3D Multi-View Autostereoscopic Display and Its Key Technologie

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***Abstract*—multi-view autostereoscopic three-dimensional (3D) display has been one of the most popular research issues in the world. And 3D displays are classified into two types: stereoscopic 3D display and autostereoscopic 3D display. The former includes head mount system, anaglyph system, polarized filter system, field sequential system and so on. The latter is also called true 3D display, it provides 3D perception without the need for special glasses or other head gear. In this paper we research on the multi-view autostereoscopic 3D display. Focusing on the multi-view stereoscopic 3D key technologies, the latest international development trends and existing problems is analyzed. a multi-view stereoscopic display system, related key technologies are detailed, which includes: Light field representation model and light field capturing system, high efficiency multi-view video coding and transmission method compatible with current video standard, high efficiency rendering method for arbitrary position view at the decoder, 3D display technologies and multi-view autostereoscopic display.**

Keywords- Multi-View; Autostereoscopic Display; Three-dimension Display(3D Display); Image Mosaic.

I. INTRODUCTION

The recent convergence of the computer graphics and computer vision disciplines into the image-based domain has generated a paradigm shift both in how 3-D scenes and events are captured, stored, and transmitted; and how viewers interact with these captured scenes. In order to enable navigation, scenes are captured using a multiple camera set-up that may be sparse or dense [1].The realization of 3D displays is a long fostered dream for mankind, because the world is three dimensions. Above 85% information is related the space position and 3D displays are the best presentation of the reality. It is predicted that 3D stereo TVs will follow HDTV and become the trend. If the black and white TV is called as the first generation TV and the color TV is the second generation TV, then the 3D stereo TV will be the third generation one. 3D display is considered one of the greatest technologies in the 21st century.

Usually, when viewing a scene in real life, an observer sees a different image with each eye and this causes the visual perception of depth. Therefore a device presents two images with a little difference for each eye or the device itself display a volumetric image, viewers can see 3D display images. 3D displays are classified into two types: one is called stereoscopic 3D display and the other is called autostereoscopic 3D display. The former includes head mount system, anaglyph system, polarized filter system, field sequential system and so on. The latter is also called true 3D display. It advances along three general approaches: (1) volumetric displays, (2) electronic holography and (3) direction-multiplexed displays[2].

In this paper, we focusing on the multi-view stereoscopic 3D key technologies, the latest international development trends and existing problems are analyzed. Meanwhile a solution for implementing we designed an autostereoscopic multi-view 3D display that has pivot function, in this 3D display several viewers without wearing eyeglass can see 3D stereo images on the prototype of the display.

II. LITERATURE ANALYSIS

Autostereoscopic 3D is realized by the principle that each eye of the user sees the different images from the same display [3-5]. To obtain the better 3D performance such as wide viewing zone and motion parallax, autostereoscopic multi-view 3D had been reported. However, resolution reduction of each viewing zone is inevitable for multi-view 3D.To partially overcome this drawback through the balanced reduction of horizontal and vertical resolution, the use of the slanted optical element has been proposed for the multi-view 3D system[6].

While subpixel structure of RGB stripe is widely used for Flat Panel Displays (FPDs), different subpixel structure are also being used, such as RGBW quad and delta RGB etc. Subpixel structure of RGBW quad is especially effective for the improvement of light efficiency. Mobile Liquid Crystal Display (LCD) and Active Matrix Organic Light Emitting Diode (AMOLED) using RGBW structure had been reported to show improvement of power efficiency [7, 8]. As the increase of white component results in the lower color saturation, many researches have been done to solve this issue of low color saturation [9, 10].

Viewing zone of autostereoscopic 3D is determined by the position of subpixels and the optical element that controls light direction. So, the design considerations for autostereoscopic 3D are accordingly different when the image display of different subpixel structure are used [11].

Rotating the display by 90-degrees, user can choose between the landscape and portrait mode, depending on the image contents. This pivot function can provide the better viewing conditions for the user such as reading Textbook at portrait mode and watching movies at landscape mode. Pivot function has become more popular for LCD application as thinner and lighter LCD is much easier to rotate compared

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with bulky Cathode Ray Tube (CRT) display. Autostereoscopic 2-view 3D display with pivot function wasreported, which uses a mosaic barrier pattern [12].However, this concept using the mosaic barrier structure was designed for 2-view 3D and cannot be directly applied for autostereoscopic multi-view 3D that uses the slanted optical element such as cylindrical lens and parallax barrier.

