UNDERGRADUATE REPORT

Hardware and Design Factors for the Implementation of Virtual Reality as a Training Tool

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UG 2006-10

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Institute for Systems Research REU Summer 2006

August 8, 2006

Table of Contents

1. Introduction

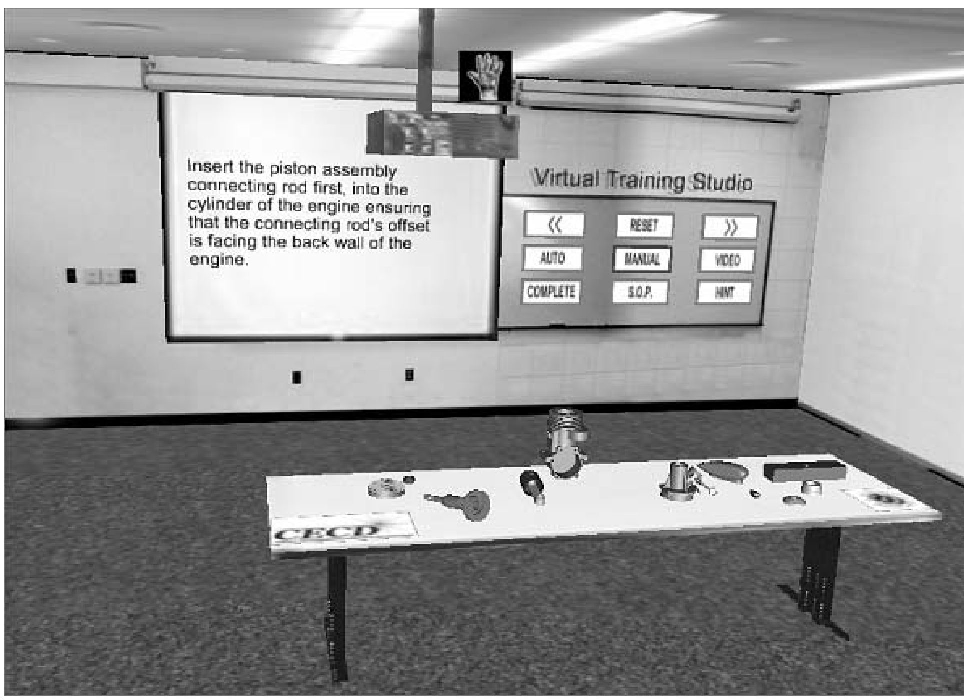
Virtual reality as a training tool is only currently used by government agencies and large companies and cost hundreds of thousands of dollars. The goal of this lab is to bring the advantages of virtual reality to mid level companies at a range of tens of thousands of dollars.

The hardware of this virtual reality system consists of a head motion device (HMD), a hand-held wand with which the user can manipulate the environment, and a virtual environment run on the computer by an application called Vizard developed by WorldViz, Inc. The HMD is distributed by NVIZ, Inc. and is called the NVisor SX. It has a resolution of 1024 x 768 pixels at 60 Hz and is adjustable to most head sizes (http://www.nvisinc.com/nvisor_sx.php). The resolution has shown to be sufficient to handle the virtual reality applications currently in use. The wand has currently been redone to offer an ergonomic feel as well as a more intuitive method to navigate and manipulate objects in the virtual world.

The position tracking is done by an optical tracking system produced by Worldviz inc. called the PPT tracker. This device uses four cameras to give the system 3 Degrees-of-Freedom (DOF) for a tracking volume of 10x10x10 meters and has a latency of less than 20ms (http://worldviz.com/products/ppt/index.html). The system can track up to four objects but it must maintain a line-of-sight with the objects. The orientation tracking is done with InterSense corp. Wireless InertiaCube3 on each of the objects. This device has 3 DOF of orientation giving data for the roll, pitch, and yaw for each object. It has a range of up to 30 meters from the receiver and a latency dependent of the operating system. The latency is ideal at 6 ms but could reach 50 ms (http://www.isense.com/products/prec/ic3/WirelessInertiaCube3.pdf).

This system is also designed as a training tool for the construction of complex or dangerous devices. They serve as tutorials so that the user can learn how to construct these products safer and easier. In it, the user is placed in a room 7.2 meters deep, 7.9 meters in width and 3 meters high. In the middle of the room there is a table where the components of the devices are placed dissembled and the user is expected to place these parts together correctly (see figure 1).

Figure 1: Room One with Assembly



If the user is not able to perform these tasks then there is a control panel and projector screen in the front wall of the room where they can choose to see animations of the assembly of the parts or receive hints on how to place these parts correctly. This assembly room was designed by the WorldViz Corp. and was designed using the 3D Studio Max modeling and animation software.

