ABSTRACT:

The illusion of 3D is the result of our human binocular vision, where each eye sees a slightly different view. This is done in the real world by our eyes being slightly apart so that each eye has its own slightly different view. The brain processes these two images into one image which has the quality of depth. Glasses-based 3D systems produce a 3D effect by offering two views simultaneously, with each view captured or digitally created to show a slightly different angle or perspective. The glasses use either polarization or a shutter to transfer only one view to each eye. The brain processes these images just as it would in real life, combing the two views to give the illusion of depth.

Auto-stereoscopic refers to a screen where the image is generated so that viewing can be achieved without special glasses. Multi view stereoscopy basically refers to displaying of different images to each eye, to imitate the natural phenomenon of stereo parallax.

The Technology used by most 3DTV Manufacturers: is based on Glasses based active switching technology, where an image is displayed for left and right eye, and users are required to wear active shutter glasses to see the 3D content.

The technology used by most Glasses-free 3DTV manufacturers: is based on “Space Sequencing”. In order to have multiple-views (perspectives), the “space sequencing” approach requires hyper-resolution (a very high number of pixels) and intensive processing power to drive them. This technology does not exist and is very costly indeed.

The technology suggested is based on “Time Sequencing” .In order to have multiple-views (perspectives), the “Time Sequencing” approach requires normal HD resolution and simple processing power. This technology is readily available and very cost effective when mass produced. There are two possible configurations: 1) “DLP back projection” based 3D monitor and 2) “Flat Panel” based.

Switchable 3D displays- can switch between 2D and 3D modes. These displays will find immense scope in mobile display technologies.

3D imaging would find extensive application in two particular places: visualization of complex scientific and medical structures; and remote manipulation in robotics.

CONTENTS

LIST OF FIGURES

ABBREVIATIONS:

1.	2D	Two Dimensional.
2.	3D	Three Dimensional.
3.	Bwx	Bandwidth Of The According Data Stream.
4.	CRT	Cathode Ray Tube.
5.	HD	High Definition.
6.	HPO	Horizontal Parallax Only.
7.	TSD	Time Sequential Display.
8.	VGA	Video Graphics Array.

Chapter 1

INTRODUCTION

Figure 1. Stereoscopic imaging.

This is some workmates watching the 2009 Super Bowl in 3D. They all need a pair of glasses. The glasses mean that watching 3D is something you do for a special occasion, It is not for watching the news, or a soap opera, or anything where you want to do something else at the same time as you watch. If 3D is to be something for more than a special occasion, then we need to do without the glasses.

Etymology :- **Autostereoscopy = auto + stereoscopy**

- Auto = self (greek).
- Stereoscopy = simultaneous vision using both eyes that produces a visual perception of objects located in space.

Autostereoscopy = 3d without glasses

Autostereoscopy is any method of displaying stereoscopic images without the use of specialized headgear or glasses on the part of the viewer. The technology maybe sub classified into two broader technologies based on the type of method used-

- Eye tracking displays.
- Multiple view displays.

Chapter 2

Stereo perception in the real world

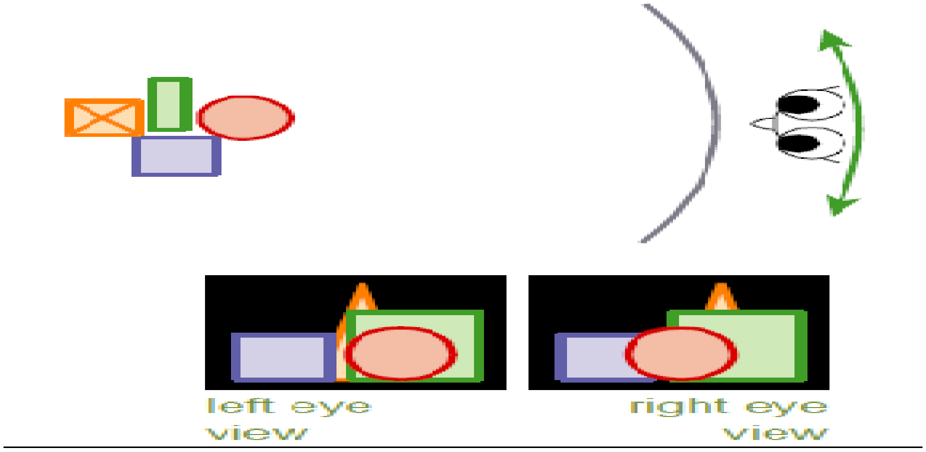


Figure 2. Stereo perception

3d viewing comprises of two basic phenomenons-

- ∢stereo parallax- each eye sees a different image of the world
- ∢movement parallax- different images are seen when the head is moved there are an infinite number of different images