For typical autostereoscopic multi-view 3D, distance between the viewing zones changes under display rotation of 90-degree.Therefore, users would perceive 3D image of the different depth or cannot perceive 3D image at all when watching the autostereoscopic multi-view 3D under 90-degree rotation. In order to combine the function of the autostereoscopic 3D with pivot function, 3D characteristics such as the zone distance and the luminance distribution of each viewing zone should be designed to satisfy the 3D display requirement at the landscape mode as well as at the portrait mode. Condition of 3D image contents such as disparity between images should be considered as well.

III. 3D DISPLAY

3D display technology had been developed about one hundred and fifty years ago. From 1850 to 1930, Brewster invented stereoscope and succeed in commercial. A stereoscopic named View-Master became more popular product from 1940 to 1950. Then, vectorgraph and earlier relief television had come into humans， life. Now, 3D display technology has been greatly improved and is in a flourish period along with the developing of computer technolog.

A. 3D Display Technology Classification

3D Display technology can be classified into several types shown as Fig.1.

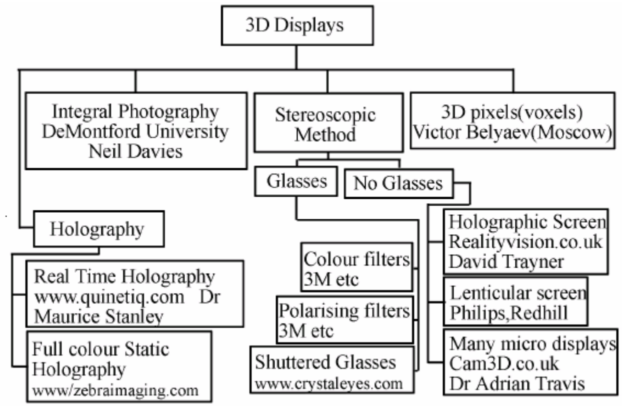

Figure 1. Classification of 3D display technologies

Holographic Display Hologram was invented by Dennis Gabor in 1948. Holographic techniques were first applied to image display by Leith and Upatnieks in 1962. The acquisition of holograms still demands carefully controlled physical processes and cannot be done in real-time. At least for the foreseeable future it is unlikely that holographic systems will be able to acquire, transmit, and display dynamic, natural scenes on large displays.

Volumetric Display Volumetric displays use a medium to fill or scan a three-dimensional space and individually address and illuminate small volexs. Althoughthere are some commercial application system, volumetric systems which can produce transparent images that do not provide a fully convincing three-dimensional experience. Furthermore, they cannot correctly reproduce the light-field of a natural scene because of their limited color reproduction and lack of occlusion. The design of large-size volumetric displays also poses some difficult obstacles.

Parallax Displays Parallax displays emit spatial varying directional light. Much of the early 3D display research focused on improvements to Wheatstone. Earlier developed techniques include parallax stereogram and parallax panoramagrams that provide only horizontal parallax. Another parallax display technique is integral lens sheets which can be put on top of high-resolution LCDs. Integral photographys sacrifice significant spatial resolution in both dimensions to gain full parallax. Multi-projector lenticular display was invented in 1931 to improve the native resolution of display. Other research in parallax displays includes time-multiplexed and tracking-based. Today,s commercial autostereoscopic displays use variations of parallax barriers or lenticular sheets placed on top of LCD or plasma screens. Parallax barrier generally reduce some of the brightness and sharpness of the image.

B. Multi-View Autostereoscopic 3D Display

Comparing with multi-view autostereoscopic 3D display, four cues are missing from 2D media; they are stereo parallax, movement parallax, accommodation and convergence. All 3D display technologies provide at least stereo parallax. Multi-view autostereoscopic provides both binocular and motion parallax for multiple observers, and autostereoscopic displays provide 3D perception without the need for special glassed or other headgear. Three technologies used in autostereoscopic display are spatial multiplex, multi-projector and time-sequential. In spatial multiplex technology, the resolution of a display device is split between the multiple views. Multi-projector technology makes a single projection display which is used for each view. A single fast display device is used for all views if time sequential technology is exploited. Drawing upon above three technologies, developers can make two different types of autostereoscopic displays: a two-view, head-tracked display for single-viewer systems or a multi-view display that supports multiple viewers. Detail description can be found in Ref. Compared to traditional stereoscopic display technology, thin film display technology of multi-view can focus on enhancing the stereoscopic effect in vertical direction.

