Design and construction of 3D computer

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Abstract:
Intensive research projects have been supported by big groups (Toshiba, Sharp, ...), in order to built the 3D display systems - the core of Virtual Reality Technology. The 3D computer includes the 3D software, 3D hardware (graphic card support 3D display), and 3D monitor. An idea was proposed: combination of 2-LCD monitor system used as a 3D monitor to show the 3D stereo image or video to the viewers. Our research focuses on the construction of this kind of 3D system, by the available materials in the Vietnam market with the affordable cost.
This paper describes the principle of 3D displaying, based on the human binocular vision and the achievements of the digital technology. We present also the main properties of our 3D monitors and the applications we have done: presentation of the 3D photo and 3D movie shot by our 3D stereo camera. At the end, we talk about the prospects and challenges of this technology in the near future.
Keyword: 3D display, 3D monitor, 3D computer, 3D simulator, beam-splitter mirror
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I. INTRODUCTION

One of the most important properties of the physical world surrounding us is the existence of 3 dimensional (3D) space. Man perceive directly the 3D world through his 5 senses (eyes, ears, tactile sense, nose, tongue), where the vision gives most of information. When we observe the outside world, the image seen by right eye is slightly different from that seen by left eye, since the two eyes are located at a different position on our face. The depth illusion of the objects in space is the result of the eyes convergence perception in our brain.
The basic principle of the stereoscopic display system is the simulation of binocular vision. The stereo-imaging system must send appropriate images, taken at slightly different angles, to the right eye and left eyes. Right eye must see only right image, and left eye must see only left image. If the image separation is not good, we can see "ghost" image.
Many solution have been used to build a 3D display system. There are two main types of 3D stereoscopic monitor in the world market.
The first type uses the temporal separation by interlacing left image and right image alternatively in one frame of the CRT or LCD monitor. The observer must wear an electronic shutter glasses, synchronised with the monitor refresh rate to separate corresponding image [1]. The disvantage of this system is that we see the flickering of the images, since the number of frames per second is only on half of the refresh rate. Furthermore, the horizontal resolution is reduced by factor 2 due to the interlacing process.

The second one is the auto-stereo LCD monitor using the second LCD parallax barrier screen [2 Sharp Actius Notebook ?]. The limit of this 3D monitor is the lack of viewing positions. The stereo effect is good only when we observe from one fixed position. The brightness and vertical resolution are also reduced by 2 times.
With a more advanced approach using beam-splitter mirror (half mirror), our research group of IMS have built successfully the first 3D computer in Vietnam. Our design consists of a 3D monitor connected with a computer containing 3D stereo data (3D image, 3D video clip, 3D simulation data). This easy-to-use system shows not only a perfect 3D effect but also gives the highest quality of color rendering and full resolution, compared with the other available systems.

II. DESIGN OF THE 3D COMPUTER

Our 3D computer consists of 2 main parts: a 3D monitor, a computer equipped with the 3d display device and appropriate software.
The 3D monitor is a combination of 2 identical LCD monitors: Samsung SyncMaster LCD 17" or LG LCD 17" for our experiment. We put the 2 monitors oriented 120^0 to each other in the specially designed mounting stand. A half mirror which has the 35% transmission and 35% reflectance bisects the angle formed between the 2 monitors mounted on the stand. The polarization conservation is an important requirement of the half mirror.
There is a fine mechanical adjustment for the mirror angle between the 2 monitor (see Figure 1).

The 2 monitors are connected to a standard computer via a 3D graphic card. The NVIDIA card is our choice. We use some 3D software to produce and mix the 3D stereo images.

Figure 1: The 3D computer

III. PRINCIPLE OF OPERATION

The 3D stereo image demonstration can be done in 3 steps:
1. Acquisition and simulation of 3D data:
Two images can be taken by the stereoscopic camera, video stereo movie clips can be shot by using two camcorders side-by-side. 3D models or scenes made using CAD programs such as 3D Studio Max, Maya, and AutoCAD are potentially stereo data
2. Rendering and image splitting:
Stereo data are then converted to the format suitable for displaying in two monitors through a dual output NVIDIA GeForce 6600 graphic card. Software written with OpenGL (or Direct X) protocol permit a real-time rendering and displaying of 3D

stereo interactive scene. Due to the horizontal span feature of this card, the screen is split to the left and right part, then through the VGA and DVI ports, the data can be sent simultaneously to the monitors (see Figure 2)