On previous experiments using this system, three out of thirty people who tested got nauseous or motion sickness. I t has been shown that in virtual reality applications, a large latency, or lag between movements, in virtual and real space cause motion sickness in participants. Latency is the primary cause of stress on the user's perceptual system and occurs when users change their view of the virtual system. Thus, it would be ideal to decrease this lag time and motion of the user to decrease the chances of motion sickness. (Sherman, 134-135)

2. Goal

The overall goal of this project is to reduce the occurrences of motion sickness among the participants. To do this, new rooms were designed in order to decrease the head motion of the user. In designing these rooms, two different modeling software packages were used and compared to determine which would be best for future use. Also, the room contains three entities that cause head motion: table, projector screen, and control panel. The goal in the design was to place these entities so that the user would minimize his head motion and as well as not obstruct the parts being assembles. Finally, suggestions were made for the hardware of the virtual environment so that the physical lag time could be decreased as much as possible.

3. Methods

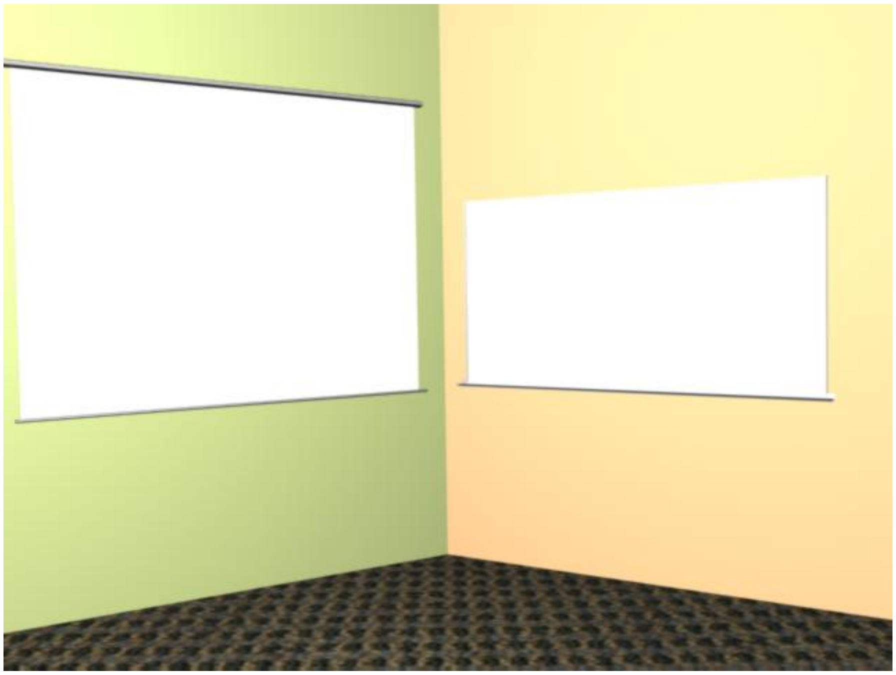
3.1. Modeling and Design of Rooms

For the design of the rooms, two different software packages were used. The software used were Lightwave 3D v.8 (Lightwave) made by NewTek, Inc. and 3D Studio Max v.8 (3DS) distributed by Autodesk, Inc. As a user, the packages differed significantly in the modeling processes. Each software package was tested for ease of use and ability to export into VRML which is the language used for the virtual environment.

In the design of the rooms, the front wall was altered and the placement of the projection screen as well as the control panel was repositioned to meet our goal of minimal head movement. The table that the original room came with was decided to be an optimal design with enough area for future larger assemblies, thus it was not changed.

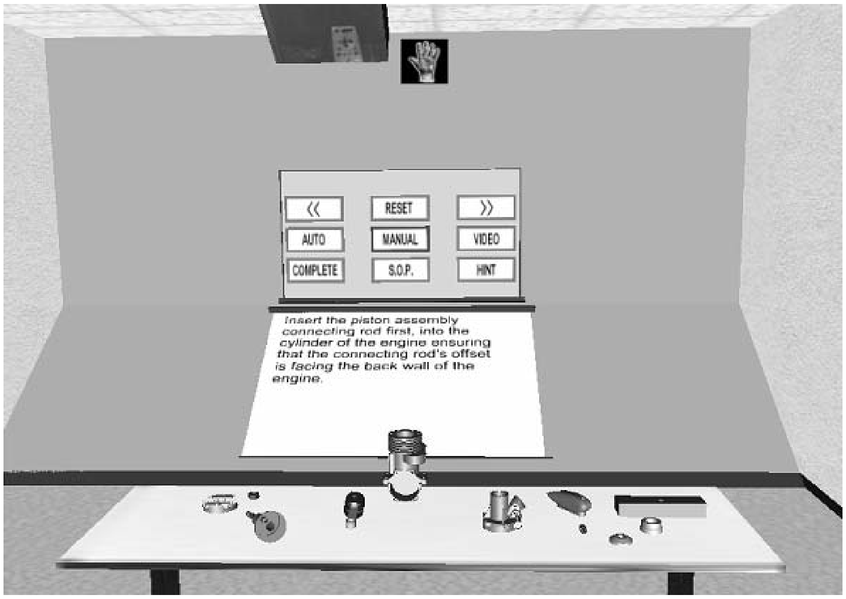
In one room, the front wall was divided in half and each side was rotated. Each half would contain the projector screen or control panel (see figure 2).