To attain these phenomenon, a thought experiment is conducted. This is how we see in the real world. Each eye sees a different image of the world, so we get stereo parallax. And we can move our heads freely, so there are an infinite number of images that each eye could see and the two eyes always see just the right images to get stereopsis.

Chapter 3

A thought experiment

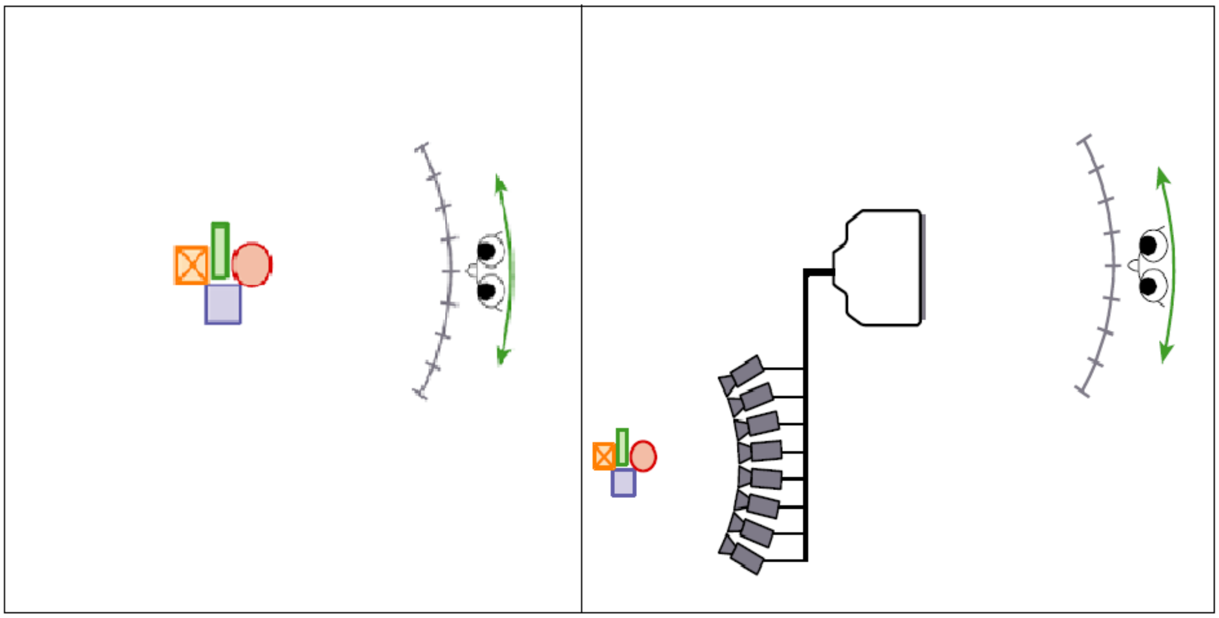


Figure 3. A thought experiment.

The thought experiment [2] is to divide that continuous viewing zone into a *finite* number of *windows.* In each window, a single image is visible across the whole window. No matter where the eye is in the window, it sees exactly the same image. As the eye moves from one window to the next, the image changes: there is a little jump from one image to the next. If we make the windows small enough, then each eye will still see a different image: stereo parallax.

And we still see different images when the head is moved: movement parallax. So we now have stereopsis with a finite number of distinct images. And multiple people can look at the scene from their own points of view, each getting stereo from their own point of view.

Hence, to make a multi view autostereoscopic display, we must make a device which displays a different image in each window to replicate-stereo parallax & movement parallax. This forms the basis of the multi-view technology that is discussed in detail in this report.

