Volumetric 3D Display System Based on Rotating Dot-Matrix LEDs

Yuanfang Lin, *Xu Liu*, Xiaojie Zhang, *Yi Yao and Xiangdong Liu*
State Key Lab. of Modern Optical Instrumentation, Dept. of Optical Engineering,
Zhejiang University, Hangzhou, Zhejiang 310027, China
Phone : +86-571-8795-1187 , E-mail : awayfromlin@hotmail.com

Abstract

A volumetric three-dimensional (3D) display system was presented, which utilizes a rotating two-dimensional (2D) display panel of light emitting diodes (LEDs) to generate more than 10 million volume pixels (voxels) within a cylindrical volume of 165 mm in height and 292 mm in diameter. Due to persistence of vision, momentarily addressed voxel information is perceived and fused into a 3D image. Important cues for depth perception, such as binocular parallax, accommodation, convergence and motion parallax are satisfied automatically and naturally, thus it is suitable for individual or group viewing, without the need for any special visual aids.

1. Introduction

The world human live in is naturally three-dimensional. Researches show that more than 80 percent of the information got in human daily activities is via vision. There has always been a desire to develop visual systems capable of displaying 3D information in a realistic and natural manner.

In the case of representing 3D images on conventional 2D visual systems, psychological depth cues such as perspective, hidden contours or shadow effects are provided to give viewers an illusion of depth. However, an inherently 3D image can't be represented on a 2D plane satisfactorily. This incompatibility gets more distinct when viewers interpret a complicated image with many objects, whose orientation and spatial relationship is changeful over time. Among the three major categories of 3D displays, volumetric displays win the advantage over stereoscopy and holography. A diverse range of volumetric 3D display systems has been proposed during the last 90 years[1]. They reconstruct 3D image within a physical volume with height, width and depth, thus almost all important depth cues[2] are automatically and naturally satisfied.

Edwin Berlin[3] proposed a concept of utilizing a rotating LED array to reconstruct 3D image, but it failed to come to an operational stage due to technological restrictions in those early days. Based on today's advanced information technologies, a LED volumetric display system[4,5,6] is successfully set up, which uses rotating dot-matrix LEDs to generate voxels in 3D volume space. Compared to other static volume system using electro-luminescent arrays layered to accomplish a volumetric display[7], it can provide huge amounts of addressable voxels while reduce significantly the amount of electro-luminescent device used. Compared to the beam addressed swept volume display system employing a passive surface[1], it needs no projection units or light-attenuating optical elements, thus the brightness is enhanced and the system is compact, easy to control and transport.

2. Experimental system

The block diagram of LED volumetric display system is shown in Fig. 1, mainly comprising a planar 2D panel on which LEDs are arranged in a dot-matrix configuration, a microprocessor and electronics to energize and address LEDs selectively, a graphics memory to store image data, a motor to effect rotation of the LED panel and other necessary components. When the system is in full operation, cylindrical volume is generated and swept out cyclically by the panel. Through the use of an software application developed, compiled and executed under Visual C++ environment in a computer, original image data of 3D models created by 3D Studio MAX are exported as 3DS format file, then mapped into the rotating LEDs within the cylindrical display volume, finally loaded into graphics memory. Under appropriate control of the microprocessor, image data are read out from graphics memory by electronics device and used to address LEDs on the panel, displaying a series of instantaneous 2D images with suitable voluminous data. These images are perceived and interpreted by viewers as a space-filling 3D image due to persistence of vision.

