Immersive Simulations and Engineering Environment (iSEE)

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Improving Fidelity of Virtual Reality Simulations

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The Immersive Simulation and Engineering Environment (iSEE) provides Kennedy Space Center (KSC) with accurate Human Systems Integration (HSI) analysis of the stresses on a human body incurred from physical work, along with accessibility and reach factors. Human Factors engineers can observe the simulations conducted by iSEE and work with the gathered data to help make the working environment at KSC safer. The software that runs the HSI analysis, however, provides users with a low fidelity virtual environment. Previously, this led to the addition and implementation of other iSEE programs that were capable of higher-fidelity simulations. The difficulties of streamlining the workflow in the lab with these new programs is currently being addressed.

Nomenclature

HMD	=	Head-Mounted Display
HSI	=	Human Systems Integration
iSEE	=	Immersive Simulation and Engineering Environment
KSC	=	Kennedy Space Center
VSS	=	Vehicle Stabilizer System

I. Introduction

A. Introduction

iSEE employs virtual reality simulations to conduct HSI analysis. An actor dons a motion capture suit and performs the desired operation, while their movements are recorded by motion capture software and transferred to the HSI analysis and visualization software. This simultaneously reduces the cost of conducting the analysis and removes the safety concern from the physical world, allowing a variety of hypothetical simulations to be carried out without any risk to the actors in the simulation. The main program in use is HSI analysis software that gives accurate stress analysis results, but fails to create realistic virtual environments. Other visualization programs are well-suited to rendering realistic scenes, but have difficulties interfacing with the lab's motion capture software. Recently, there have been attempts to streamline the process that sends raw motion capture data to a game engine that is used as visualization software, and although results are promising, the development of this workflow is still in its infancy.

B. Overview

Increasing the fidelity of iSEE simulations first required an understanding of how the current system worked. Understanding the limitations of the HSI analysis software led to a realization that higher fidelity virtual environments would benefit the lab by fully immersing actors in the simulation, allowing them to more easily focus on the required tasks.

In order to interface the motion capture software with the game engine, intermediate programs had to be employed. This required familiarization with these new programs and a restructuring of the regular workflow in the iSEE lab. Virtual environments built in the HSI analysis software had to be rebuilt using the new workflow in order to demonstrate that the new process was at least as good as the old, if not better.

New hardware was also acquired in the hopes of further increasing the fidelity of the simulations. There have, however, been unforeseen problems with its implementation.

II. iSEE Operations

D. Lab Environment Overview

The iSEE lab contains a large square area that is left open and used for motion capture, a smaller area with servers, workstations, and a 3D printer, and space around the motion capture area that is used for storage. The equipment used for motion capture includes 33 motion capture cameras, motion capture suits, motion tracking markers (reflective orbs that are easy for the cameras to see and distinguish from the surroundings), and motion capture software. In order to build mock-ups (real-life representations of a virtual environment used to create realistic boundaries for motion within the environment), 3D printed parts are connected and coated with metal wire mesh; where necessary, they are mounted to metal poles.

The software necessary to process the motion capture data runs on three computers, each running a different program in order to minimize stress on the computers. In order to immerse the actors in the simulation, wireless head-mounted displays are used, which receive transmitted visual data from the visualization program of choice and display it in front of the actor's eyes.

E. iSEE Operations Procedure

iSEE operations are based on specific procedures, with troubleshooting applied as necessary.
1. Initial setup:
    a. Motion capture cameras are turned on in a specific order to avoid server parenting issues.
    b. The computers that carry the motion capture software and HSI analysis software are turned on.
    c. The motion capture software is connected to the cameras.
    d. Room calibration is conducted, a process that locks in the position and rotation of each camera in 3D space and conveys that information to the motion capture software.
2. Operational setup:
    a. The HSI analysis software is turned on.
    b. The virtual environments necessary for the operation at hand are loaded into the HSI analysis software.
    c. Motion tracking markers are placed on all actors and props needed for the simulation.
    d. If any actor or prop needs to be calibrated, they perform a "range of motion" in the capture area, and their virtual skeletons are saved in the motion capture software. Otherwise, previously saved skeletons are imported into the virtual environment.
    e. The HSI analysis software is connected to the motion capture software, allowing it to receive streamed motion capture data and connect the skeletons to 3D models and avatars.
    f. The operation is conducted and recorded with screen-capture videos. HSI analysis data are also collected as needed.
    g. The HSI analysis software in steps a–f may be interchanged with the game engine. However, this would not allow for the collection of HSI analysis data.

F. Operations Conducted

This semester, several simulations were conducted. An analysis of the Vehicle Stabilizer System (VSS) was conducted, which involved analyzing the difficulties encountered when installing a component in a tight space. In order to conduct the analysis, a 3D model of the environment was uploaded to the HSI analysis software. Following an inspection of the actual work area, it was apparent the 3D model provided to iSEE would not suffice for the given operational constraints. Thus, additional 3D models had to be constructed in 3D modeling software and uploaded to the HSI analysis software.

Several "dry runs" were conducted, which consisted of actors performing the operation in virtual reality only, without physical mock-ups as references. The actors only wore motion capture markers on their heads and hands in order to expedite the process.

