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Designing a Virtual Reality Game for the CAVE

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Abstract

Virtual Reality has for many years been a technology which has stagnated in application and software development for games. The applications available for VR environments have increased but they mostly remain related to scientific purposes while computer games in VR are still being developed and only show a part of their actual potential. The game industry has begun to see the possibilities of VR games in a near future with the implementation of some popular games to a CAVE system. However, a full immersion VR solution still remains uncommon and expensive. This paper aims to demonstrate the potential of VR games, and in particular games for the CAVE, now that affordable solutions are close to reach as more powerful hardware is available at low price. The focus is also on the methodology to be pursued while designing a VR game. Results were encouraging and tests performed on a first prototype demonstrates system feasibility.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism

1. Introduction

Several systems have been developed for Virtual Reality (VR) with different display and interaction possibilities. Systems with large visualization screens have been proposed for immersive presentations, e.g. Powerwalls, Panorama arenas, as well as system for individual use but allowing for high interaction, e.g. the CAVE system [CNSD], or Head Mounted Display (HMD) systems. Figure 1 and 2 show examples. VR systems may provide different input signals to the human sensor modalities in order to enhance a sense of presence in the generated virtual world. Other than vision, audio and touch represent main stimulated human sensors. However, being the vision the dominant human sensor modality, large attention has been payed to the visualization aspect and different technologies have been developed for 3D stereo visualization. Among them, passive systems as those using Anaglyph and Polarized filters solutions and active systems typically based on shutter glasses. The above mentioned systems usually require a user to wear special goggles, (fig. 2).

1.1. Virtual Reality for the Masses

In the early 1990's VR found its way to the consumer market and the masses. Film became one of the first media to incorporate and advertise for this new medium. Films like: The *Lawnmower Man* (1992), *Johnny Mnemonic* (1995) and *The Matrix* (1999) have all provided us with a fictional glance of the possibilities and the future of VR applications and systems. We could say that the *Lawnmower Man* and the emergence of VR games introduced VR to the masses. Both the movie and the technology created a "boom" within the research of VR. Suddenly the technology became more accessible and developers were able to create new applications. This became especially noticeable within the entertainment area, where game consoles had dominated the market since the early 1980's. As within many new technologies, the interest grew and companies like *Atari* focused on VR games. *Atari* in cooperation with *Virtuality Inc.* manufactured the *VR Pods*, [vwe], and introduced the *Jaguar VR*, [ata95], (console with VR Pack) in 1993 to the consumer market offering a HMD system to a low cost price of only 300$. Many other companies in the early 1990's competed in releasing products for the consumer market, but they saw a lost of interest, which main reason was the increased competition of the console market (16 and 32 bits game machines, e.g. *PlayStation*, *Sega Saturn & SNES*).

The technology has progressed, new projectors and better graphic cards allow for higher quality and faster rendering, however, a VR system still costs a minor fortune. This is the main reason behind VR's lack of success within the con-

Figure 1: *The CAVE structure (left) and a representative view of the CAVE (center), at the Aalborg University VR Media Lab. The HMD system with data glove (right), at the Institute of Computer Science, Technical University of Lodz.*

sumer market since the downfall of the early 1990's. The technology has found new roots in the scientific field where VR has through the years proved a great success within the professional industry, car manufactures, design companies, universities and military institutions. At the universities VR games are still being developed as a means of illustrating the possibilities of VR within various VR environments. We can identify two main problems which prevent VR to enter the consumer market:

- there are not, currently, new game applications developed specifically for VR;
- the cost of producing a VR facility still is too high for the consumer market.

1.2. The Resurrection of VR Games and the CAVE

Despite of the stagnation of the development of VR games, the research in industry is slowly changing direction. The processing power needed to render and visualize the graphics in real-time on multiple displays can now be delivered by cheap PCs or cluster of them. Today powerful PCs are present in many homes and universities around the world. This has not only benefited the computer science community, but especially the game industry (which in 2005 has sold for almost 26 billion dollars world wide). It is in times like these, where the VR community and VR games have the opportunity to promote the technology. Researcher Paul Rajlich and Jeffery Jacobson from Visbox have taken the first step by implementing the games *Quake* and *Unreal Tournament* in a CAVE-like setting, [vis]. This may also inspire the gaming industry to start researching in new and cheaper VR systems and especially games specifically designed for VR. Despite it is still too early for average consumers to have the space for a CAVE system in their living room, it does show the possibilities. A new genre called serious games has slowly crept into the gaming industry, which has the potential to be the genre which breaks the barrier of the current stagnation of VR games. Furthermore, new methods and games are appearing on the market.