IV. MULTI-VIEW AUTOSTEREOSCOPIC 3D DISPLAY THEORY

A. Autosterescopic multi-view 3D using subpixel structure of RGB stripe[6]s

In autostereoscopic multi-view 3D, different image has to been by each eye of the user at the different spatial positions and these spatial positions are called the viewing zones. Only partial numbers of total pixels are seen at each viewing zone. And data of the different images are assigned to each group of subpixels corresponding to each viewing zone. View number N is defined as the total numbers of these images or viewing zones. Users see the subpixels of each viewing zone distributed in the area of the image display. While the 3D display size remains the same, pixels numbers for each viewing zone will decrease as the view number increases. As numbers of these 3D subpixels are smaller than total subpixels numbers of the image display, uniform distribution of 3D subpixels in the display area is one of the requirements to observe 3D image of good quality. When optical element such as parallax barrier patterns and cylindrical lens are aligned vertically, only horizontal resolutions of 3D image decreases. Design principle using the slanted optical element has been reported for the purpose of the balanced reduction of horizontal and vertical resolution for autostereoscopic multi-view 3D [6]. The report is focused on subpixel.

Pitch of the optical element and subpixel pitch along the horizontal direction are the key parameters for design of autostereoscopic multi-view 3D.Zone number for each subpixel is determined by the horizontal distance from each subpixel to the edge of each component that composes the optical element. Good 3D image quality can be obtained when subpixels of each 3D viewing zone are located uniformly in the display area. Subpixel spatial distribution is a parameter that is related to this uniformity and defined as the distance between the subpixels of the same zone number. An example of 9-view 3D is illustrated in Fig.2 where ellipses represent the subpixel positions of the same zone number and the distance between subpixels of the same zone number is the subpixel spatial distribution.

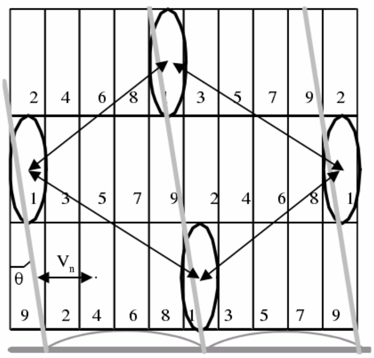

Figure 2. An example of zone configuration of autostereoscopic 9-view 3D with RGB stripe subpixel structure.Thick gray lines represent the edges of lenticular lens and the rectangle represents each subpixel.Distance between center of subpixel and the edge of lens determines zone number of each subpixel.Numbers 1-9 in each subpixel represent zone numbers corresponding to each viewing zone.Distance between subpixels of the same zone number is defined as the subpixel spatial distribution[6].

Fig.3 illustrates the reported subpixel spatial distribution for different view number N when the image display has the RGB stripe structure and the slanted optical element of arctan (1/6) degree is used [6]. Subpixel spatial distribution of view number N fluctuates between N and Root N. When spatial distributions are located near the curve of Root N, subpixels of each viewing zone are distributed uniformly and good 3D quality is expected accordingly. When subpixel spatial distributions of view number N are placed around line of N, non-uniform distribution of subpixels for each viewing zone occurs and color lines or black lines tend to be noticeable. In the reported case, good 3D image quality is expected for N=4 and 9 as spatial distribution approaches the curve of Root N. Other view number is not preferred because subpixel spatial distributions are far from the curve of Root N.

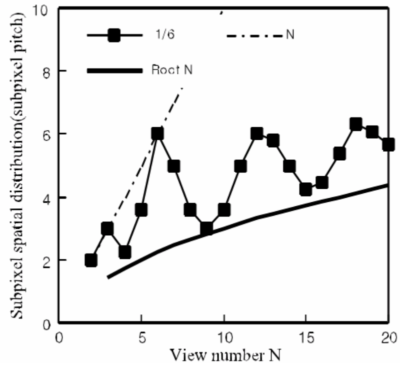

Figure 3. Subpixel spatial distribution of multi-view 3D for the view number for the case of RGB stripe subpixel structure and the optical element of the slanted angle of arctan(1/6).N represents the view number[4].