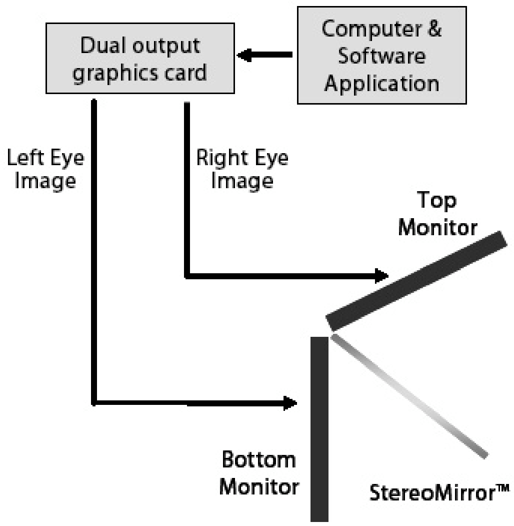

Figure 2: Architecture of the full system

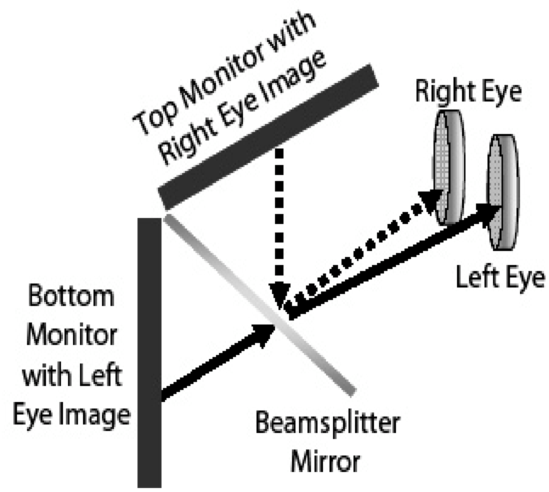

Figure 3: Image separation in the 3D monitor

3. Image convergence and separation:

In our design, the two images are totally overlapped due to the half-mirror arrangement in an adjustable stand (see Figure 3). Initially, the plane of polarization for light emitted from LCD monitor is at 45^0 to the horizontal plane [2]. The reflected image from the half mirror conserve its linear polarization, however, the plane of the polarization in the light path of the top monitor is effectively rotated 90^0 upon reflection (see Figure 4). When stereo pair images from the two monitors are viewed through crossed-polarizing glasses (glasses with polarizing films mounted on the eyepieces with their planes of polarization at a right angle to one another), the user only sees the left eye image with the eyepiece having the 45°-oriented polarizer and the right eye image with the eyepiece having the 135° polarizer (see Figure 3). Light with a perpendicular polarization is not transmitted. The result is a single, fused stereoscopic image.

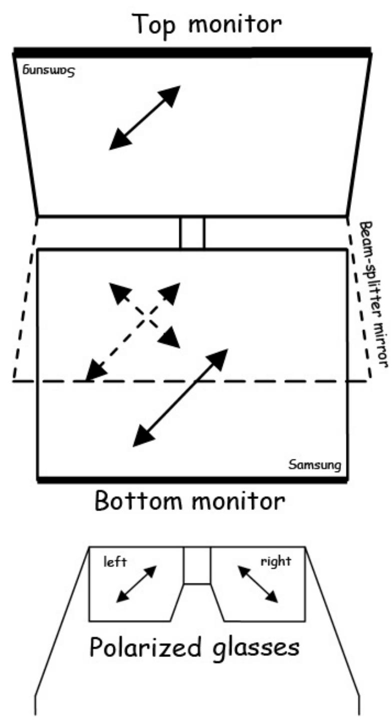

Figure 4: Conservation of polarization by half-mirror

IV. PERFORMANCE AND APPLICATIONS

The half-mirror is a key element of the 3D computer. An ideal half-mirror for our purpose must have 50% transmittance and 50% reflectance, but these parameters are never reachable in the reality. In order to verify the quality of the product, we have made a precise measurement of these parameters of our half-mirror.