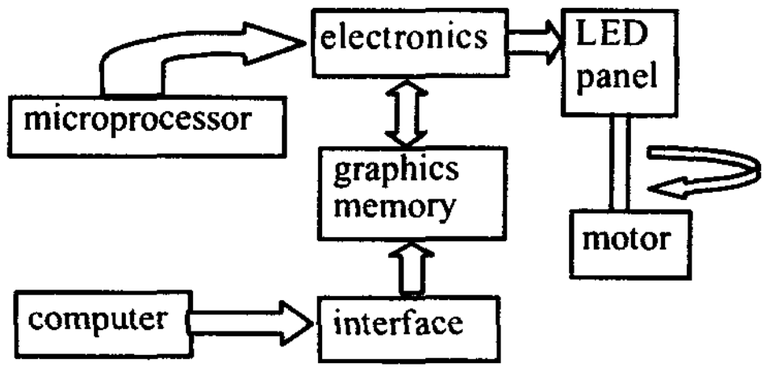

Figure 1 Schematic of volumetric LED display system

3. Results and discussion

LEDs of 500 ns response time are used to constitute a dot matrix with 64 rows and 256 columns. The design speed of rotation for LED dot matrix in full operation is 900 rpm. The system is capable of providing at least 10 million voxels within a cylindrical volume of 165 mm in height and 292 mm in diameter. Experimental results are as shown in Fig.2, wherein Fig.2 (a) are wireframes of a bull displayed on 2D computer screen corresponding to three different views. Fig.2 (b) are photos taken from three different viewing angles of the reconstructed bull. It is comprised of 275019 voxels. The difference between them in essence is that the former can't be viewed coinstantaneously without data reprocessing, while the latter are coexistent once the data processing is done, viewer simply need to walk around the display system. The reason is that the reconstructed image truly occupies a 3D volume, thus is inherently three-dimensional, can provide viewers with binocular disparity, motion parallax and such depth cues. Therefore, 3D information is displayed in a realistic and natural manner; viewers' ability to interpret 3D data and to reliably determine the shape, orientation and relationship of objects in space may be considerably improved. Nevertheless, as far as brightness uniformity is concerned, the reconstructed image is not satisfactory. In addition, because of the distortion of LED panel, a small portion of the image is hidden from viewers by part of the panel. Therefore, there are occlusion zones in the reconstructed image, as shown in Fig.2 (b). The next major task is to solve these problems and improve the image quality.

