A CONCEPT OF LOW-COST VIRTUAL WALL FOR VIRTUAL REALITY SYSTEMS TO EDUCATIONAL PURPOSES

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Abstract *— Immersive systems allow a high degree of involvement for the users and they can offer wide visual field and stereoscopic visualization for multiple users. This paper presents the VirtWall, a concept that uses a single fast processor computer with a dual-head video card to produces immersive stereo graphics for virtual reality (VR) applications at low-cost. The main goal is to disseminate the use of VR systems for educational purposes. The programming tools used were free source code, which provided the development of reliable and high performance systems for VR, comparable to commercial systems of high cost. The VirtWall can support several kinds of applications, as example: teaching of topics algebra dependents and geometry, as digital image processing and geographical information systems (GIS) and visualization and statistical analysis of multidimensional and multivariate data. Other possible uses of that technology include distance learning, immersive training of techniques through simulation, etc.*

Index Terms — technology for education, virtual wall, virtual reality, low-cost systems.

INTRODUCTION

Virtual reality systems use computational platforms and devices to create virtual environments for simulations and interactive visualization. These systems can be classified as immersive and non-immersive according to user's involvement with the application [13]. The immersive systems allow a high degree of involvement for the users and they can offer wide visual field and stereoscopic visualization for multiple users besides the interaction. Examples of immersive systems are the Virtual Walls [6] and the CAVE systems [5] which one or more large dimension screens are used for stereoscopic projection of images. Both systems present high cost and can reach to a million of dollars. However, the possibilities of use of that technology are countless and its use is already verified in different applications.

Nowadays, examples of applications for these systems can be found in Brazil, as in the case of EMBRAER – Brazilian airplane industry – that uses virtual walls to prototype its airplanes [17], the General Motors automotive industry that uses CAVEs in its design projects [8] and Petrobrás – Brazilian petroleum industry – that accomplishes simulations of petroleum sheets by the use of immersive systems of the same nature [4]. The main advantage in the use of those systems is to minimize costs in some stages of researches for the obtaining of new productive processes or even new products. As features those systems present: possibility of visualization for multiple users, full or partial immersion, high dependence of specific computational platforms (high performance graphic stations), high cost and no-mobility. Additionally, those systems require specialized workers for their assembly in a definitive place. Due to these reasons and the high cost involved, those systems become unviable to be widely used in Brazilian small and medium companies and universities.

The present paper shows how to solve the problems related to the cost and mobility of immersive systems presenting an accessible solution for Brazilian companies and universities for several applications. This solution offers a system for immersive and interactive visualization for multiple users and allows the diffusion and popularization of low cost technologies for immersive virtual reality systems. It is based on domestic computational components, easily found in the Brazilian market, and public domain software. Special attention was dispensed to do not allow the lost of performance or graphical quality.

BACKGROUND

The virtual wall technology can be a low-cost option against the CAVE technology. The applications of both systems are similar, but the degree of user's immersion can present differences depending the number of virtual walls used. However, virtual walls have some advantages over the CAVE systems: the computational system is less expensive, the screens require less space and it is more practical for a large number of simultaneous users. The main advantage resides in the fact that this kind of low cost system helps to expand the use of immersive Virtual Reality environments for public and educational institutions as such as all the society.

It is known that domestic computational systems already possess capability of data and video processing and

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that they are capable to offer technological solutions for immersive virtual reality [18]. In the literature, there are several attempts to reduce high costs of CAVE and virtual wall systems. Pair et al. [14] designed a triple-screen, four Intel PC-driven and passive stereo display system to generate and synchronize graphics, which are displayed using VREX-2210 stereoscopic projectors. Their CAVE like system was built at total price less than US$ 60,000. Studies and experiences of Bennett et al. [Bennett00] and Pape et al. [15,16] based on Intel processor PC platforms and accelerated video cards obtained good results with a virtual wall using passive stereo. Belleman et al. [2] designed a single-screen active stereo system called Linux Immersive Environment (LIE). LIE uses a single Linux PC with a video sync-doubler to generate active stereoscopic images.

In Brazil, studies about the use of domestic computational systems for immersive virtual reality can be found in the VR group at USP. They are building a cluster of dual processor PC's to the development of platforms for full immersion [18]. We do not have notice from any another Brazilian research group about development of a low-cost virtual wall.

