VOLUMETRIC-SWEPT DISPLAY SYSTEM BASED ON HELIX ROTATING SCREEN AND DMD

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Abstract: Based on the helix rotating screen and the digital micro-mirror device(DMD), the former proto of volumetric-swept display system is improved. The 3-D display system adopting a helix rotating screen to construct an imaging space meliorate the defects, such as the smaller image space, the fewer voxels and the severer voxel overlap dead zone caused by planar rotating screen. DMD with spatial light modular (SLM) technology increases the transmission bandwidth of 3-D data in the voxel activation subsystem and activate multi-voxel once time. The volumetric-swept system based on helix rotating screen and DMD is developed. The experimental results show that the image space, the vision dead zone, the voxels on slice, and the voxel activation capacity of the designed proto are superior to the plane rotating screen system.

Key words: true 3-D display; volumetric 3-D display; volumetric-swept display; helix rotating screen; digital micro-mirror device(DMD)

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INTRODUCTION

Conventional 3-D computer graphics applications utilize the psychology depth cue, or utilize the technology of ray tracing and polygon generation. Its depth cue cannot be expressed clearly. True 3-D display technology has actual imaging space which not only display the true physical depth cue, but also the showed object can be observed by walking around the 3-D image without any auxiliary equipment. This technology includes holography and volumetric display techniques. Volumetric display techniques stimulate the matter in the semitransparent imaging space with proper manner, and produce visible light voxel. A lot of disperse light voxels reconstruct the image information in the true 3-D space[1].

The ability of display devices to display 3-D information in a realistic and natural manner has long been the subject of investigation. The FELIXLIX 3-D system has been developed in northern Germany. It is characterized by its comparatively simple system configuration. One or a combination of the three projection techniques can be implemented[2]. Perspecta™ 3-D system has been developed by Actuality Systems, Inc. It utilizes the digital light processing (DLP) projector that projects a serial 2-D section of 3-D model on a rotating screen to realize 3-D display[3]. In China, the study of the 3-D display technology is still on the phase of principle exploring and experimental demonstrating.

1 FORMER VOLUMETRIC-SWEPT DISPLAY SYSTEM

Volumetric 3-D display system can be sepa-

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rated into static volume display system and swept volume display system. According to the stimulating mode of the lighting voxel, the swept volume display may be classified into two categories, the active lighting manner and the passive lighting manner. And according to geometrical character of rotating screen, the swept volume display system may be classified into the plane rotating screen and the helix rotating screen volumetric-swept systems[1,4].

The key technologies of the volumetric display are researched, and the volumetric-swept display system prototype based on such technologies is implemented by Nanjing University of Aeronautics and Astronautics and has got a great progress[5-7].

The prototype of laser-swept 3-D display system based on entire solid state laser implement and the prototype of DMD projection 3-D display system are set up. The shortages of the system above are smaller imaging space, asymmetrical display luminance, lesser slices of 3-D model, existing serious dead zone, and fewer voxels. The system has serious limitations on expressing complex 3-D model. These shortages will be improved by adopting helix rotating screen to construct an imaging space and by adopting passive mode and spatial light modular (SLM) element to activate voxels in the system.

In order to meliorate the inherent defects caused by planar rotational screen, the prototype of helix rotating screen volumetric-swept display system is developed.

The designed system synthesizes the physical model of Felix 3-D system and the structure of Perspecta™ 3-D system. Felix 3-D system uses laser implement to scan a rotating helix screen, and produces light points on surface of helix screen[2]. The system has some disadvantages as that the velocity of the laser scanning implement is slow and the mode of transmitting data stream is in series, resulting in producing only one voxel once projection. The Perspecta™ 3-D system utilizes high speed DLP projector to project 2-D section image sequences of 3-D model onto plane screen, and forms 3-D image display[3]. But the system introduces complex and exact optical relay turning instruments to solve the inherent defects, such as voxel overlap dead zone, caused by planar rotating screen. The prototype design of helix rotating screen 3-D display system is based on the helix rotating screen and the digital micro-mirror device (DMD).

2 IMPROVED VOLUMETRIC-SWEPT DISPLAY SYSTEM

The volumetric display system comprises three major subsystems, i. e., image space creation, voxel generation and voxel activation subsystem, and each of them has a profound impact on the nature and quality of images depicted by the system. The helix 3-D system adopts the image space creation subsystem based on helix rotating screen and the voxel activation subsystem based on DMD.

2.1 Image space creation subsystem based on helix rotating screen

Based on helix rotating screen, the 3-D image space is dispersed by the information angle of rotation of helix rotating screen. The 3-D space turns into a series of discrete 2-D sequences. The discrete code of 3-D space is fulfilled according to the 2-D coordinate of each projection plane[8].