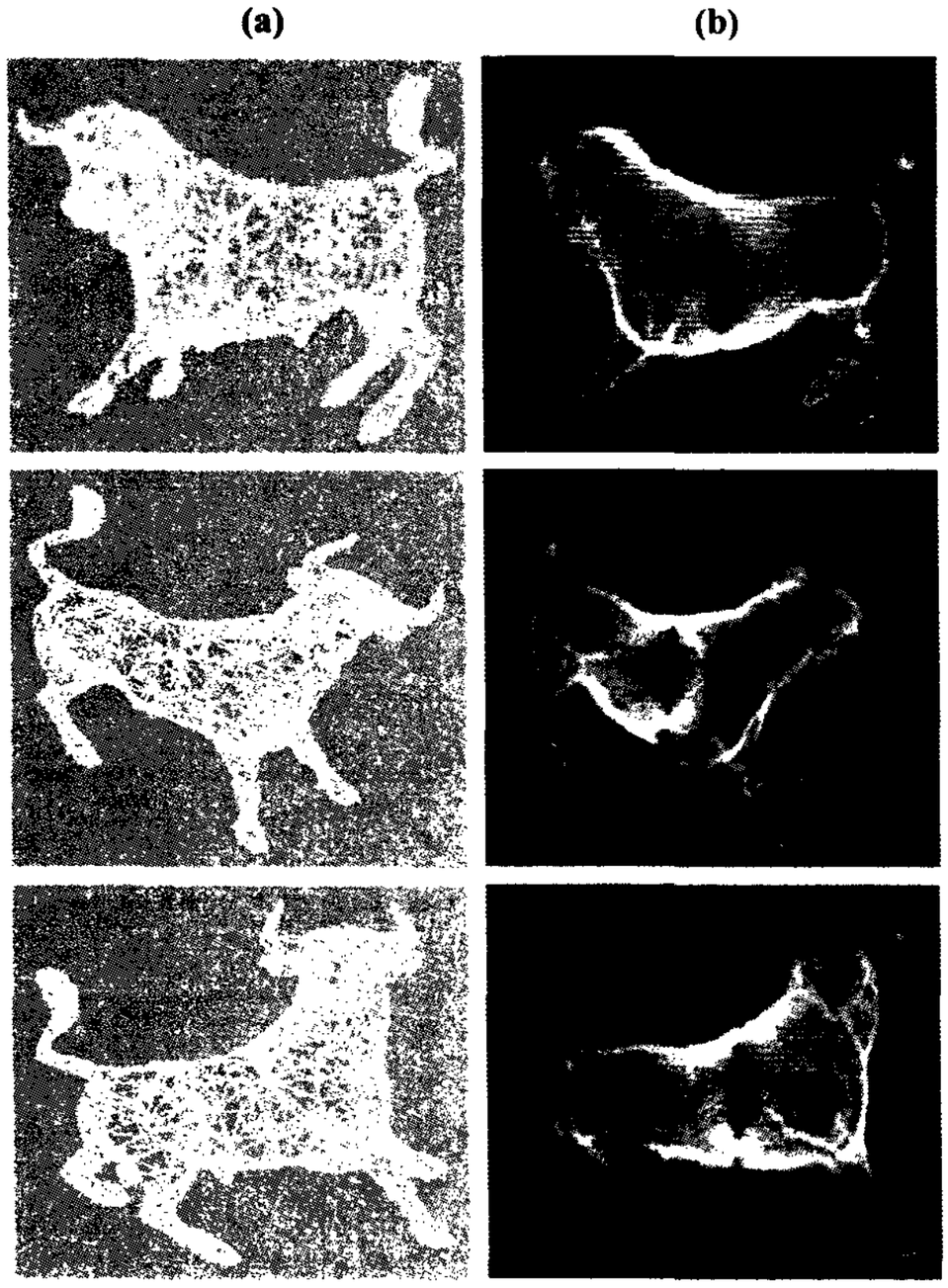

Figure 2 Experimental results; (a) Different perspective views of a bull created by 3D Studio MAX. (b) Photos taken from three different viewing angles of the bull reconstructed by LED volumetric display system

4. Conclusion

By using the volumetric display system based on rotating dot-matrix LEDs, 3D image reconstruction is accomplished. The inherent three-dimensionality of displayed images and the freedom of selecting viewing orientation, together with the convenience for group direct viewing mark the significant advantages of the LED volumetric system. It provides an effective experimental platform upon which ideas for 3D display may be evaluated, and provides a means to assess the suitability to such applications as education visualization, computer aided design, air traffic control and medical imaging.

5. References

[1] K. Langhans, D. Bahr, D. Bezecny, D. Homann, K. Oltmann, K. Oltmann, C. Guill, E. Rieper and G. Ardey. Felix 3D display: An interactive Tool for volumetric imaging, *SPIE*, **4660** (2002)

[2] C. D. Wickens, Three-dimensional stereoscopic display implementation, Guidelines derived from human visual capabilities, *SPIE*, **1256** (1990)

[3] J. Berlin, Three-dimensional display, *U.S.Patent **4160973*** (1979)

[4] Y. F. Lin, X. Liu, X. D. Liu, X. J. Zhang and W. Xu. Three-dimensional volumetric display system utilizing a rotating two-dimensional LED array, *Acta Optica Sinica*, **23**, 10 (2003)

[5] Y. F. Lin, X. D. Liu, X. Liu and X. J. Zhang. The analysis of voxel attributes in three-dimensional volumetric display system based on the rotation of a two-dimensional display panel, *Acta Photonica Sinica*, **33**, 4 (2004)

[6] Y. F. Lin, X. Liu, X. D. Liu and X. J. Zhang. Principle and distortion analysis of reconstructing three-dimensional image utilizing a rotating display panel, *Opto-Electronic Engineering*, **31**, 5 (2004)

[7] J.Whitesell, Electroluminescent arrays layered form a volumetric display, *U.S. Patent **5929572*** (1999)