Others low-cost virtual walls

As mentioned before, several authors are involved with research of low-cost virtual walls. Following we will discuss two well successfully experiences in this area.

Bennett et al. [3] developed a commodity based projection system suitable for group viewing of 3D (stereoscopic) images. They used a computer with Linux operating system, two projectors, a dual-head X server, two PCI video cards, passive polarized glasses and a special silver screen. They created stereoscopic applications produced with MESA software.

Pape et al. [15,16] developed their system using three PCs. The main computer used for the graphics is a dual processor 700 MHz Pentium III with Linux operating system. The system also has two projectors, a dual-head 3D video card, passive polarized glasses, a special screen for back projection and a tracking device. They created stereoscopic applications using CAVE VR software tools, compatible with SGI workstations.

We observe several similarities and several differences between these two projects and we could note that passive stereo conception is similar in both systems. This occurs because most of the common LCD and DLP projectors are not capable of scan rates necessary for active stereo. The main differences are in number of PCs and the kind of video cards used. The number of PCs can be explained by the graphical quality expected from the applications. The kind of video cards used (AGP and PCI) can be explained by the difference of two years between these projects. Other difference observed is related to the projection: the use of front projection is less expensive and uses less space than back projection.

Based on these observations, we propose a different approach to low-cost virtual wall. We are using a single AMD Athlon PC with Linux operating system, a recent AGP dual-head video card, passive stereo, two LCD projectors and front projection.

The VirtWall

The VirtWall system is a concept that uses a single fast processor and a dual-head video card to produces immersive stereo graphics for virtual reality applications. Besides that, all the components must be found in the Brazilian market. Using those components and based on that concept, we build a virtual wall: a single AMD PC based running operating system Linux and tools of public domain. That computer has some special features related to the amount of RAM memory and to the video card. Because the processing of the images is made by software and it is done twice to generate the stereo effect [3], the CPU speed was an item of attention.

In our implementation of the VirtWall concept, we use two Sony multimedia projectors with high intensity of light, which we can be used in illuminated rooms, as for example, classrooms. These projectors are found in the national market and they present costs very lower if compared to stereo projectors used for applications in virtual reality. Even so, those projectors possess resolution features and illumination intensity that allow a clear and comfortable visualization. The choice of the projectors observed the necessary optical properties for the good operation of the system without distortions, what could compromise the stereo effect. This stereo effect is obtained adjusting a pair of polarized filters in front of the projectors lenses.

The programming tools used were C/C++ languages, OpenGL graphics libraries and VRJuggler developing package. These tools provide the development of reliable and high performance systems for Virtual Reality, comparable to commercial systems of high cost.

Despite of the technological advances, the main conceptual similarities among the Bennett et al. [Bennett00], Pape et al. [15,16] and VirtWall are: use of PCs to building virtual reality systems; commercial multimedia projectors and passive stereo.

The main differences are related to the number of PCs – we used a single PC with a reasonable quantity of memory – and related to the video card – we used one which driver is compatible with Linux/Xfree86. The use of a free accelerated drive provided by Nvidia for GeForce 4 video cards determined the choice Nvidia/GeForce 4 set. We also used a 120 inch silver screen made in Brazil and it presented good quality for polarized stereo projection.

Applications Of The VirtWall Concept

The VirtWall can support applications that involve several kinds of applications in the university community providing immediate benefits. Examples are: teaching of topics algebra dependents and geometry, as digital image processing [9], visualization and statistical analysis of multidimensional and multivariate data [1]. Other possible uses of that technology include teaching at the distance [7], immersive training of several techniques through simulation [11], the virtual campus [10], etc. The benefits can also be extended to all society providing facilities to works as: studies of environmental impact [4], urban planning, development of products prototype, treatment of phobias, study of internal structures of the human body and personnel's training in critical missions, at costs lower than the current ones using commercial platforms.

Nowadays, some applications are already running and others are under development in our implementation of the VirtWall concept: the virtual human body atlas, a system to help teaching image classification and a virtual reality system to help teaching geographical information systems (GIS). Other application under development is the visualization system of multidimensional and multivariate statistical data.