Chapter 4

Autostereoscopic displays- possible technologies

1. Multiple projectors
2. Lenticular lenslets
3. Parallax barriers
4. Fourier-plane shuttering
5. Retro-reflective mirrors
6. Half-silvered mirrors

There are many ways to make an autostereoscopic display. All it needs to do is display a different picture to each eye, and there are a range of optical devices that can achieve that. The first four in the list shall be discussed in this report, which are the three most common methods and the method which was used in the 1990s (Fourier-plane shuttering).

So it is possible to implement these displays, but there are fundamental limitations that mean it will be difficult for autostereoscopic technology to find its way into the home which shall be discussed later.

Chapter 5

Multi-projector display

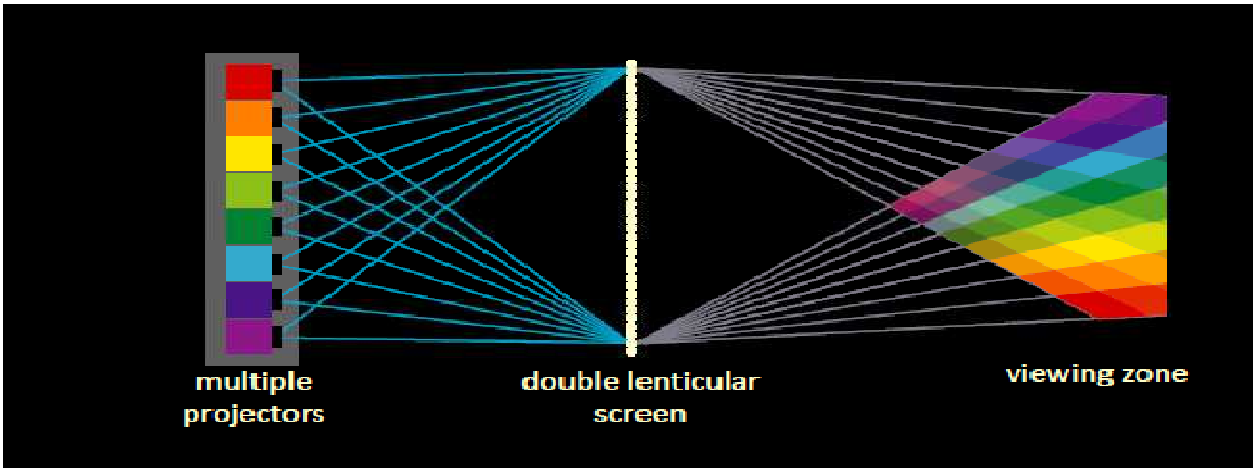


Figure 5. Multi-projector displays

The simplest multi-view display to explain is the multi-projector display[6]. We take one projector per view and arrange them horizontally. Each projector images onto a double lenticular screen. That screen is the surface on which the viewer sees the image. The double lenticular screen focuses light back down into a little area in the viewing zone. If your eye is in the right place, it will see an image from exactly one projector. Later on in this report, the shape of the viewing zone, and what a viewer sees from each point within it will be discussed. Experimental multi-projector displays have been made with up to 128 views. That requires 128 projectors, which is expensive. Mounting and aligning those projectors is a time-consuming job. There have been attempts to commercialize this technology, with a smaller number of projectors, but there are no commercially-available multi-projector systems. At the optimal distance the viewing zone comprises abutting windows, in each of which only one view is visible. If we used a large lens, rather than a double lenticular sheet, each of the projectors' lenses would image to a circular region in space. That would mean that the eyes would have very limited positions in which they could see stereoscopically. We need to add a little bit of horizontal diffusion to make those stripes, so as to provide a continuous viewing space in which the eyes can move freely and view stereoscopically.

