts. This was greatly reduced, a factor which can be attributed to the robustness of the new motion capture software. The technical gains did not stop there either. The analysis PC was running very smoothly, despite performing collision detection analysis, tracking on two virtual avatars and a prop, running video capture software, and streaming data from the motion capture software at the same time. This helped verify how much of an improvement and the respective capabilities that the new computers brought to the lab. As a result of this and by some further investigation, it was decided that strides be taken to purchase another computer. There were more evidence that supported the fact that the motion capture software would run even better on a newer computer. The analysis software requires both of the newer computers to fully submerge two people in a virtual environment due to the amount of ports available on the graphics cards of each one.

Research and Development – Going Beyond

J. Vicon Optimization

For the last couple of months, iSEE has been making preparations for a visit from one of the lead motion capture vendor representatives. This meeting finally happened during late March. Overall the optimization that came as a result of this meeting was a success. The representative provided a lot of information that improved how the system in the lab operated.

This served as an educational seminar to discuss some of the key concepts behind maintaining and operating the various types of hardware, including but not limited to, focusing the camera lenses and capturing multiple people at once. The technician reinforced the fact that a healthy hardware setup is crucial to a healthy system. He also took the time to explain how to use certain aspects of the motion capture software. Some of the topics discussed were calibration, fixing problems with the hardware configuration, how to capture objects and props without having to remove everyone, and everything from the scene as well as some general use tips and tricks.

With the information gained from this point, iSEE can move forward with full awareness of the motion capture system's ability to perform well given any situation. The optimizations that were done over the course of the visit reinforced some of the important methods behind post processing and character capture, allowing iSEE to be more productive with the ability to capture up to three people as opposed to two as well as adequately handle errors in the system should they arise.

K. Scripting with Siemens Jack

A research project utilizing the scripting module in our analysis software was undertaken this spring. Last semester it was discovered that our analysis software was able to be expanded through the use of scripting. A concept was further developed for what was called "Virtual-Virtual Interaction", specifying that a person in a virtual environment would be able to interact with fully virtual objects. This would expand the abilities of the environment by reducing, and possibly eliminating, our reliance on making props. Other benefits include the analysis and testing of mere concepts before any major money is spent and possible applications for training personnel to work in hazardous environments.

Research into how to do this started with gaining an understanding of how the program's scripting language worked. This was done by reading through the program's documentation and a number of tutorials. While this approach did provide a decent understanding of the scripting language itself, it failed to assist in how to apply it towards something that could be utilized for the lab. The solution was to reach out to the analysis program's vendor themselves. After a good amount of correspondence and a proof of concept, a prototype script, *iSEE Navigator,* was able to be produced. The simple goal behind this script was to 'expand the capture volume'. The script provided a means to move the area of analysis within the environment by moving the environment itself. This would be done by the pressing of a virtual button from a virtual avatar that the actors would control in the same way they would their avatars during a regular analysis operation. While simple in design, this expands the area that iSEE can perform a human factor analysis to be virtually limitless.

As important as this was, it was merely the first step. Soon after, development started on two more scripts. One of the scripts, named *Virtual force,* would demonstrate the ability to add a virtual touch component to the analysis software—to make it so that virtual avatars could pick up and move things. The second script *Virtual Gravity* would provide a method by which objects that are not supported by another object or a hand would fall down. iSEE will be able to do more than originally anticipated with the inclusion of these scripts.

L. Expanding knowledge base

The majority of the tasks this semester were within iSEE, however as an intern I did participate in numerous other activities that assisted in gaining skills. Some of these skills would be applied to working in the lab and others would be applied to other aspects of my major. This semester I started job shadowing with my mentor, Antonio Pego, who often has a myriad of assignments. Some of the activities were primarily his responsibilities that included meetings relating to qualification and testing. I was able to acquire a general understanding about the complicated process of design, qualification, and testing of the many components required for various pieces of hardware. I also was able to witness how people from different departments come together to accomplish a shared goal and brainstorm ideas that would allow for optimization of this process.

During the second half of this internship, I was able to participate in an overview for a procedure detailing how to perform testing on one of the firing room consoles. While not my main goal during this internship, this activity really helped to broaden my horizons in regards to what's possible and the many tasks that go on at Kennedy Space Center.

Conclusion

M. New Documentation

This semester marked the conclusion of the modernization of the iSEE, from installing new hardware to troubleshooting and software updates. How to operate the software and the tips and tricks learned from the optimization, are to be recorded in great detail in the new manual for the lab. Many of the experiences were recorded in addendums to the current set of documentation throughout the semester to provide some direction in the event the primary manual is unable to be completed. At this time, however, the new manual will include information on how to perform the necessary scripting for the analysis program as well as explain the proper use of the motion capture software. Keeping tradition from last semester, another section will also be added as the troubleshooting guide to provide aid is needed.

N. Goals of iSEE

The immersive Simulations and Engineering Environment's main goal is to provide one of the many tools necessary to ensure that our workplaces stay safe. While the range of capabilities and uses are moving beyond where and what was originally imagined, this environment will always represent an optimistic, supportive relationship between man and machine. iSEE will continue to provide an insightful and deeper understanding of how people will work around, work with, and utilize the equipment that will ultimately become part of our everyday lives. This relationship is going to be ever more important as we venture out farther into space. iSEE's modernization marks a step towards easy access to a field that has becoming increasingly important in spaceflight. With the new capabilities, new software and hardware, the lab will be ready once more to provide cost effective and efficient solutions to Human Factors, Human Systems Interfaces, and Ergonomics throughout Kennedy Space Center.

Acknowledgments

I would like to thank my mentor, Antonio Pego, for not only guiding me throughout this internship and the renovation of the lab, but also for showing me all the great things in life that are possible through perseverance. He helped me immensely with invaluable insight on development of my character and how to succeed through understanding myself and mainly those around me.

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Finally, I extend my sincerest thanks to Dr. Gena Henderson for giving me the opportunity to partake in this wonderful and very insightful internship. I can say with utmost certainty that I have learned more here than I would have ever imagined.

References

Wessley Dennis (2017) *immersive Simulations and Engineering Environment*, University of Central Florida

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[i] See immersive Simulations and Engineering Environment, by Wessley Dennis for information regarding how the calibration process works