Figure 2: Room Two



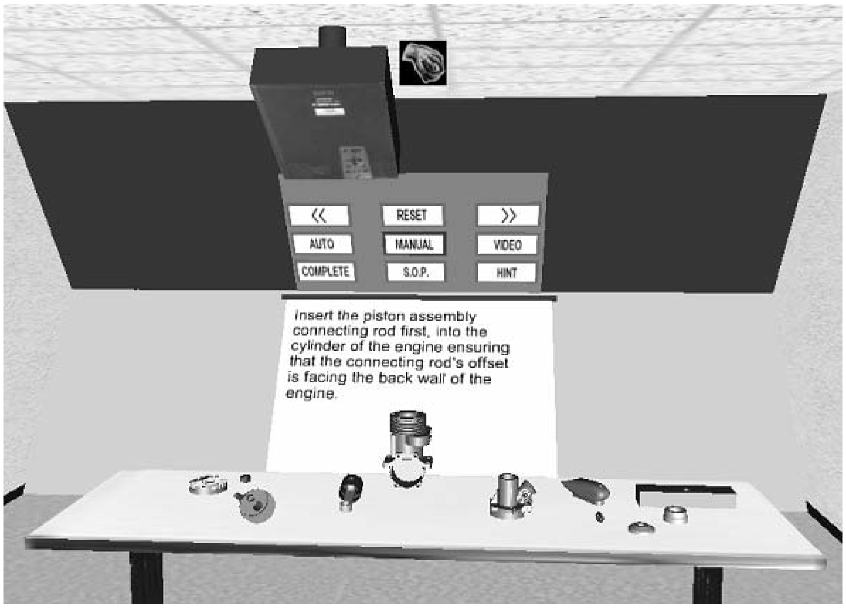
In the third room the front wall was divided between a lower and upper portion. The lower portion was rotated. The upper portion contained the projector screen while the lower portion contained the control panel. In order to compensate for the decrease in user range the room's dimensions were changed (see figure 3).

Figure 3: Room Three



The fourth room designed was also had the front wall divided into two portions, the upper and lower portions. Like room two, the upper portion contained the projector screen while the lower portion the control panel. The dimensions of the rooms can be seen in the appendix (see figure 4).

Figure 4: Room Four



3.2. Experimentation of Rooms

The rooms were tested in comparison with the current room designed by WorldViz, Inc. The way they were tested is to have subjects run through a series of procedures. The user standing in the middle of the room would have to perform the following:

1) Read text on projector screen.
2) Push the “fast forward” button
3) Push the “rewind” button
4) Push the “animation” button
5) Watch the animation
6) Repeat steps 1-5 until the assembly is complete

The logic behind these steps is that by pushing those three buttons, buttons that are at the upper right, upper left and lower left corners of the control panel the user would have to transverse the height and width of the control panel (see figure 5). By making the user read the text the user would have to view the entire projector screen and by making the user watch the animation it is essentially the same head movements required for the assembly of the product.

Figure 5: Control Panel

There was a program that was designed to log information of the user after each step of the assembly process. A step is considered to be from procedure one to procedure five. The way the program works is that a places an imaginary plane 0.4 meters in front of the HMD device. It tracks the position at which the users head is focused and for each steps outputs a maximum x, minimum x, maximum y, and minimum y. the range was then calculated as well as the average of these steps to determine which room results in less head movement.

The four rooms were tested in the following order: original room, room one, room two, room three. Five participants were tested in each of the four rooms. To eliminate bias from users who have different experience level with the virtual reality system the following was implemented and noted. The user must avoid interactive simulation, the animation assembled the parts for the user, and the user would not have to physically move the parts in the virtual world. Also, the animation must be viewed in order for the animation to happen. If the part is not being viewed by the user then the animation will pause and not resume until the part is in the viewing area once more. It was assumed that by having the user watch the animation then the same movements could be used to manually assemble the parts. The user must also stand still in one location, this was essential so that the maximum and minimum values would not be altered by the user walking around. It was also made clear to the participant that random head motions must be minimized once logging was implemented.