Chapter 6

Spatial multiplex

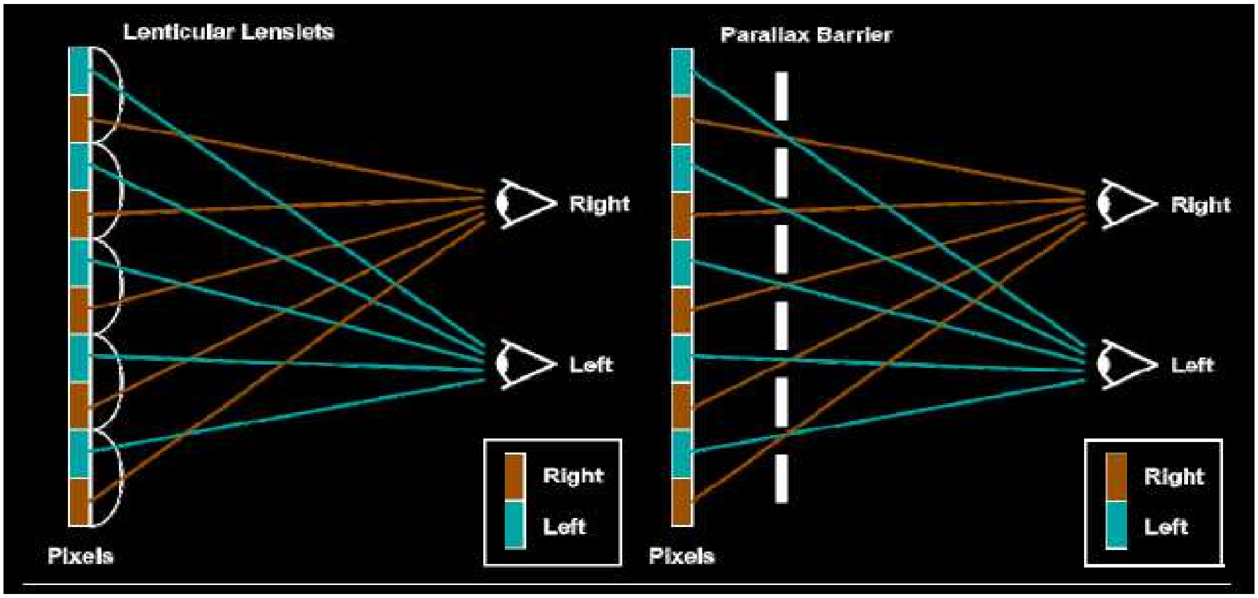


Figure6. Spatial multiplexing

The most common way to make 3D displays is to use either a lenticular lenslet array or a parallax barrier array. These optically divided the columns of pixels into two or more sets, each visible from particular directions. These divide the horizontal resolution of the display into two or more sets of pixels, each set visible in a particular window [5].

conventional: vertical barriers/lenslets, up to four views.
commercial: slanted barriers/lenslets, up to nine views.

Chapter 7

Lenticular lenselets and parallax barriers

7.1 Parallax barriers

A parallax stereogram [2] displays a stereoscopic image pair by interleaving columns of the two images on the film, one column of each image per slit. An appropriately-positioned viewer will see the right view of the pair through the slits with the right eye, the left view with the left. A stereoscopic image is thus produced.

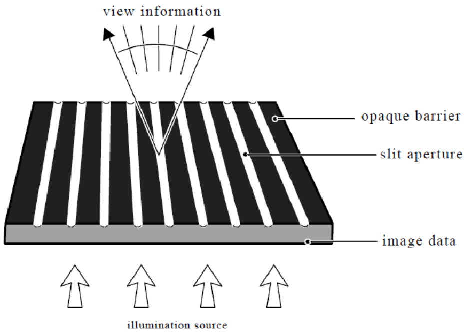
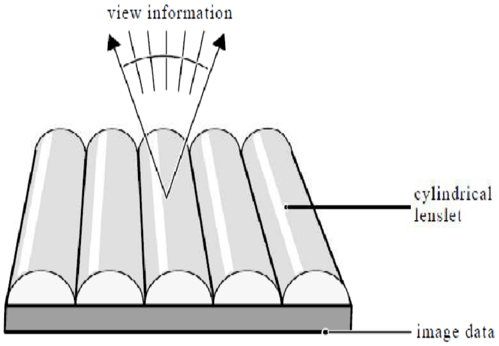


Figure7.1. Parallax panoramagram.

