Virtual Reality in Air Traffic Control Research for US Federal Aviation Administration

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Summary

As the technologies and techniques of virtual reality have been making there way into a growing number of disciplines and industries throughout the world, the Federal Aviation Administration (FAA) has also recognized and embraced its many benefits in the areas of rapid-prototyping and visualization for Air Traffic Control (ATC) research. This paper will overview some of the FAA's needs, uses, benefits, capabilities and applications of virtual reality in this area of science and research.

History

Progressing before our very eyes, we can see that technologies and techniques that are considered cutting-edge today will be considered archaic tomorrow, just as what was considered cutting-edge yesterday seems archaic today. In the not-too-distant past we employed technologies and techniques for ATC-related research and development (R&D) purposes that we would consider archaic by today's standards but were in fact the best available at the time. Such was the case in the areas of designing or modifying ATC-related equipment, work consoles, facility layout and tower placement as examples.

It was not uncommon for vendors of many disciplines to develop products merely from written specifications. A good visualization would have typically been accomplished by simply using two-dimensional (2D) plans or sketches. One could mentally interpolate a three-dimensional (3D) perspective with the availability of a few 2D drawings from different perspectives. A more elaborate 3D visualization would have been a scaled desktop architectural model. When spatial issues or ergonomics are of concern, one of the FAA's techniques is to build life-sized models made of paper, cardboard, foam and/or wood. These mock-ups have been built for many projects such as the design or modification of ATC consoles and for the design, layout or modification of ATC towers. When none of these methods were enough to give a person a satisfactory visualization for specific circumstances, more drastic measure had to be taken. For example, various methods have been used around the world to visualize and evaluate potential sites for air traffic control towers. They include the observers hovering in a helicopter, being lifted by a crane, sailing in a blimp, standing in a cherry-picker (bucket truck) and floating in a hot-air balloon.

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Problems

There are circumstances when each of these methods of visualization may have been appropriate and sufficient. However, there are also problems that result when the use of a particular method is not sufficient, even though it may have been the only option available at the time. End-users sometimes do not get a visualization of design or layout until the end product is delivered. Many design/layout issues are realized only after end-users "see" the finished products. Once products are developed and delivered, the cost of modifications or corrections can be astronomical and will now take much more time to complete and will also hinder field operations. The farther along development is to delivery, the greater the negative impact is if/when problems are realized. This is not only true of user issues, but also for flaws and errors in physical design that are realized when a product goes to production or delivered to the field and then can not be integrated with other products or equipment.

Textual specifications are often interpreted differently, leading to unacceptable products. When a textual specification is written, it is done so according to the writer's mental visualization of the design or requirements. Often the writers believe that the words accurately and sufficiently describe the design because they already have a preconceived mental visualization of what the product will look like. A problem arises when the recipient of the written specification reads those same words, develops their own mental model, and develops a product that clearly conforms to the written specifications but is not at all like the writer's intent and is clearly not acceptable to the writer or to the end-users of the product. Even 2D plans or sketches do not fill in all of the blanks left open by a textual specification. There are circumstances when typical 2D drawings simply would not illustrate design flaws unless the flaws were already known and the appropriate perspectives were purposely drawn. Occlusion and user line-of-sight are good examples of this, especially when the drawings are in an orthographic view. While some of these issues could be discovered with the use of 3D desktop architectural models, it would still be very difficult to gain a real-world 3D perspective looking at a miniature model. These models also tend be lacking even a modest amount of detail. Life-size 3D mock-ups give a real human a better real-world perspective. These however take more time and more money to produce. They too usually lack detail unless an actual prototype is developed, which costs even more and takes even longer.

Historically speaking, the higher the fidelity of the visualization, the more costly it is, the longer it takes, the more prohibitive it is to explore alternatives, and the less it will be visualized within the context of its final destination.

Solution and Benefits

If a picture is worth a thousand words, then a virtual environment is worth a million. Virtual reality technologies and techniques allow developers to quickly and inexpensively build, visualize, evaluate and correct the design/layout or modification of equipment/facilities before the design process is even completed. Building a virtual prototype involves many of the same steps that would be taken to develop the actual product. Therefore, while still back in this design stage, flaws are discovered just as they eventually would have been in the actual production or in the development a full-scale prototype. An example would be the incorrect or incompatible measurements of product components.

Virtual prototypes not only aid in the early discovery of hard issues such as dimensions, but also in the early discovery of soft issues such as ergonomics and subjective usability issues. Now instead of users seeing the product for the first time at delivery, they get to “see” it back in the early design phases of development when their input can still be incorporated into the design with little impact on production. The virtual prototypes can be at any level of detail necessary to achieve the goal of the particular visualization.

Using virtual prototypes to identify and make corrections, or even to explore alternate design scenarios, is significantly quicker and less expensive than the historically used methods of visualization and evaluation. This is especially true when compared to the cost of correcting a product that is already delivered. Even when it is appropriate to build physical models, mock-ups or prototypes, using VR as a precursory step still reduces the time, money and effort in those later steps because the integrity of the design will have already been tested, corrected and established in VR before developing a physical representation. When end-users see the virtual product or environment, they detect potential issues that they probably would not have detected from a written specification or even sketches and drawings. Now it is possible to have the end-users see, evaluate and accept the product prior to delivery.