3.3. Hardware

Different hardware systems were researched so that an optimal system could be implemented for future use. An optimal system consists of a system that may reduce latency and cost of the system. The factors that would determine the new system would be altered from what was originally conceived.

4. Results

4.1.Software

The 3DS software package was used to design the final rooms for each of the three different room designs. This was because of the more intuitive nature of 3DS and its more flexible exporting options.

The 3DS software package was simply easier to model and design in. For instance, making precision modeling and placements of objects in 3DS was much easier with the text drop down controls then the pop up text controls of Lightwave. Also, it was more difficult to navigate in the 3D environment of Lightwave than it was in 3DS. This is because of the more intuitive controls of 3DS. For instance, to zoom in or out in Lightwave, one would have to go to the upper right boxes of Lightwave viewports and click and hold on the button for zoom, then any movement to the left or right would zoom out or in respectively. Now, if the user would want to pan, they would then have to move to the pan button and do the same respectively. Also, any movement in one view panel would result in the same movements in all view panels. Now in 3DS, the options of zoom and pan are done from anywhere on the screen and are easily performed using the middle scroll button of the mouse. Also, only one view panel is done with an option of performing the same tasks to all panels, but this option was rarely used. The option to rotate was also easily available by holding down the alt button and using the middle scroll button of the mouse.

Other important tasks that made 3DS more user friendly was the options for moving, scaling and rotation. 3DS allows the user to move, scale, or rotate about any axis from any viewpoint where Lightwave was confined to the viewport in which one was on. The Boolean and solid modeling options in 3DS were much easier to use also.

The only area in which Lightwave was easier to use was in the design of easy textures. 3DS texture options were difficult to understand in there panels and sub-panels and sub-sub-panels and the user could easily bury themselves in options which were very irrelevant to the task at hand. Since these textures would eventually be transported to

VRML (virtual reality modeling language) format, many of these options offered by 3DS were inappropriate and redundant.

In the end, all rooms were designed using 3DS. The reason for this was because of the more intuitive nature of 3DS and mostly because of the stronger exporting features of 3DS. 3DS exports directly to VRML and offers many options when exporting, including a simple and customizable directory to locate the necessary textures. Lightwave unfortunately does not export directly to VRML. Thus, third party applications are necessary in order to convert and this is usually done by an intermediary step that converts a Lightwave model into some other format and then eventually VRML. This is done without the choice of options and is also vulnerable to errors in the exportation. For instance, a doorknob was made by rotating a profile curve of a doorknob about its center axis. During its exportation, the doorknob in virtual reality seems to have imploded. It seems as if the polygons had there normals inverted, but this could not be confirmed.

4.2. Optimal Room Design

It was discovered that room three worked best to minimize head motion. This can be seen in table 1. The averages among the five participants for the average of the ranges was lower for both the x values and y values.

Table 1: Average Range Values

	Room 1		Room 2		Room 3		Room 4	
Subjects	X average	Y average	X average	Y average	X average	Y average	X average	Y average
1	2.097360	1.817414	1.226957	1.341977	1.267112	1.525898	1.896735	1.491975
2	3.235857	1.724771	2.273965	1.652814	1.700388	1.228601	2.395285	1.377361
3	2.697417	1.809847	1.751370	1.529941	1.383555	1.411098	2.141584	1.195082
4	2.490802	1.810455	2.288187	1.445106	1.465806	1.201139	2.229715	1.579672
5	2.616148	1.455052	1.308637	1.191435	0.935577	1.304796	2.134427	1.396774
Average	2.627517	1.723508	1.769823	1.432255	1.350488	1.334306	2.159549	1.408173
St Dev	0.410746	0.154841	0.507592	0.176422	0.281036	0.134520	0.180638	0.143981

4.3.Hardware Improvements

When the virtual system currently used was created, it was assumed that the user would have to transverse physically at least a 3 x 3 meter area. Thus the only wireless tracking system that could give sufficient range was thought to be an optical position tracking device working collectively with inertia based orientation tracking. Through previous tests with subjects it has been shown that the movement could be reduced to a much smaller region. Thus, a system that offers a smaller range and less latency is desired. Since the user may not have to move as much, a wireless system is no longer necessary. By having wired inertia based orientation trackers, the lag time and cost could both be reduced.

For instance, a magnetic field based position tracker may be shown to produce better results. The LIBERTY by Polhemus, Inc. has a latency of 3.5 ms compared to the 20 ms that the current position tracking device currently contains. This system can also track up to 16 objects compared to the current limit of 4. Iats range is drastically reduced to 3 to 6 feet, but range is no longer a limiting factor (http://www.polhemus.com/J-Bots%20Plus%202002/LIBERTY/LIBERTY_brochure.pdf).