The parallax panoramagram extends this concept by introducing thinner columns of more views behind each slit. Parallax panoramagrams are limited because the barrier, while necessary to block the unwanted views, also blocks light from getting to the viewer. Displays of this type rely on the fact that spatial and directional information is spatially multiplexed onto the film, which leads to several other problems. First, a viewer positioned far enough to the left or right of the display will be able to look through one slit to see the image data associated with the slit's neighbour. As a result, the image appears to repeat its perspectives as the viewer moves. Second, the resolution of the film limits the maximum number of views that can be displayed. The spacing of the slits determines the maximum spatial resolution of the display.

The parallax panoramagram is three-dimensional only in the horizontal direction; vertically, the image of the display behaves just as if it were a flat photograph. As a viewer moves closer or further from the display, vertical edges of the image will appear to shift naturally with respect to each other, just as they would in a real object. Horizontal edges, though, remain fixed relative to each other. This kind of display is said to be horizontal parallax only, or HPO.



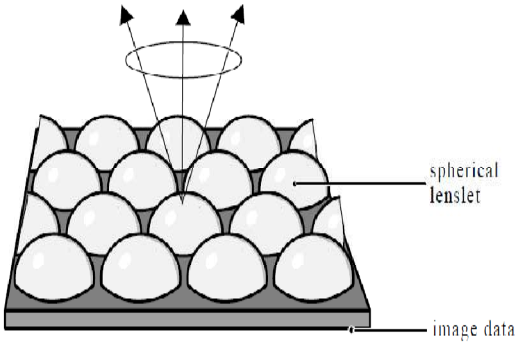


Figure7.2. lenticular panoramagram.

Figure 7.3. Integram.

7.2 Lenticular sheet displays

The word “lenticule” is a synonym for “lens”, but the term “lenticular” has come to refer to a type of three-dimensional display that using an array long, narrow lenses instead of slits to display three-dimensional information. Figure depicts a lenticular panoramagram. This display type is functionally very similar to the parallax panoramagram. Each lens focuses on the image information located behind it and directs the light in different directions. A lenticular panoramagram is brighter and optically more efficient than the corresponding parallax panoramagram. The entire surface of the lenticular sheet radiates light; there are no dark stripes such as those produced by a parallax barrier. Making high quality yet affordable lenticular sheets is one of the major difficulties of creating lenticular sheet displays. Lenticular panoramagrams can also be used with a CRT or other two-dimensional display device to produce a dynamic three dimensional image. The spatial resolution of the two-dimensional display must be high enough in the horizontal direction to provide both spatial and directional information. Optical alignment of the underlying display with the lens sheet is essential to producing distortion- free three-dimensional image. Like parallax panoramagrams, lenticular panoramagrams display only horizontal parallax.

7.3 Integram

Another display type, the integral photograph or integram [2], uses spherical lenses instead of cylindricalones to present horizontally and vertically varying directional information, thus producing a full parallax image. Figure shows the integram’s spherical lens array. Integrams are less common than their cylindrical lensed counterparts mostly because even more of their spatial resolution is sacrificed to directional information.

