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VIRTUAL ENVIRONMENT COMPUTER SIMULATIONS TO SUPPORT HUMAN FACTORS ENGINEERING AND OPERATIONS ANALYSIS FOR THE RLV PROGRAM

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Introduction

The Army-NASA Virtual Innovations Laboratory (ANVIL) was recently created to provide virtual reality tools for performing Human Engineering and operations analysis for both NASA and the Army. The author's summer research project consisted of developing and refining these tools for NASA's Reusable Launch Vehicle (RLV) program. Several general simulations were developed for use by the ANVIL for the evaluation of the X34 Engine Changeout procedure. These simulations were developed with the software tool dVISE 4.0.0 produced by Division Inc. [2] All software was run on an SGI Indigo2 High Impact. In the process of developing these simulations, the author worked with two Summer Faculty Fellows also assigned to the ANVIL. Dr. Pat Lindsay and the author analyzed the mannequin feature provided with the Division software [5]. Dr. Joe Dumas and the author worked on using various input devices with the Division software [3]. This paper describes the simulations, various problems encountered with the simulations, other summer activities, and possible work for the future. We first begin with a brief description of virtual reality systems.

Virtual Reality Systems and their Applications

Virtual Reality (VR) is a computer generated world in which the user can interact in real time. Typically this world will consist of three major components. The first consists of the various objects in the world which are represented by accessing their associated geometry files. The geometry files are CAD (Computer Aided Design) generated and consist of a description of vertices and polygons which define the shape of the object. The second component is the user. The user, who often wears immersive input devices such as a head mounted display (HMD) or data glove, is described by a body file. The body file contains the geometries of body parts and can be customized for various types of individuals. This implies one can take parameters such as reach and height into consideration. The third, and perhaps the most important, component of the virtual world consists of events and behaviors that govern the interactions between objects and the interactions between the user and objects. An example of this is the event of the user's hand touching an object which then generates a behavior such as a sound, message, or even an animation.

VR has great potential in the areas of human factors engineering and operations analysis. The greatest strength of VR is that it allows designers to visualize and interact with their products. Thus one can detect design flaws much earlier in the design and development process which can save substantial costs in the long run. Also, because one can perform the human factors analysis in the virtual world, costs incurred in the building a full-scale model of the product can be reduced.

Virtual Reality Simulations for the ANVIL

During the course of the summer, the author developed several VR simulations for use in the ANVIL. The main focus was to implement events and behaviors in these simulations which would allow interaction between the objects and interaction between the user and the objects. Two of these simulations were concerned with the evaluation of the X34 Engine Changeout procedure. The first was geared for human factors studies and the second addressed operations analysis of engine removal. In both simulations the X34 CAD files were generated by Orbital Sciences Corporation and MSFC. These CAD files were then imported into the Division software. It was at this point that the author began defining the various events and behaviors for the simulations. The dVISE program is intended to be a GUI (graphical user interface) based program. However, when designing customized simulations using dVISE, one often has to go to the level of the Division code (essentially function calls to their executable code written in the C Programming Language).

The simulation developed for human factors engineering was a virtual environment in which the user attempted to disconnect bolts from the X34 engine. This simulation allowed human subjects to interact with the virtual world for training purposes or for performing reach analysis.

The user is outfitted with a data glove which provides an immersive interface between the user's hand, and hence their body, and the virtual world. The data glove device drivers for use in the Division software were written this summer by Dr. Joe Dumas [3]. Features of the simulation include: the ability to move the user to any fixed starting point thus allowing for a common frame of reference when testing the same or multiple subjects; the ability of the user to reach and grab various objects in the world including a wrench and bolts; sounds and pop-up messages to let the user know when the wrench or the user's forearm has collided with other objects; and various animations such as the removal of a bolt when the user's hand touches the bolt. Currently we are using one body file, which means that arm length and height are the same for all users. Future work will be to develop several body files which fit the NASA 5th percentile female to 95th percentile male categories and to test these files with human subjects [6]. These body files would be usable in all of the simulations developed with the Division dVISE software.

The simulation developed for engine changeout analysis focused on providing support for operations and design analysis. The X34 Engine is a Fastrac 60K designed by the MSFC Propulsion Laboratory. The ANVIL has been asked to assist in the determination of engine removal paths and to provide demonstrations of these paths. These paths should include collision detection and close proximity detection for clearance assessment. With this in mind, the author developed the engine changeout simulation for the X34. Features of this simulation include: the ability of a user to try various engine removal paths; accurate measurement of removal, thus allowing for easy testing and verification; animation of removal paths; different camera angles from which to review various removal paths; accurate (polygonal) collision detection on individual engine parts during the engine removal process; and pop-up messages and visual cues such as color changes upon detection of collision of the engine with other parts of the spacecraft.