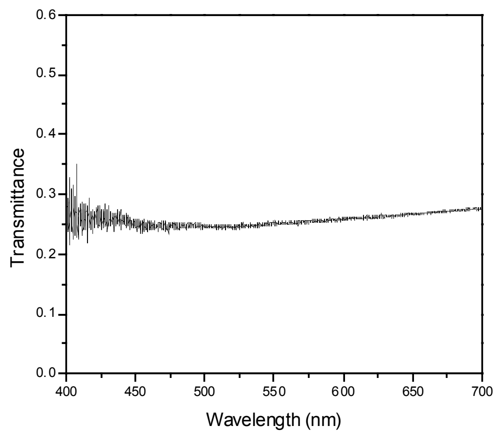

Figure 5: Transmission spectrum of the half mirror

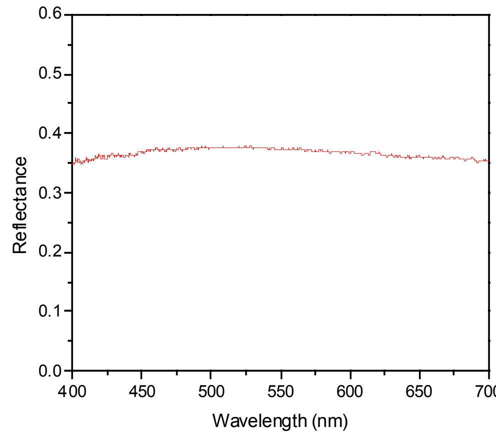

Figure 6: Reflection spectrum of the half mirror

The graphs show that the transmission spectrum and reflection spectrum are flat and stable on the visible spectrum band, so the half-mirror is fairly neutral for the visible light. We perceive a tiny inclination toward the red in transmission and a tiny inclination toward green in reflection. It means the left image might be slightly redder and right image might be slightly greener, but the difference is insignificant.

Furthermore, the average transmittance is about 0.25 and average reflectance is about 0.35, so the right image might be slightly brighter than the left image.

The extinction ratio is 1% when we rotate the polarizer by 90^o, indicating that there is no ghost, while this effect is often seen when we use the 3D projection system on silver screen.

The basic application of our 3D computer is the display of 3D stereoscopic photo. The result is impressive. The depth of the pictures increases when we increase viewing distance. Furthermore, the color quality and resolution quality of 3D image are unchanged compared with the original monoscopic photo showed on each monitor.

Figure 7: Example of displaying a stereo 3D photo

The good brightness and the wide stereo viewing angle permit multi-user utilization in the office illumination.

The second experiment we have done is the display of simulation program of car driver's training cabin. The interactive image has been exported to 2 streams by the virtual stereoscopic camera. The 3D effect is excellent which permit the student a good estimation of the distances from the virtual car to the obstacles.

V. CONCLUSION

1. For the first time in Vietnam, a complete 3D computer with stereo polarization display was investigated.
2. The image has full resolution, color rendering quality are excellent.
3. The depth sensation is impressive without any ghost effect. The image quality is perfect for multiple users.
4. Since the 3D computer is the newest technology, the cost is also unreachable for the Vietnamese users, while the price of our self-assembled product can be reduced significantly.
5. The markets for 3D computers are in geospatial intelligence, scientific visualization and industrial design, medical systems. The 3D monitors might have a great potential application in the entertainment industry, such as for 3D game or 3D cinema.

Reference

1. James L.F, Scott D. R, Charles W. M, Blake B., Adi A., Thomas E. B, Patrick J. G "*An innovative beamsplitter-based stereoscopic/3D display design* " IS&T/SPIE 17th Annual Symposium - Electronic Imaging Science and Technology, 16-20 Jan 2005
2. http://www.planar.com
3. Lipton, L. "Stereo3D Handbook", http://www.stereographics.com/support/downloads_support/ handbook.pdf
4. Woodgate, G.J., Harrold, J., Jacobs, A.M.S., Mosely, R.R., Ezra, D., "Flat panel autostereoscopic displays — characterization and enhancement", SPIE Vol. 3957, and reference therein
5. J.L. Fergason, "Monitor for Showing High-Resolution and Three-Dimensional Images and Method", U.S. Patent 6,703,988, March 9, 2004
6. http://www.nvidia.com
7. http://www.opengl.org