Chapter 8

Problems with spatial multiplexing

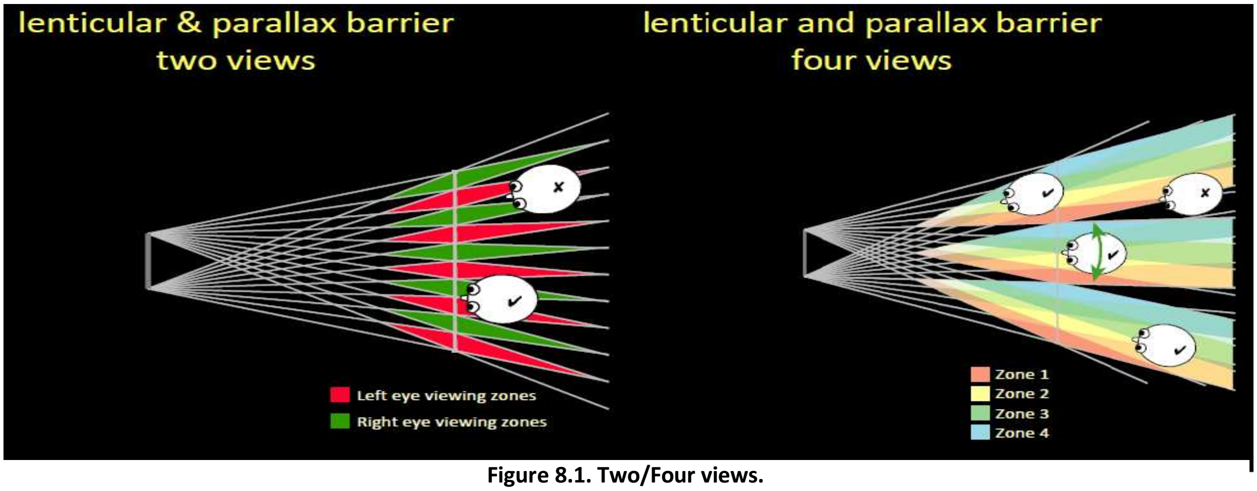


Figure 8.1. Two/Four views.

For two-view displays, we get these diamond-shaped zones in space, in each of which either the left or right image is visible. The nature of the optics means that a parallax barrier or lenticular display has multiple zones, alternating left, right.

So long as the viewer has her left eye in a left zone and her right eye in a right zone, she will see stereo (lower head). Unfortunately there is a 50% chance that the viewer's head will be in the wrong place (upper head): seeing the left image with the right eye and vice-versa. This gives a *pseudoscopic image*: inverted stereo. We can make the lenticular lenses wider.

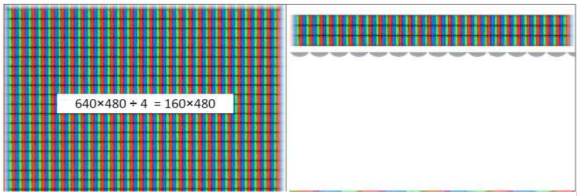


Figure 8.2. limitations of panoramagrams.

In the early 1990s, four views was thought to be the best you could do with lenticular or parallax barrier technology. That was because the lenticular lenslets were vertical, so they split only the horizontal resolution of the underlying pixel array. So a 1990s VGA display (640x480) became a 3D display with ridiculously low horizontal resolution. Another problem was the fact that those lenslets magnified the sub-pixel structure out to the viewing zone.

Chapter 9

Slanted lens

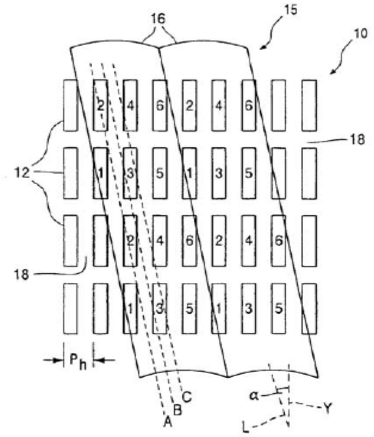


Figure 9. Slanted lenselets.

This all changed in the mid 1990s, when Cees van Berkel [6], at Philips research lab in the UK, discovered that slanting the lenticular array solved both problems. The slanted configuration meant that both horizontal and vertical resolutions are divided amongst the multiple horizontally-spaced views. We thus get a reasonable resolution in both dimensions In all views. The slanted lenslets also smear out the dark bands so that they are no longer visible.

Philips commercialized a 7-view display based on this idea. It was discontinued a couple of years ago, just before 3D movies really took off. They are considering re-introducing a product.

Stereographics produced a 9-view version. They avoided leasing Philips' patent by citing a much earlier patent that did much the same thing, demonstrating the well-known fact that some good ideas get invented before their time, get forgotten, and then get re-invented.

Chapter 10

“The Cambridge display”

Adrian Travis’ Fourier-plane shuttering

The following discussion is dedicated to the Cambridge display [3]. This is done because this display is the basis of our analysis of multi-view displays and, while that analysis applies to all types of multi-view display, it is easiest to understand in terms of this display.

Figure 10. Cambridge display.

These are the original research prototypes: 10” colour display at left, 25” monochrome display at right. They have between 6 and 16 views, depending on the version. The image on the left hand screen is of John Moore, the genius engineer who did the detailed electronic design and built the displays. He is taking the photograph that you see, himself being videoed by the multi-view camera array (top centre) and imaged onto the screen, in multi-view 3D, in real time.