The virtual human body atlas

To help medicine learning and others students in biomedical fields, three projects for interactive visualization and human structures identification are in progress: the virtual woman pelvis [11], the virtual man head and virtual woman heart. The goal is allow an immersive visualization and exploration of the human body anatomy, sticking out its main structures.

FIGURE 1.
THE VIRTUAL MAN HEAD SYSTEM RUNNING IN THE VIRTWALL.

The virtual woman pelvis presents an internal visualization of a female pelvic region with three layers of details: external viewing, skeleton viewing and bone marrow viewing. The next steps in this system include the reproductive organs visualization and identification. The virtual man head has the objective to provide a study of some structures found in the human head, as the skin, the facial muscles, the cranial bones and the brain. The system includes the identification of each structure and allows a partial dissection from the skin to the brain. The layers involved in the dissection can be observed in the Figure 1. Nowadays, the system offers stereoscopic visualization by anaglyphs and is being updated to offer that visualization by polarized filters/glasses.

The heart is a complex human organ and its study involves the comprehension of its structures, as blood vessels, arteries, atriums, ventricles and valves. For that, the virtual woman heart structures are being modeled and identified. This project is actually in development by a Biomedical Engineering master student.

System to help teaching image classification

The virtual reality system to digital image processing education which was developed for CAVE like system [9, 12], was adapted to run in our implementation of VirtWall concept to help studies in image classification – Figure 2 and 3. It is an important application because is hard to teach abstract statistical concepts as feature space, what is essential to image classification studies. The student can visualize, for example that point in the same class are near in the feature space, besides that points is not near in original image. As the previous version this version support studies in Hierarchical and K-NN classifiers. The Figure 2 shows the new implementation running in our implementation of VirtWall concept and the Figure 3 shows the previous implementation in a CAVE like system [9] at USP.

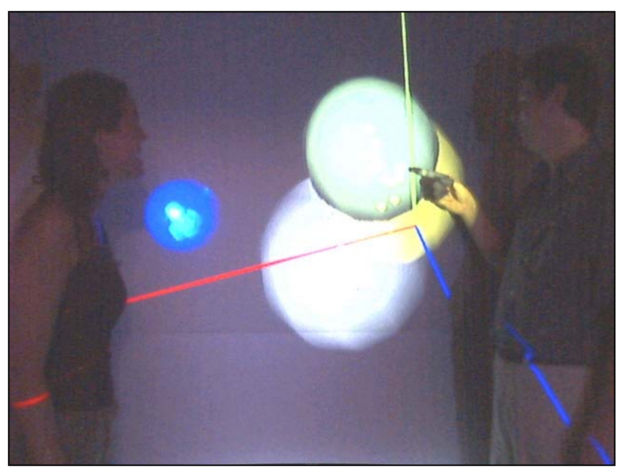


FIGURE 2.
SYSTEM TO HELP DIGITAL IMAGE PROCESSING EDUCATION RUNNING ON OUR VIRTWALL IMPLEMENTATION.

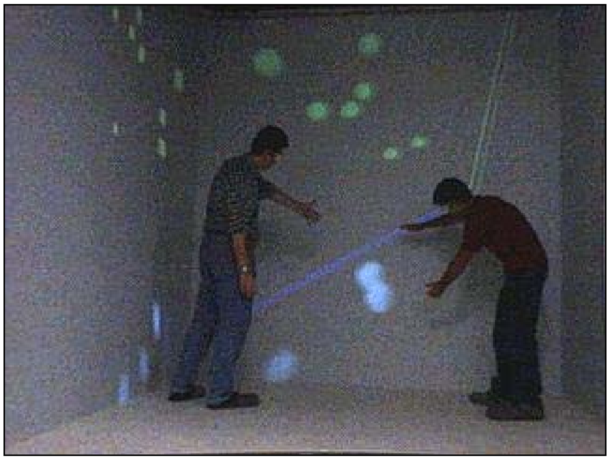
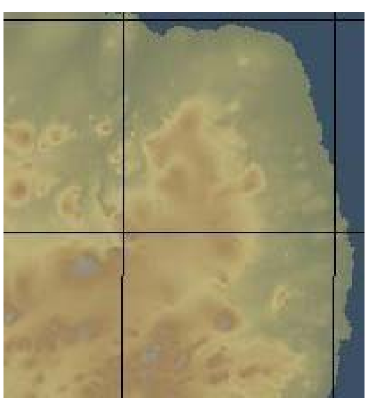