Using helix rotating screen instead of plane screen may meliorates the defects as the smaller image space and severe vision dead zone caused by planar rotational screen in volumetric-swept display system. And it may produce more voxels in helix slices.

The image space may be formed by the rapid motion of a surface. Because aero dynamical resistance and frontal area has a direct proportion relation, it results in the stability of display system weakened and the lower display performance. The directions of the centrifugal force and the gravitation of rotating screen are changeless in helix screen revolving process. Accordingly the increased rate of wind resistance with the larger size of the helix screen is more reduced than that with the larger size of the plane screen. The helix rotating screen adopted to construct 3-D physical imaging space may enlarge the imaging space.

The voxel overlap dead zone is caused by the phenomenon of the border voxels producing overlap partially. Because of the structural character and the formative manner of voxel of the plane screen system, the voxel dead zone cannot be avoided. With the helix structural character, in the imaging space the changing rate of the angle incidence of projective light and the revolving helix surface is smaller than that of projective light and the revolving plane. So it can meliorate voxel overlapping phenomenon caused by the asymmetrical points of projection on the screen surface. And with the formative manner of voxel, in the plane screen sweeping manner, the voxel is a small cube formed by elongating the light pixel alongcircle and the perimeters of inner circles are shorter than those of outer circles, so voxels are inequal on inner circle. Differing from plane screen sweeping manner, in the helix screen sweeping manner, the voxel is formed by the pixel on the slice of helix that moves vertically between two adjacent helix slices along direction of helix axis. So the size of all voxel in helix space may be equal approximatively. This sweep mode may avoid the voxel overlap zone skillfully.

In the voxel generation subsystem, according to the character of the imaging space formed by helix rotating screen, the generation method for helix slices of 3-D model is that the imported 3-D model data is sliced equally to a series of 2-D images. For voxels are points of intersection of the different helicoids and all the triangle meshes on 3-D model, there are more voxels on the helix slices than on the plane slices. The comparisons between algorithms for helix slice and plane slice are shown in Table 1. The generation algorithm results in more calculation time than the plane slices generation algorithm. In the non-real time manner, this may not influence the display capability[9].

Table 1 Comparisons between algorithms for helix slice and plane slice

Model	Slice type	Triangle meshes	Time/ms	Voxel
Secondary planet	Helicoid	1 140	562	9 755
	Plane		56	1 076
Airplane	Helicoid	2 320	921	131 655
	Plane		109	16 675
Automobile	Helicoid	7 322	1 443	324 265
	Plane		204	47 317

It is obvious that using helix screen is good to enlarge imaging space and improve the dead zone of vision. Helix screen makes use of image space adequately. And it can produce more voxels on the helix slice. A high fidelity image may be achieved in this structure theoretically.

2.2 Voxel activation subsystem based on DMD

The voxel activation subsystem represents the pathways through which information passes from the graphics engine into the image space. Voxel activation represents the stimulus used to influence the transition of each voxel from inactive to its active state. The voxel activation capacity of the display system is decided by the maximum number of voxels (N_a) (N_a is limited by the voxel time (T) required to create each voxel.), the number of voxels (P) that can be generated concurrently, and the time available for each image refresh frequency (τ_r). Since τ_r is reciprocal of the image refresh frequency (f_r), the voxel activation capacity may be expressed as[1]

$$N_a = \frac{P}{T f_r} \tag{1}$$

If f_r is the same, and the difference of T between parallel pattern and lineal pattern activation is small, N_a is influenced clearly by the variety of P between parallel and lineal activation.

In the paper, the voxel activation mode is passive, and the SLM element is used to activate the voxel in the system. DMD is one kind of the SLM apparatus whose reaction speed is the fastest. DMD is responsible for loading the 2-D light field information of image, and modulating various light intensions into light-wave and parallel exporting to improve the transmission bandwidth of 3-D data in the voxel activation subsystem, thus activating multi-voxel once time[10]. Fig. 1 is the diagram of voxel activation subsystem based on DMD. The DMD controller adopts TI 0.7 XGA DMD Discovery TM 1100 made by TI Company in America. It is composed of 16 blocks of micro-mirror with the resolution ratio of 1 024 × 48. If system uses one of the 16 blocks only, P is 49 152. P of the lineal activation mode is 1. From Eq. (1), the voxel activation capacity of the display system based on DMD is more predominant than the system based on entire solid state laser.

Fig. 2 is the prototype of helix rotating screen 3-D display system in which image space creation subsystem is based on helix rotating screen and the voxel activation subsystem is based on DMD.