And then developed further, to produce a 50” 3DTV, that produced a beautifully clear 50” diagonal stereoscopic image viewable under normal lighting conditions.

Chapter 11

TIME SEQUENTIAL DISPLAYS

11.1 Theoretical implementation:

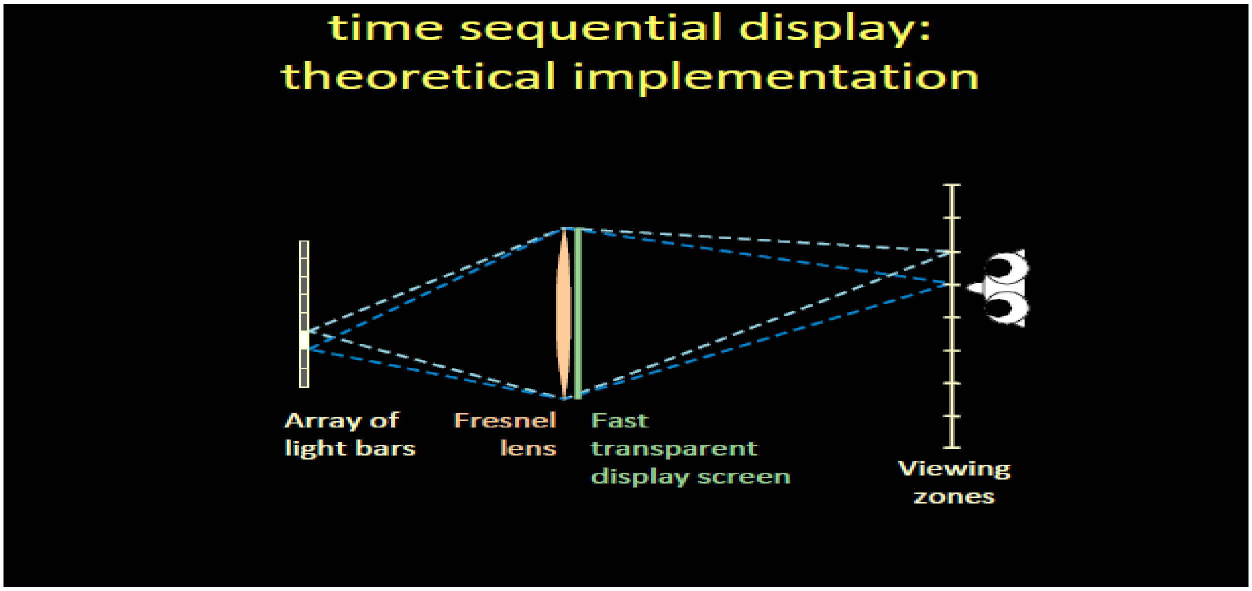


Figure 11.1. TSD - theoritical implementation.

Adrian Travis'[3] original concept is elegant. You display the multiple images sequentially on a fast transparent display screen. For 8 views, you need a refresh rate of at least 480Hz. Behind the screen is a lens. Some distance behind that is a set of vertical light bars. You turn one bar on. It illuminates the whole screen but the lens means that illumination is only visible in a certain zone in space. In our example, the viewer's right eye sees the image on the screen while the viewer's left eye sees a black screen.

Synchronizing the display with the changing of the light bar causes a different image to be visible in each zone, so each eye sees a different image and different images are visible when the head is moved. The display does not need to know where the viewer's head is, so long as the viewer's two eyes are in illuminated zones. Multiple viewers can look at the display, each seeing stereoscopic 3D from their own correct point of view. Unfortunately, there is no technology that can produce a fast transparent display screen that can refresh at the required rate. Adrian thus shelved his idea for a couple of years.