Two concerns became apparent in the development of the X34 Engine removal simulation. They were the determination and implementation of common reference points for measuring translations and angles of rotation of the engine and the implementation of close proximity collision detection. As described above, the geometries for all of the X34 objects are imported CAD files. This leaves the VR simulation designer somewhat at the mercy of the CAD designer as to where the geometrical origin of an object is located. In the case of the X34 engine, the origin of the geometry was directly in front of the nose of the aircraft which made it difficult to accurately describe movement of the engine. In this simulation we determined a way to get around this by fixing a common point of reference (inside the engine nozzle) from which we were able to accurately measure all translations and rotations of the engine. Certainly it is possible to change this point of reference. The author recommends an agreed-upon point of reference so that engineers can communicate effectively about the engine removal paths. In the process of moving the engine in the simulation, one sees various objects, such as the fuselage, change color when the engine collides with the object. Because we want accuracy in the engine removal process, we are using polygonal collision detection. Polygonal collision detection checks to see if any polygons of any two objects are colliding. Although strides have been made in this area and the Division software uses many of these advances [1, 4], polygonal collision detection is the most expensive computationally. We were able to avoid slow updates of the rendering window of the system by carefully choosing which parts of the engine to add collision properties. The more interesting problem encountered in this simulation was how to implement near collision detection. At the present we have found no existing software which can accurately perform near collision detection. We briefly discuss two ideas for future development in this area.

The first idea for performing near collision detection is to create a new geometry for an object called a "neighborhood". For instance, a one inch neighborhood about an object would consist of all points in space whose distance from the object is less than or equal to one inch. One could then use a one inch neighborhood geometry for the X34 Engine to see if engine removal could be accomplished with at least a one inch tolerance. The problem with this idea is generating the neighborhood, especially with complicated geometries such as the X34 Engine. The author believes the problem of generating a neighborhood geometry from an existing geometry is a hard (in the sense of not being computable in polynomial time, i.e. NP) problem. The second idea for performing near collision is to compute distances between objects as they move and then determine the minimum distance. This is also a non-trivial problem. However, it is being addressed by some of the leading researchers in the field [7]. Future work could be developing and/or finding algorithms for near collision detection and then implementing them in the Division software.

In addition to the X34 simulations, the author also worked on a simulation developed for the Grand Opening of the ANVIL. This simulation was a virtual ribbon cutting and featured a fly-through of a virtual world that included helicopters, tanks, and various NASA spacecraft. The author principally worked on the animation sequence for the fly-through.

Other Projects

In addition to developing the above simulations, the author also worked with other Summer Faculty Fellows in the ANVIL lab in using the Division software for various tasks. Dr. Pat Linsdey and the author evaluated the Division mannequin (called "manikin") . We determined how to make a library of these mannequins that fit the NASA standards. We also determined how to import these new mannequins into the existing X34 simulations for the purpose of human factors engineering. The mannequin should not be confused with the user body described above. In fact, the mannequin is considered another object in the virtual world and does not use input devices such as the data glove. The purpose of the mannequin is to visualize and test human factors parameters such as reach envelope. For more information on the mannequin please see the paper by Dr. Pat Lindsey [5].

Dr. Joe Dumas, another ANVIL Summer Faculty Fellow, was assigned the task of writing device drivers for several input devices in the ANVIL. These included the space shuttle hand controllers, the data glove, and the HMD. Once he had written the device drives, the author helped him get the input devices working correctly with the Division software. Principally, the author worked on creating body files that would work with various combinations of input devices. For more information on the various input devices please see the paper by Dr. Joe Dumas [3].

Conclusions and Future Work

Although the author is pleased the simulations developed this summer are currently being used by the ANVIL, she believes more can be done to make these simulations easy to use for human factors, operations, and design engineers. The geometry models for the user need to be scaled to the NASA standards. These geometry models should also be tested with humans, wearing various input devices such as the data glove, who meet those standards. Once this is done, NASA will have a very nice library of body types for use in all immersive simulations which run the Division software package dVISE. The problem of near collision detection is interesting from both theoretical and practical points of view. Having this type of collision detection implemented in the Division software would be a real boon to the ANVIL. Lastly, there a several combinations of input devices available for the user (Fakespace, data glove, etc.). Some of these combinations of input devices have not been configured for use in the software. The different combinations should be tested to determine the best way for the user to have an immersive interface in the virtual world.

Before starting the Summer Faculty Fellowship Program, this author knew very little about VR and its applications. Upon completion of the program, she feels that VR is an up and coming technology that will be used for many types of applications. The author would like to thank NASA and in particular the Summer Education Programs for providing her with this excellent experience.

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