The use of virtual prototypes greatly reduces the potential for diverse interpretation of specifications and requirements, and therefore alleviates surprises and improves acceptability. Not only are virtual prototypes and virtual environments advantageous for visualizing and evaluating the product itself, but these methods are unmatched when visualizing and evaluating the product within the context of its proposed environment. Even though the product may be acceptable on its own, it may not be compatible or acceptable as part of a larger environment. As an example, designers and users can quickly, easily and inexpensively see proposed ATC consoles within the context of all the other equipment that surrounds them in the ATC center, or see and evaluate a proposed new ATC tower within the context of the entire existing airport and the surrounding geography. ATC controllers can evaluate it from their perspective while facility maintenance personnel can evaluate it from their job perspective and functionality, and safety personnel according to their rules and regulations.

These technologies allow for the graphic visualization of things that are typically not seen in the real world or in physical mock-ups, such as user line-of-sight, human reach envelopes, operation of moving components, and required space for certain work areas for things like maintenance. Virtual reality allows developers and users to be there before there is there. When “feeling like you are there” is not enough for human factors ergonomic evaluations, virtual reality even allows extremely accurate measurements and evaluation using a virtual human inside the virtual environment. This anthropometric model is a computer-generated human that is introduced into the virtual environment and can be adjusted to represent any percentile male or female. This allows for the ergonomic and functional evaluation of space, size, reach, line-of-sight, primary field of view, etc without having to build an actual physical prototype or mock-up. The bottom business line is that VR helps us save time, save money, save face and save lives.

Utility

In addition to using VR for the visualization and evaluation of designs, layouts and changes to facilities and equipment, there are a number of other areas in which it is useful. For example, conveying complex concepts such as dynamic air traffic flow patterns or proposed new designs for airspace are clearer and more accurately conveyed using VR than with words, 2D drawings or even a 3D model that is static. Another example is in the area of complex data sets which might otherwise be too complex to visualize any other way. Examples of this would be analysis of data from a flight data recorder, airspace configuration, weather, luggage scanning, and analysis of structural stress on aging aircraft.

Capabilities

Depending on the purpose for which the overall system is developed, there are many permutations of the components that are available or that can be built. Below are the technical capabilities currently in use at the Virtual Reality Laboratory in the FAA William J. Hughes Technical Center’s Research Development and Human Factors Laboratory. These are the components that allow us to realize the benefits of VR.

- Graphics computers
    - Onyx2 Infinite Reality2 supercomputer (by SGI)
    - Octane graphics workstations (by SGI)
- 3D goggles - goggles that provide the viewer with 3-D, vivid, color viewing of the interactive virtual environments. (CrystalEyes by Stereographics)
- Virtual hand - allows users to effectively reach a virtual hand into a virtual world and interact with it using a glove that controls the virtual hand’s position, orientation and

articulated joint movements. Also provides user with tactile feedback when virtual hand interacts with virtual objects. (CyberGlove by Virtual Technologies)

- Electromagnetic tracking system - a six degree-of-freedom (DOF) position and orientation tracking system. Can be used with devices such as the glove, HMD, etc. (Flock of Birds by Ascension Technology)
- Head mounted display (HMD) – a high resolution, full-color, stereo, immersive display system a user wears on their head offering 3D viewing. (by N-Vision)
- Acoustic and gyroscope tracking system – a high fidelity, six DOF position and orientation tracking system to be used with devices such as the glove, HMD, etc. (by Intersense)
- Virtual anthropometric human model - a human modeling software package capable of performing measurements and ergonomic analysis inside a virtual environment. The software can model any percentile male or female, and allows for early detection of human factors issues at the start of the design process. (JACK by EAI)
- 3D modeling software - 3D object creator/editor to build virtual environments. (Creator by MultiGen)
- Real-time software - to create a real-time simulation environment which supports special effects, lighting modes, view sequencing and the ability to conduct “virtual fly-throughs”. (Vega by MultiGen)
- Video recording equipment to capture real-time fly-throughs and views from key vantage points according to customer requirements.

Examples

Figure 1: Changes to LaGuardia Tower

Figure 2: Integration/Evaluation of New Equipment

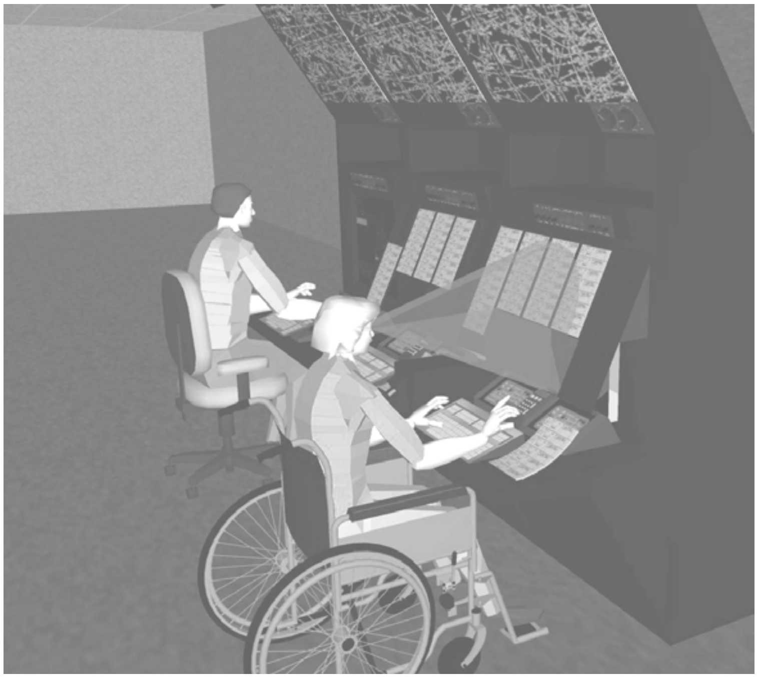

Figure 3: Ergonomic Evaluation Showing Field of View