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Also available are wired inertia trackers. The latency could be reduced to 2 ms if using the InertiaCube 3 by InterSense, Inc. the wired versions of the InertiaCube are less susceptible to damage caused by magnetic fields (http://www.isense.com/products/prec/ic3/InertiaCube3.pdf).

5. Conclusions

5.1. Suggestions in Modeling

It is necessary that all future modeling be done in 3DS. If changing modeling applications for whatever reason, many things must be taken into account. (1) The program must export comfortably into VRML language. (2) The program must be intuitive to use and navigate. The idea behind these suggestions is to save time in modeling and exportation.

5.2. Suggestions in Room Design

As the results show, it would be best to implement room three into future tutorials for training applications in comparison with the other rooms. It is ideal though, to develop a room that is customizable by the user, so that the orientation of the projector screen and control panel, as well as the angles the front wall make are all adjustable. This way, the user can choose their most comfortable method to view the rooms as well as adjust during the process of the tutorial.

5.3. Suggestion in Hardware

After an investigation in current tracking technologies and with a better understanding of the limiting factors for the virtual reality system, it is suggested that the current system be replaced with different tracking technology.

The HMD, wand, and program running the virtual environment all work well and meet the minimum requirements for the applications running in the system. The position and orientation tracking can be replaced with faster equipment that offers less range. The logic for this is that in faster systems the lag time between real movements and virtual movements could be reduced. It has been shown that lag time is one of the reasons for motion sickness and nausea among participants. By replacing the current system with a faster system then the occurrences of sickness can be reduced. Also, the range initially desired has shown to be in excess of the range that is actually required.

5.4. Suggestions in Experimentation

Since the user has becomes familiar with the process, it is necessary to make the order in which rooms are tested random. Also, the heights at which the users are placed are different in each room, and this could lead to bias or even different results among the range of values. For instance, many participants felt most comfortable and felt least head movements among room four, but the results show room three resulted in less head movement. Finally, the amount of comfortableness of the users must be taken into account when designing a room. A survey should proceed each room where the user can rate how comfortable as well as how real each environment felt.

6. Appendix

6.1. Appendix I: Data Tables for Subjects

Table 2: Data for Subject 1

		X- range	Y-range	X-Average	Y-Average
Room 1	Step 0	2.885747	1.977961		
	Step 1	1.364700	1.772946		
	Step 2	1.817474	1.813012		
	Step 3	1.833647	1.762798		
	Step 4	2.433573	1.893693		
	Step 5	2.249017	1.684075	2.09736	1.817414
Room 2	Step 0	0.107639	1.408516		
	Step 1	1.639208	1.428519		
	Step 2	0.779106	1.198071		
	Step 3	1.396102	1.102156		
	Step 4	2.255658	1.713116		
	Step 5	1.184030	1.201485	1.226957	1.341977
Room 3	Step 0	0.391609	1.376992		
	Step 1	1.339326	1.727790		
	Step 2	1.124732	1.698168		
	Step 3	1.590338	1.526860		
	Step 4	1.667616	1.517386		
	Step 5	1.489050	1.308194	1.267112	1.525898
Room 4	Step 0	1.193113	1.639965		
	Step 1	2.248235	1.459470		
	Step 2	1.285925	1.435238		
	Step 3	2.615789	1.329679		
	Step 4	2.075566	1.585662		
	Step 5	1.501835	1.501835	1.896735	1.491975

Table 3: Data for Subject 2

		X- range	Y-range	X-Average	Y-Average
Room 1	Step 0	2.914200	1.345761		
	Step 1	3.109951	1.988993		
	Step 2	3.078166	1.675844		
	Step 3	3.053165	1.732868		
	Step 4	3.590764	1.968193		
	Step 5	3.668897	1.636966	3.235857	1.724771

Room 2	Step 0	0.759589	1.742912		
	Step 1	2.635975	1.246206		
	Step 2	1.993269	1.835842		
	Step 3	2.735485	1.427888		
	Step 4	2.932359	2.194329		
	Step 5	2.597111	1.470709	2.273965	1.652814
Room 3	Step 0	0.572216	1.241207		
	Step 1	1.241190	1.582765		
	Step 2	1.452090	1.086397		
	Step 3	2.229631	1.176731		
	Step 4	2.657276	1.308208		
	Step 5	2.049923	0.976301	1.700388	1.228601
Room 4	Step 0	1.701636	1.370262		
	Step 1	3.139549	1.307932		
	Step 2	1.647469	1.523259		
	Step 3	3.350543	1.483070		
	Step 4	2.160502	1.505694		
	Step 5	2.372012	2.372012	2.395285	1.377361