2. Designing a VR Game for the CAVE

We have developed a game specifically designed for the CAVE. Nevertheless, most of the considerations and findings concerning game design for the CAVE will apply to VR game design in general. We believe that the possibilities provided by the CAVE technology had never been fully exploited.

What makes the CAVE unique? To understand how we can take advantage of the possibilities provided by a CAVE system we first have to identify what characterize it the most. The 3 main features are: Omni-Directional Visualization, Region of Exploration (REX), and User Interface. The above features lead in turn to design anew the entire game, being that these features are not present in traditional console games.

- **Omni-Directional Visualization.** In a CAVE system the player has an omni-directional view of the scene at all times. This means that we have a new possibility for creating an omni-directional visually immersive game scenario which should be built around an environment designed for omni-directional viewing. Where we had corridors and narrow confined spaces (working well for conventional games), panoramic scenarios would now be more suitable. To enhance this further, the vertical depth of the scene can also be included as a part of the scenario, (the floor and ceiling may also be displays allowing for a vertical span in the scene). This includes the "fear of heights", since it is one of the properties well portrayed in a CAVE.
- **Region of Exploration (REX).** Other than being suitable for panoramic scenarios, the CAVE provides space in the near proximity of the player which is available for game designers. Virtual graphical elements positioned within the CAVE dimensions give the illusion that objects are right in front of you, and unlike conventional displays, objects in a VR application can have the same scale as in the real world. The sense of presence in a game can be enhanced by this feature. Furthermore, the REX can be ex-

Figure 2: *The Panorama arena at the VR Media Lab (left). The projector system with polarized filters for the Powerwall system at the Aalborg University Copenhagen, Medialogy Lab (center). Goggles for 3D stereo visualization systems (right): red-cyan Anaglyph on white frame, Polarized filters on black frame, shutter glasses on gray frame.*

ploited to insert (or bring with you) in the game, environment real objects. This allows for mixed reality scenarios which may increase a sense of presence in the application, as investigated in the EU research projects BENOGO related to Presence in VR, [gra05].

- **User Interface.** The application interface in CAVE systems allows for controlling and interacting with a VR game through body movements. This is mostly due to the presence of tracker systems. Most CAVE systems have two tracking sensors: one tracks the head orientation, while the other is often connected to a peripheral device (e.g. a 3D mouse, data gloves). This characteristic also provide a big creative input for game designers. Furthermore, solutions have been proposed to provide the ability to physically walk through the virtual world (without actually going anywhere), e.g. locomotion interfaces which use circulation of moving tiles [Iwa04], or shoe peripherals with pressure sensors [Nor05]. This form of navigation interface enhances presence.

3. VR Game Implementation

The game content (concept art, models, textures, animations) has to be considered from the very start, [AJJ05]. For our first prototype, we have chosen the *Star Wars* universe being this a very suitable game setting, due to its detailed visual documentation and depth of story, as well as being very suitable for a CAVE system application. In addition, the copyright contracts allow for producing *Star Wars* related content as long as this not commercially motivated.

The proposed game is simple with only 3 active elements: a sword, a beam, and the Remote, (the rest of the content is for the most of decorative and visual effect nature). In particular, a scene from the *Star Wars IV* is the main stage for our game, where the protagonist of the movie practices his lightsaber skills against a little hovering droid. The droid shoots laser beams at the player, while the player has to defend himself against the hovering droid. The figure 3 show the game main stage. The player is armed with a lightsaber on his sword through which he/she can block a laser beam. The player gets and loses points according to his/her performance. Earning points will increase/decrease the difficulty level. The setup and game play potential of this sequence seemed to be the perfect platform for developing a "CAVE game". In particular:

- the player will need to use his full viewing field to track and effectively fight against the droid;
- the player will be equipped with a real lighsaber-like tool, so that he/she can benefit from the available REX
- the droid will rotate around the player forcing this to turn head and body, so the player may naturally interact with the game environment through tracked body movements.