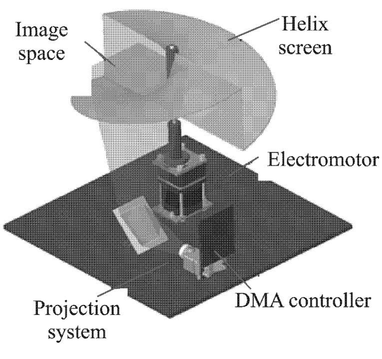

Fig. 1 Voxel activation subsystem based on DMD

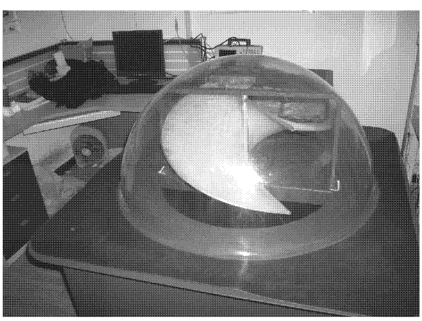

Fig. 2 Prototype of helix rotating screen in 3-D display system

3 EXPERIMENTAL RESULTS

In the voxel activation subsystem, the ordinal sequence 2-D images are projected fleetly and continuously on the corresponding rolling angle of helix screen. The helix screen captures these images and transmits them to retina, thus forming a tridimensional vision of the true 3-D image. Fig. 3 is the display result of airplane model in the helix 3-D system, and Fig. 4 is the display result in the plane screen system.

Fig. 3 Result of 3-D model in helix screen system

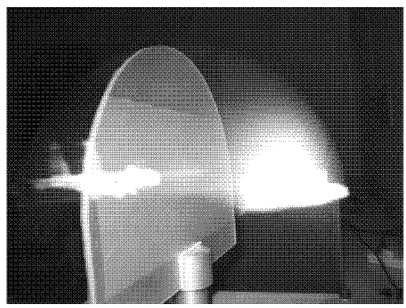

Fig. 4 Result of 3-D model in plane screen system

Compared Fig. 3 with Fig. 4, there is an obvious improvement on the imaging space, uniformity of display brightness and dead zone, especially, on the expressing model of complex information. The helix screen is more superior to plane screen.

4 CONCLUSION

In the paper, synthesizing the physical model of Felix 3-D system and the structure of Perspecta^{TM} 3-D system, a prototype of helix rotating screen volumetric-swept display system is developed. In the system, the key techniques on the image space creation subsystem based on helix rotating screen and the voxel activation subsystem based on DMD are researched. It may meliorate the defects, such as smaller image space, severe vision dead zone and fewer voxels on slice, and improve the voxel activation capacity. And these are validated by the experimental results.

References:

[1] Barry G B, Adam J S. Volumetric three dimensional display systems [M]. New York: Wiley-Interscience Publication, 2000:2-27,50-57.

[2] Langhans K. New portable FELIX 3D display[C]// Proceedings of SPIE. San Jose, California, USA: [s. n.],1998, 3296:204-216.

[3] Favalora G E. Volumetric 3D displays and application infrastructure[J]. IEEE Computer, 2005: 37-44.

[4] Blundell B G, Schwarz A. The classification of volumetric display systems: Characteristics and predictability of the image space[J]. IEEE Transactions on Visualization and Computer Graphics, 2002, 8 (1): 66-75.

[5] Tan Hao. Research on key technologies of volumetric display system[D]. Nanjing: Nanjing University of Aeronautics and Astronautics, 2006. (in Chinese)

[6] Shi Lianjun. Research and implementation of volumetric 3D display system based on DMD[D]. Nanjing: Nanjing University of Aeronautics and Astronautics,2007:38-44. (in Chinese)

[7] Li Li. Research and implementation on key technologies of volumetric display system[D]. Nanjing: Nanjing University of Aeronautics and Astronautics, 2008. (in Chinese)

[8] Geng Z J. Method and apparatus for high resolution three-dimensional display[P]. US, 6064423, 2000.

[9] Yue Jian, Fan Qingjian, Jiao Feng, et al. Construction of helix rotational screen volumetric-swept display system[J]. Journal of Wuhan University of Technology, 2010, 32(16): 72-75. (in Chinese)

[10] Robert E M. DMD pixel mechanics simulation[J]. TI Technical Journals, 1998, 15(3): 64-74.

基于螺旋旋转屏及DMD的体扫描显示系统

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摘要:基于螺旋旋转屏和数字微镜元件(Digital micro-mirror device,DMD)技术,对原体扫描显示系统原型进行了改进。采用螺旋旋转屏构建体扫描显示系统的成像空间,可改善平面旋转屏体扫描系统中存在的成像空间较小、体素数量较少和体素重叠死区严重等缺陷。利用DMD空间光调制技术,在体素激活子系统中提高了三维数据传输的带宽,达到同时激活多个体素的目的。研制了基于螺旋旋转屏和DMD的体扫描显示系统原型。实验结果表明,所设计的系统原型与前期平面旋转屏系统相比,在成像空间、视觉死区、切片上的体素数量及体素激活能力等方面都有所改善。

关键词:真三维显示;体三维显示;体扫描;螺旋旋转屏;数字微镜元件

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