Table 4: Data for Subject 3

		X- range	Y-range	X-Average	Y-Average
Room 1	Step 0	2.485311	1.473226		
	Step 1	2.328534	1.712353		
	Step 2	2.828687	1.723553		
	Step 3	1.924334	2.110212		
	Step 4	3.667910	2.137626		
	Step 5	2.949725	1.702115	2.697417	1.809847
Room 2	Step 0	0.750694	1.026842		
	Step 1	1.396850	1.875286		
	Step 2	1.869612	1.540603		
	Step 3	2.472353	1.535032		
	Step 4	2.143099	1.759456		
	Step 5	1.875615	1.529941	1.75137	1.544527
Room 3	Step 0	0.500666	1.251384		
	Step 1	0.717597	1.648766		
	Step 2	0.946718	1.096072		
	Step 3	3.143159	1.325089		
	Step 4	1.689864	1.386984		
	Step 5	1.303326	1.758292	1.383555	1.411098
Room 4	Step 0	1.508311	0.685906		
	Step 1	2.462750	1.123582		
	Step 2	1.513391	2.831882		
	Step 3	2.831882	1.078753		
	Step 4	2.808985	1.846274		
	Step 5	1.724186	1.366970	2.141584	1.195082

Table 5: Data for Subject 4

		X- range	Y-range	X-Average	Y-Average
Room 1	Step 0	1.695877	1.797021		
	Step 1	2.442904	1.865426		
	Step 2	1.882663	1.483230		
	Step 3	2.645821	1.682232		
	Step 4	3.183830	1.912898		
	Step 5	3.093719	2.121922	2.490802	1.810455
Room 2	Step 0	0.470758	1.422254		
	Step 1	1.979725	1.232626		
	Step 2	3.611268	1.462753		
	Step 3	3.693120	1.598305		
	Step 4	1.813016	1.255779		
	Step 5	2.161234	1.698921	2.288187	1.445106
Room 3	Step 0	0.364651	1.484739		
	Step 1	0.716458	1.785650		
	Step 2	1.436248	1.779124		
	Step 3	1.750998	1.203189		
	Step 4	2.003709	0.493255		
	Step 5	1.773423	1.045389	1.465806	1.201139
Room 4	Step 0	0.979290	1.523867		
	Step 1	1.650768	1.636779		
	Step 2	2.237831	1.965970		
	Step 3	3.286483	1.340807		
	Step 4	3.340542	1.557168		
	Step 5	1.883374	1.453440	2.229715	1.579672

Table 6: Data for Subject 5

		X- range	Y-range	X-Average	Y-Average
Room 1	Step 0	2.912460	1.514425		
	Step 1	2.669209	1.588190		
	Step 2	2.025309	1.346935		
	Step 3	2.547960	1.519294		
	Step 4	3.172169	1.538318		
	Step 5	2.369780	1.223151	2.616148	1.455052
Room 2	Step 0	0.497995	1.237584		
	Step 1	1.234660	0.873280		
	Step 2	1.199520	1.126694		
	Step 3	1.267083	1.393233		

	Step 4	1.869962	1.386572		
	Step 5	1.782605	1.131246	1.308637	1.191435
Room 3	Step 0	0.343988	2.084204		
	Step 1	0.186947	1.162977		
	Step 2	0.770228	1.346805		
	Step 3	1.543918	1.447957		
	Step 4	1.392331	1.018795		
	Step 5	1.376051	0.768036	0.935577	1.304796
Room 4	Step 0	1.103394	1.631948		
	Step 1	2.593534	1.420417		
	Step 2	1.565154	1.362880		
	Step 3	1.879311	1.452819		
	Step 4	2.426525	1.502296		
	Step 5	2.238642	1.010285	2.134427	1.396774