B. *Subpixel structure of RGBW quad*

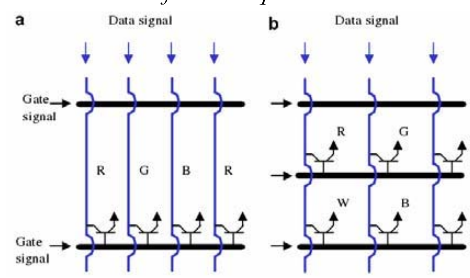

Figure 4. Subpixel structure of(a)RGB stripe and(b)RGBW square.R,G,B and W represent subpixels of Red,Green,Blue and White.Horizontal and vertical lines represent the gate bus lines and the data bus lines,respectively.

Most of full color LCD uses pixel structure where each pixel consists of subpixels of three primary colors.Fig.4 (a) illustrates this subpixel structure of RGB stripe where Red, Green and Blue subpixels are aligned as the vertical stripe. When Color Filter (CF)is used to make full color display, only 1/3 of incident light pass through CF layer. Addition of white subpixel W has been considered for the purpose of improvement of the light efficiency because light through white subpixel is not absorbed by CF layer. RGBW subpixel structure of square shape is illustrated in Fig.4 (b).Pixels are repeated along the horizontal direction and vertical direction. Gate signal through horizontal gate bus line controls the on/off switching of Thin Film Transistor (TFT) and data signal is supplied to each subpixel through vertical data bus line. In case of RGB stripe structure, one horizontal gate line and three vertical data lines control the signals for three subpixels inside each pixel. On the other hand, in case of RGBW quad structure, two horizontal gate line and two vertical data lines control the signals for four subpixels inside each pixel. Data for R, G, B subpixels are provided from the image source. Data for W subpixel had to be determined from the luminance data of R, G, B and the various conversion schemes had been reported to improve the color characteristics of RGBW structure [9, 10].

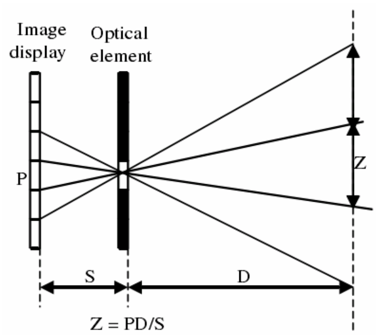

Figure 5. Relations between the zone distance Z and subpixel pitch P when nonslanted optical element is used.S represents the distance from the image display to the optical element.D represents the distance from the user to the optical element. Zone distance Z is proportional to subpixel pitch P.

We applied the slanted optical element to the image display that uses the subpixel structure of RGBW square and tried to find the optimum conditions for the good 3D image quality in consideration of RGBW structure[11].Due to translation symmetry of two subpixel pitch, subpixel group corresponding to each viewing zone does not include R, G, B, W subpixels simultaneously when view number N is even number. Full color 3D is possible only for conditions of odd view numbers for RGBW structure. Specifications of the prototype are summarized in Table 1.

3D of narrow zone distance provides smooth motion parallax and is suitable for the personal use.3D of wide zone distance is more effective for the multiple viewers. Just by using the display having 3D pivot function, a single 3D display can satisfy these two requirements.

TABLE I. SPECIFICATION OF AUTOSTEREOSCOPIC 6-VIEW 3D

2D	Image display	LCD
	Subpixel size	148.5 lm by 148.5 lm
	Diagnoal size	14-in
	Pixel numbers	1400 by 1050
	Subpixel structure	RGBW quad
3D	View number	6
	Optical element	Slanted parallax barrier in front of LCD
	Slanted angle	arctant(1/2)
	Viewing distance	38 mm
	Pivot function	YES

Experiment was performed using the parallax barrier as the optical element because it is relatively easy to fabricate the parallax barrier pattern, exactly controlling the pitch within the error range of 0.1 lm by photolithographic process.

V. AN AUTOSTEREOSCOPIC MULTI-VIEW 3D DISPLAY

We propose a solution for implementing a multi-view autostereoscopic display. Figure 5 shows a schematic representation of it.

However, the result can be applied to the 3D system where cylindrical lens array is used as the optical element, as well.

VI. CONCLUSIONS

In this paper, we outline recent trends in the key technologies to implement a 3D multi-view stereoscopic display. In end we designed autostereoscopic multi-view 3D using the LCD of RGBW square subpixel structure as the image display. In this 3D display several viewers without wearing eyeglass can see 3D stereo images on the prototype of the display.

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