In the figure 3 we see the different elements in the scene. The geometry named target is the representation of the player. If the laser beam hits inside this zone the player will have taken a hit. The target box is some what larger than the target to insure that the Remote does not have a perfect aim. This kind of interface simply will only be possible in a CAVE environment. Furthermore, to provide the user with a stronger sense of depth in all directions, we emphasize the monocular depth cue by placing tall buildings in all direction around the "stage" with a distance between them.

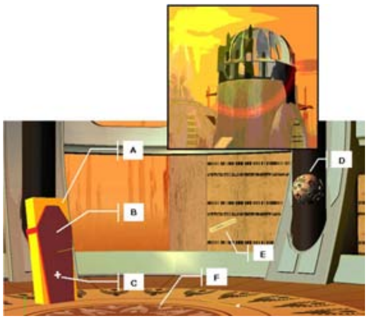

Figure 3: *The VR game main stage elements: target-box "A", target "B", target locator "C", Remote "D", laser-beam "E", floor "F". Top figure shows the main stage seen from outside.*

4. Creating an Affordable VR System

We try to apply the latest advances in hardware and software towards the creating of an innovative VR game. We are not just interested in developing a working prototype, but also to assess its applicability for a future market. Two important parameters which need to be considered are then technology accessibility and affordability. It is a matter of cost-benefit that our users will have to consider before plugging in a new technology for their creative hub.

VR systems are very expensive having a price tags ranging from 50,000 to over 1 million$. This happens because they feature state of the art technology. E.g. at the Siggraph 2002 *Mechdyne* and *Fakespace* announced multimillion dollars VR systems and support products [Isd02]. There do exist several VR system manufactures who claim to produce affordable systems, e.g. the *Geowall Consortium*, the *SAS Cube*, the *VizBox*, the *VizTek*, [umb01]. However, prices are still too hight. E.g. from our research, the price of a *VizTek* system ranges from 46,000$ for an active single wall system (800x600, 1000 Lumens, sound, VR simulation environment, high-end workstation), to 740,000$ for an ICUBE (active 6-walls 1280x1024). The above still represents an unaffordable budget for many corporations and research institutions, not to mention home applications. Therefore, to create a low cost VR system one must compromise. The above does not necessarily mean to minimize the available options. In particular, when choosing to create a low cost VR system it is important to consider: available budget, user requirements, and equipment quality. If the price tag is still too high, then creating the system in-house is the way to go.

Following the above considerations we have decided to crate our "affordable" system in-house. This solution would also allow us gaining know-how on what is actually achievable, and so test feasibility of the proposed concept. Other than low cost, we want the proposed system to address mobility and modularity. The system should also allow for different 3D stereo visualization technologies to be employed, in particular, passive anaglyph and active with shutter glasses.

Modularity. In order to obtain modularity we needed to produce a system which would allow the projection walls to be placed side by side. Consequently, our design features three identical stand-alone walls which can be combined in order to obtain different system configurations. In particular, other than a CAVE solution, the proposed system may be configured to be a Panoramic display with different degrees of screen curvature, up to a Powerwall display. The figure 4 shows the proposed 4-sided modular CAVE system (3 lateral walls and a top-projected floor).

Projection Screen The basic element of our modular solution is a 1-side CAVE, which we decide to build and test as first step of the implementation. Despite the proposed modularity we need to project images through the entire screens area without discontinuities. A Plexiglas material is then proposed to be used in order to place the screen canvas out from the wall frame and allow the incoming projector light to fill the entire wall surface. The choice of Plexiglas to distance the screen canvas from the frame is in order to create seamless edges. In particular, the transparency of Plexiglas enables light to penetrate out to the screen canvas edge. The distance between the wall frame and the screen canvas is a result of the projectors throw ratio distance.

Material Choice. The final design blueprint was created after thorough investigation of available materials. In particular, we found that most stationary CAVE systems are built from wood because it does not interfere with the magnetic tracker systems and it is robust. Plastic pipes are an alternative which is very light. For our system this material is too flexible when stretching a screen canvas on a plastic pipe frame. Our selection of frame material landed on aluminum because it has both the strength of wood and the lightness of plastic. The aluminum pipes we use (produced by *Termotex*), are complemented by convenient joint tools which set the construction time to a minimum. The wall structure is illustrated in figure 4.