Upon completion of the dry runs, it became clear that mock-ups would be necessary to properly delineate the 3D space and provide physical collision boxes that the actors could interfere with. These mock-ups were constructed out of spare 3D printed parts and metal wire mesh. Small parts that were not available as spares were 3D printed from the

3D models that had been built earlier. Once the mock-ups were complete, they were positioned in the motion capture area of the lab to match the locations of their corresponding virtual models.

After the environment was complete, actors were measured and their information was uploaded to the HSI analysis software in order to create avatars that could accurately mimic the actors' real-life movements. Once the set-up was complete, a representative from Human Factors observed the operation and the associated HSI data being displayed real-time.

In addition to the tight space component installation test, an analysis of a reach problem was also conducted, which involved the actors attempting to reach a component without touching the surrounding environment. This was of particular importance because of the volatile substances present in that environment, and therefore the necessity of simulating technicians wearing environmental suits while performing the operation. This is an ongoing project, and so far a virtual walk-through has been conducted, following all the steps mentioned above except the building of mock-ups. While the virtual environment could neither simulate physical collisions nor toxic chemicals, it provided a baseline measurement for how far a normal person could reach in that environment. With this project, the next steps would be to determine if a mock-up is necessary for Human Factors to finish their analysis of the operation, and if so, to build one and then repeat the simulation.

III. Software

G. Software Used
The software used by iSEE is as follows:

1. Motion capture software, which connects to 33 cameras of known position, focal length, etc. to be able to "see" motion tracking markers in 3D space. It allows the user to connect markers with bones, which can then be exported to the visualization software of choice.
2. HSI analysis software, which receives data from the motion capture software and allows the user to link bones and skeletons made in the motion capture software to 3D objects and avatars. It also allows for the visualization of 3D scenes with objects and avatars in them, and it can receive live-streamed data from the motion capture software. Lastly, it offers HSI analysis tools like lower back stress analysis, which helps Human Factors decide if an operation is too difficult or dangerous for technicians to carry out.
3. Game engine visualization software, which performs all the tasks that the HSI analysis software does, with the exception of HSI analysis. However, the game engine can produce much higher fidelity models, and unlike the HSI analysis software, can render models with textures, materials, and lighting, resulting in a more immersive and realistic simulation for the actors wearing the head-mounted displays.
4. Intermediate software, which links the motion capture data to the game engine. This is not necessary for the HSI analysis software, which automatically connects to the motion capture software.
5. 3D modeling software, which allows users to construct custom detailed 3D models of objects that can be imported into the HSI analysis software or the game engine.
6. 3D printing software, which converts files from the 3D modeling software into files that the 3D printer can read.

IV. Hardware

H. Hardware Used
The hardware used by iSEE is as follows:

1. 3 computers. One runs the motion capture software and streams data to the other two. Another runs the HSI analysis software and the intermediate software. Since these two pieces of software will not be used simultaneously, it will not be too taxing on the computer. The third computer runs the game engine, taking inputs from the computer with the intermediate software.

2. 33 motion capture cameras. While it is not strictly necessary to have that many, a higher number of cameras reduces error in the motion tracking calculations.
3. A range of motion capture equipment, including suits, markers, and calibration equipment.
4. Head-mounted displays (HMDs), which allow the actors to see and be immersed in the simulation.
5. A newer model HMD, which has a superior display and is more streamlined than the old HMDs.
6. A 3D printer, which allows for the creation of small custom-designed mock-ups.

V. Additional Projects

I. Game Engine Integration

The VSS environment was used as a proof-of-concept for the game engine workflow. In order to switch from the HSI analysis software to the game engine, the game engine would have to be proven to have better immersive capabilities while not sacrificing the efficiency, speed, and specific features of the HSI analysis software. To test this, the VSS operation was recreated in the game engine. The 3D models, when imported into the game engine and textured properly, looked much more realistic than the models in the HSI analysis software. When the actors' avatars were connected to the game engine, however, there was a noticeable latency in the motions of the avatars when compared with the actors. This problem is still unresolved.

J. Updated HMD Integration

In order to further increase immersion, a newer HMD was acquired, and there have been ongoing attempts to integrate it with the systems already in place. The new HMD offers a higher quality image and more pleasant head-mounting (additional padding and customizability), but there have been problems with its integration.

One problem involved the computers not having the right cable ports. Adapters were acquired, but the HMD's native software did not recognize the adapter as being the HMD's cable. This is, for now, unresolved.

Another problem was that the new HMD was much more difficult to turn into a second monitor than the old one. In order for the simulation to work, the HMD must simply carry the image of what the actor is looking at. The old HMD does just that, while the new one is paired to its native motion tracking software. Currently, efforts are underway to disconnect the new HMD from its native motion tracking software and simply use it as a second monitor onto which the avatar's eye view window can be transferred.

VI. Conclusion

K. iSEE Future Goals

The eventual goal of iSEE is to provide fully immersive simulations that accurately reflect working environments. This can be accomplished through continued use of the lab to conduct Human Factors operations and through integration of the game engine and new HMD with the existing motion capture system. However, there are still issues that need to be resolved before the upgrades can be completed. Once the new software and hardware are fully integrated, the lab can begin providing more in-depth HSI simulations and analyses than ever before, streamlining operations around KSC by reducing workplace hazards and preventing injuries before they can happen.

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