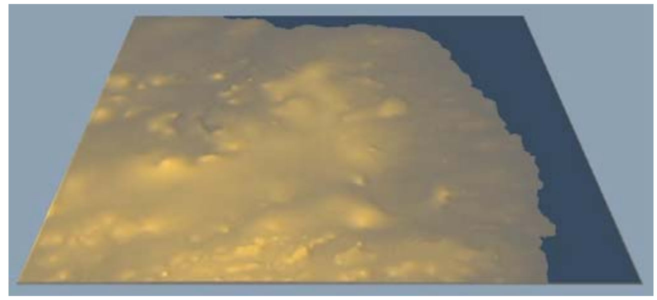
FIGURE 3.
SYSTEM TO HELP DIGITAL IMAGE PROCESSING EDUCATION RUNNING A CAVE LIKE SYSTEM.

Virtual reality system to help teaching geographical information systems (GIS)

Terrain numerical models as digital elevation mode data are been visualized in our implementation of VirtWall concept to help studies in Cartography and 3D visualization in geographical information systems. We can visualize those images as common image, anaglyph and stereo version, as Figure 4 shows it. In that Figure, we can visualize an area of northeast from Brazil including an area of Rio Grande do Norte and Paraíba states. In the Figure 4A we see a digital map of surface and the Figure 4B presents the common image in geographical perspective with altimeter information of surface. In the Figure 4C we observe anaglyph image in geographical perspective of same scene and in the Figure 4D shows the stereo image of same scene.



(A)



(B)

(C)

(D)

FIGURE 4.
(A) MAP OF PART OF NORTHEAST BRAZILIAN REGION; (B) COMPUTATIONAL IMAGE GENERATED FROM DIGITAL ELEVATION DATA; (C) ANAGLYPH IMAGE GENERATED FROM (B); (D) STEREO IMAGE GENERATED FROM (B).

CONCLUSIONS

In this paper we presented a concept to implement low-cost virtual wall for immersion in virtual reality called VirtWall. We show how a system of this kind can be built and the total prices to setup a system with components easily found in the Brazilian market. We presented also, some examples of applications that are running in our system and a short performance comparison with others systems.

We evaluated other two concepts to do a low cost virtual wall. The Benett et al. concept, which use a domestic computer and two independent video cards and commercial video projectors to stereo images. The Pape et al. concept uses a cluster of dual processor PCs where one PC is only responsible to drawing graphics and it has a dual head video card. Both concepts use Linux operational system and passive stereo by polarized light. Our concept uses a single processor computer with large quantity of RAM memory and a dual head video card with large memory based on. As the previous works, we use Linux operational system and passive stereo by polarized light. A prototype using VirtWall concept was built and the final costs was lower than US$ 9,000 and lower than other implementations found in the literature.

In spite of others concepts of same objectives have already been tested previously in other countries, such technologies cannot be considered adapted to the Brazilian reality, because many available products in another countries are not sold in Brazil. That differential is the main feature of the presented work besides the proposition of a technological solution applied to the development of a nonexistent product in the national market. The results present great potential of the VirtWall concept utilization for other segments of the society with benefits in several areas.

We believe that the expansion of low cost systems like the presented will allow the development of high performance and quality applications. The immersion benefits offered by the virtual reality can offer immediate benefits for education and will bring progresses in several areas of the industry, services and production.

The use of 3D visualization in classes can accelerate or facilitate the learning process, specially were multidimensional structures explanation is involved. The low-cost and utilization of popular hardware in the platform allows its use in many other fields in education. At this moment the VirtWall is already being used to applications for the education in the biomedical, statistics and geography in the Federal university of Paraiba (Brazil)

ACKNOWLEDGMENTS

The VirtWall project is supported by CT-INFO – CNPq, Brazilian research council, under number CNPq 552031/2002-0. We would like to thanks Ismênia Mangueira Soares Medeiros for the technical support.

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