Interaction. To allow the player to look around and use his lightsaber we use motion tracking. This is done with a *Polhemus Isotrack II* with 2 sensors, that have 6 degrees of freedom, enabling easy interaction with the game. The first sensor placed on the head of the player and the second sensor attached to a makeshift of a lightsaber hilt. Combining motion tracking with 3D stereo visualization gives the feeling of holding an actual lightsaber in your hands.

Hardware. It is in the selection of hardware where the cost of a VR system can be reduced significantly. Our solution uses one (or two) PC with a dual graphic card. The PC render platform includes: *Pentium* dual-core processor D830 3.0GHz, 2GB DDR2 RAM, 200GB HD. The 256MB dual graphic card setup with an SLI bridge provides us with 4 synchronized video outputs. The *Polhemus Isotrack II* magnetic tracker is used for user interaction. This tracker has a low cost but it has a limited range of 1.5m around the magnetic transmitter. Projectors for active stereo are typically very expensive, but new less expensive products are now on the market. In particular, we found the Infocus DepthQ projector at a price tag of 4000$ which is much lower than its competitors. Other miscellaneous devices include active stereo glasses from E-Dimensional (99$) and also different kinds of passive glasses.

Game Design Software. The software for developing VR applications is *Virtools* [vir05], although OpenSG can be used. Virtools is designed for PC clusters and supports many of the industries VR peripherals. It also supports most displays (e.g. CAVE, SAS Cube, panoramic rooms, immersive desks and HMD's). Developing applications in *Virtools* provides designers with an off-the-shelf solution to manage content and create applications, but also fast prototyping and low application development costs for VR systems.

Figure 4: *The proposed affordable system: basic structure (left), powerwall and panorama (center), CAVE (right).*

5. Evaluation Test

At the Aalborg University we already have an expensive 6-sided CAVE system, as well as a 160 degrees Panorama Arena and a front-projected large Powerwall, (figs. 1, 2). The CAVE and the Panorama system use active stereo visualization, while the Powerwall uses passive stereo with Polarized filters. We believed the above would provide us a splendid possibility for testing the system that we propose. We tested moving around in the VR game and the lightsaber, both worked well. The figure 5 shows a moment of the testing phase and the way the game is perceived when playing it. For what concerning depth perception, the application was tested both in case of passive and active stereo. However, for practical reason the active stereo solution was only tested for a screen size smaller than the large CAVE wall. It became evident that the depth cues we had implemented worked impeccably, using both the passive and active goggles. The cues of distance and occlusion were particularly good. In addition it can be said that if one can abstract from the color difference and roll-related ghosting effect the passive glasses give us good a depth perception as good as with the active glasses. The large screen size of the back-projected wall enhanced the experience for the player. In addition the passive 3D stereo visualization enhanced by the monocular depth cues gave a greater feeling of immersion and presence which, together with the appositely designed game scenarios, definitely increased the feeling of being present in the game. Hence, supporting the idea that a VR game designed specifically for a CAVE would play a role in the future of gaming.

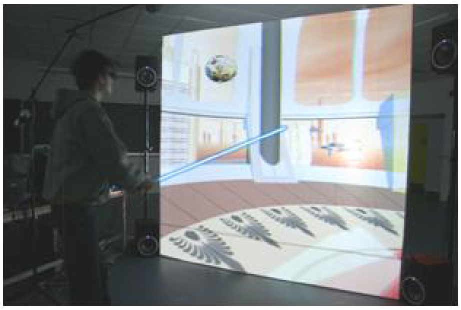

Figure 5: *Testing phase: mockup/lightsaber test.*

6. Conclusion

The technology has evolved and provided us with tools that make the rebirth of VR games feasible in a near future due to the possibility of building VR systems at low cost. This would allow for more immersive games. The achievement of the above objective needs a new way of designing games as underlined in the presented work in case of designing a game for the CAVE. To provide a strong sense of immersion has been one of the main goals in the design of our VR game. The results were encouraging and tests performed on a first prototype demonstrates system feasibility. We can predict that VR games can raise again if the right business model is defined between the developers and the consumers.

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