6.2. Appendix II: Room Dimensions

Figure 6: Dimensions for Room One

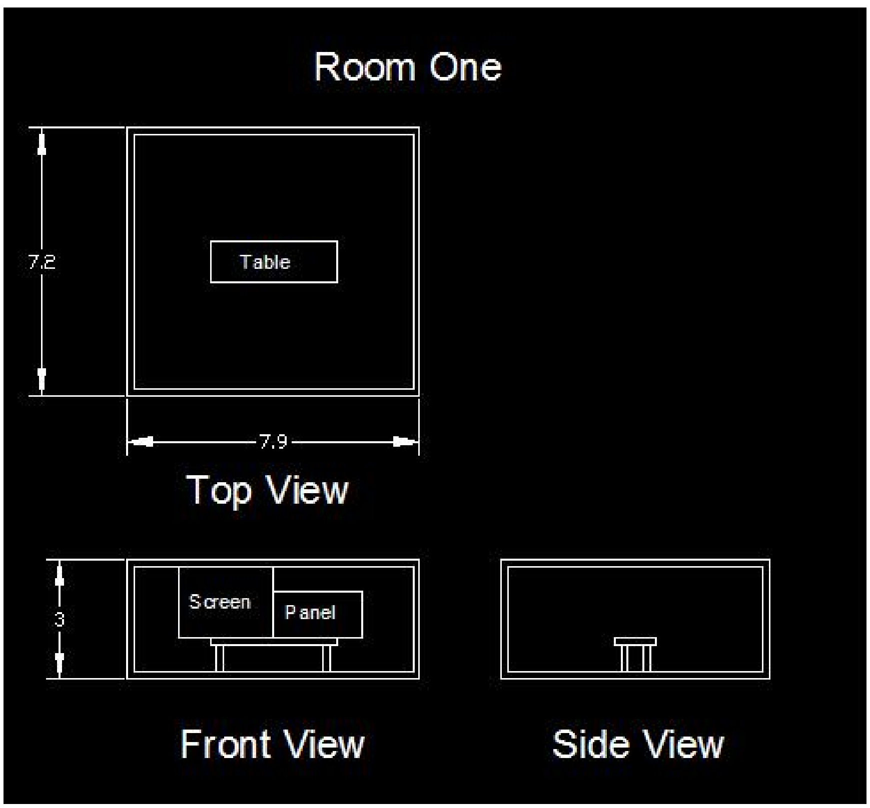


Figure 7: Dimensions for Room Two

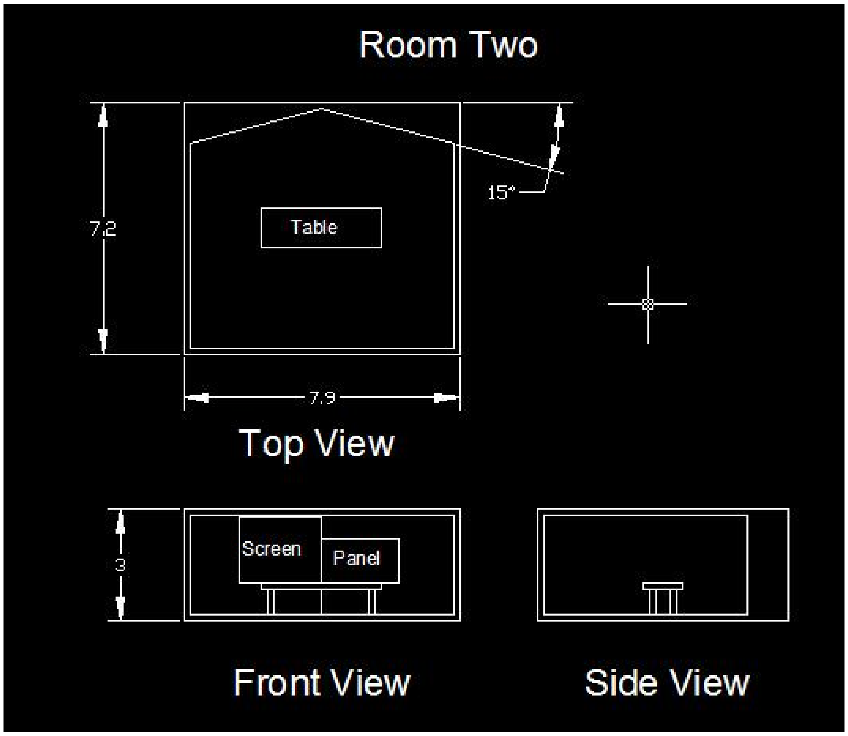


Figure 8: Dimensions for Room Three

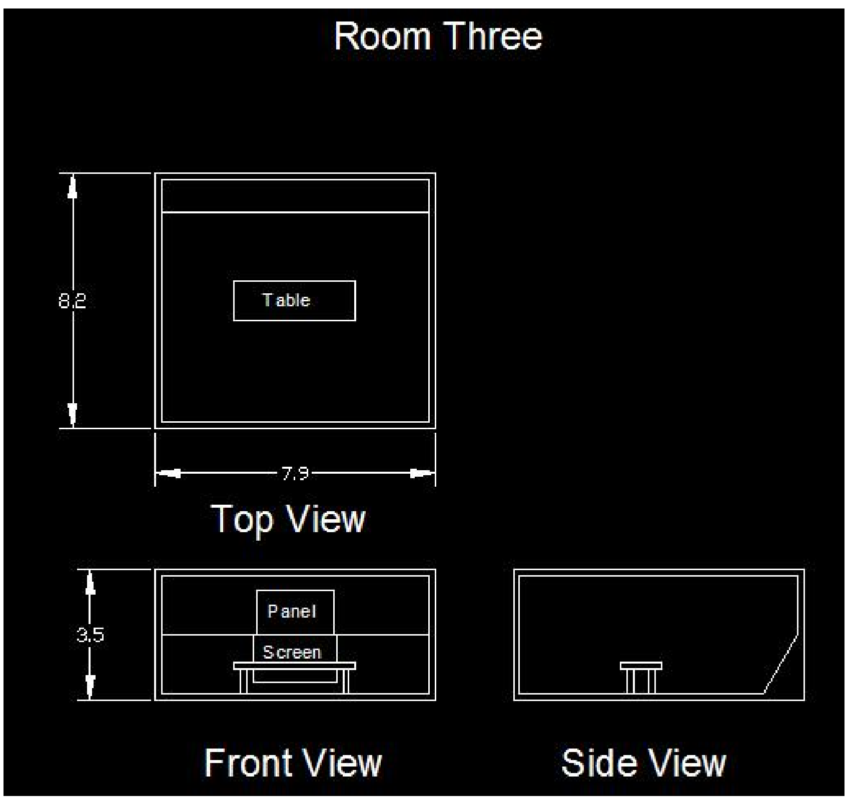
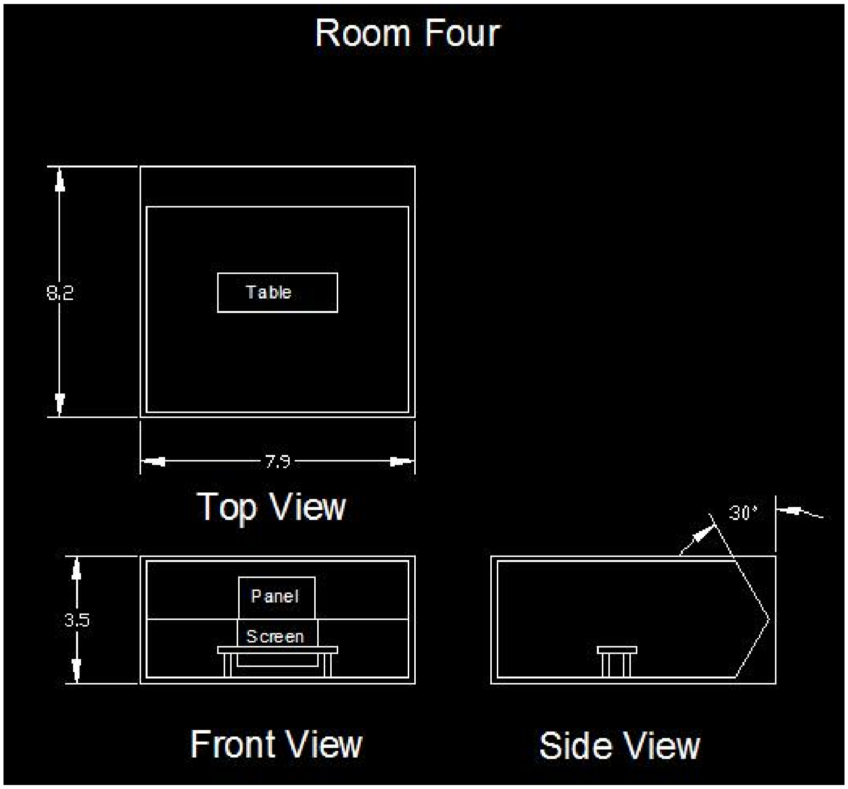


Figure 9: Dimensions for Room Four



6.3. Appendix III: Works Cited

Burdea, Gricore C., and Philippe Coiffet. Virtual Reality Technology. 2nd ed. Hoboken: Wiley-Interscience, 2003.

Burdea, Gricore C. Force and Touch Feedback for Virtual Reality. 1st ed. New York: Wiley-Interscience, 1996.

"Flock of Birds." Ascension-Tech. 2000. 8 Aug. 2006 <http://www.ascension-tech.com/products/flockofbirds.pdf>.

"InertiaCube3." InterSense. 8 Aug. 2006 <http://www.isense.com/products/prec/ic3/InertiaCube3.pdf>.

John, Vince. Introduction to Virtual Reality. 1st ed. London: Springer, 2004.

"Liberty." Polhemus. Feb. 2004. 8 Aug. 2006 <http://www.polhemus.com/J-Bots%20Plus%202002/LIBERTY/LIBERTY_brochure.pdf>.

"Precision Position Tracker." WorldViz. 8 Aug. 2006 <http://worldviz.com/products/ppt/index.html>.

Sherman, William R., and Alan B. Craig. Understading Virtual Reality: Interface, Application , and Design. 1st ed. San Francisco: Morgan Kaufmann, 2003. 134-135.

Vince, John. Essential Virtual Reality Fast. 1st ed. New York: Springer, 1998.

"Wireless InertiaCube3." InterSense. 8 Aug. 2006 <http://www.isense.com/products/prec/ic3/WirelessInertiaCube3.pdf>.