11.2 Practical implementation:

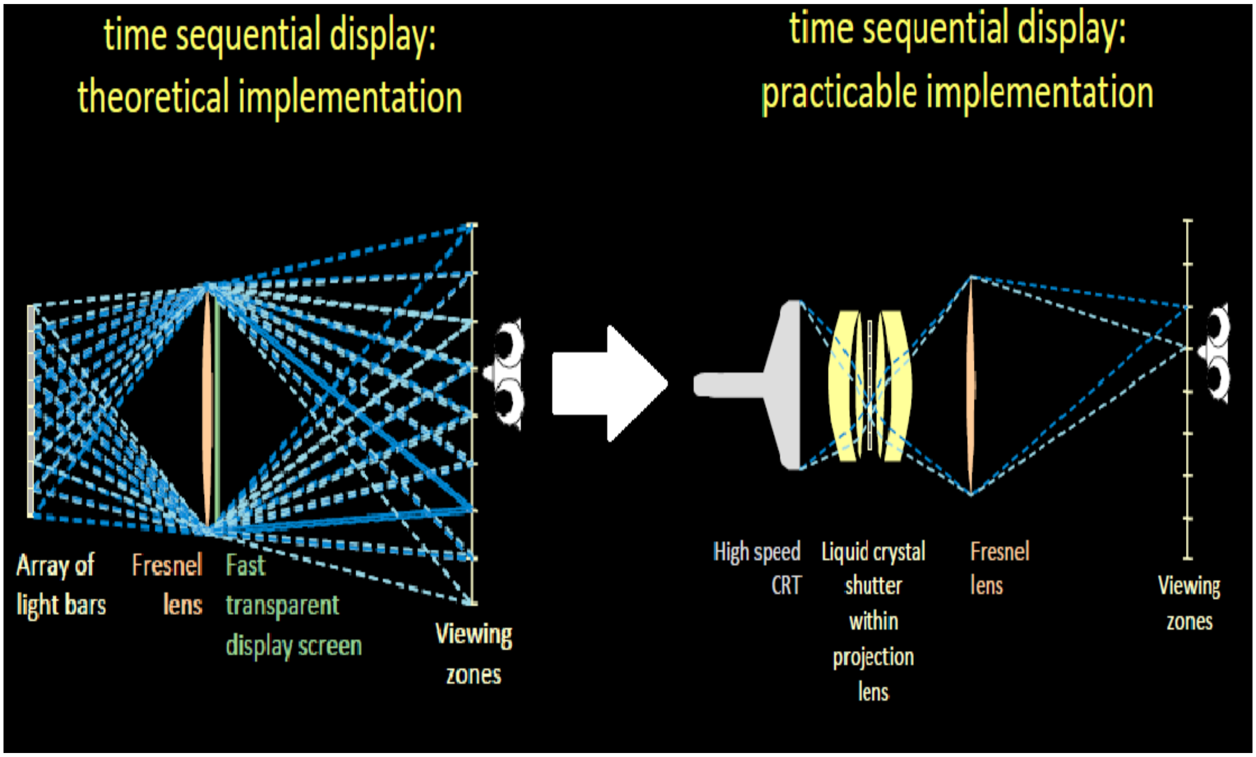


Figure 11.2. TSD - practical implementation.

But he then realized that he could build an equivalent system using a CRT. CRT refresh rates can be over 1kHz, so they are fast enough. The CRT image is projected onto the Fresnel lens. In the Fourier plane of the projection lens we put a set of shutters. At any given time, one shutter is transparent and the rest opaque. This gives an effect equivalent to the theoretical design. Today one would use a projector rather than a CRT.

Chapter 12

Optimal number of views

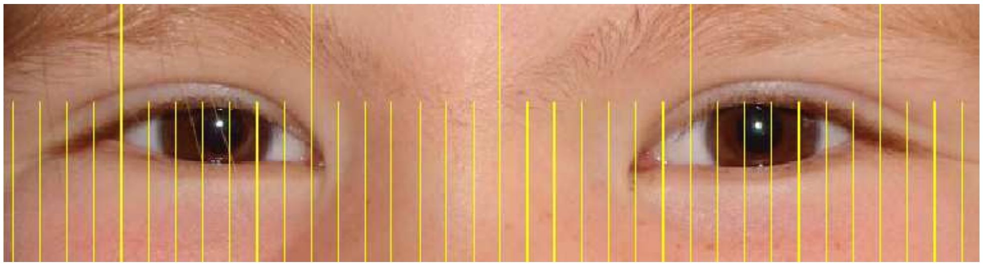


Figure 12.1. width of pupil.

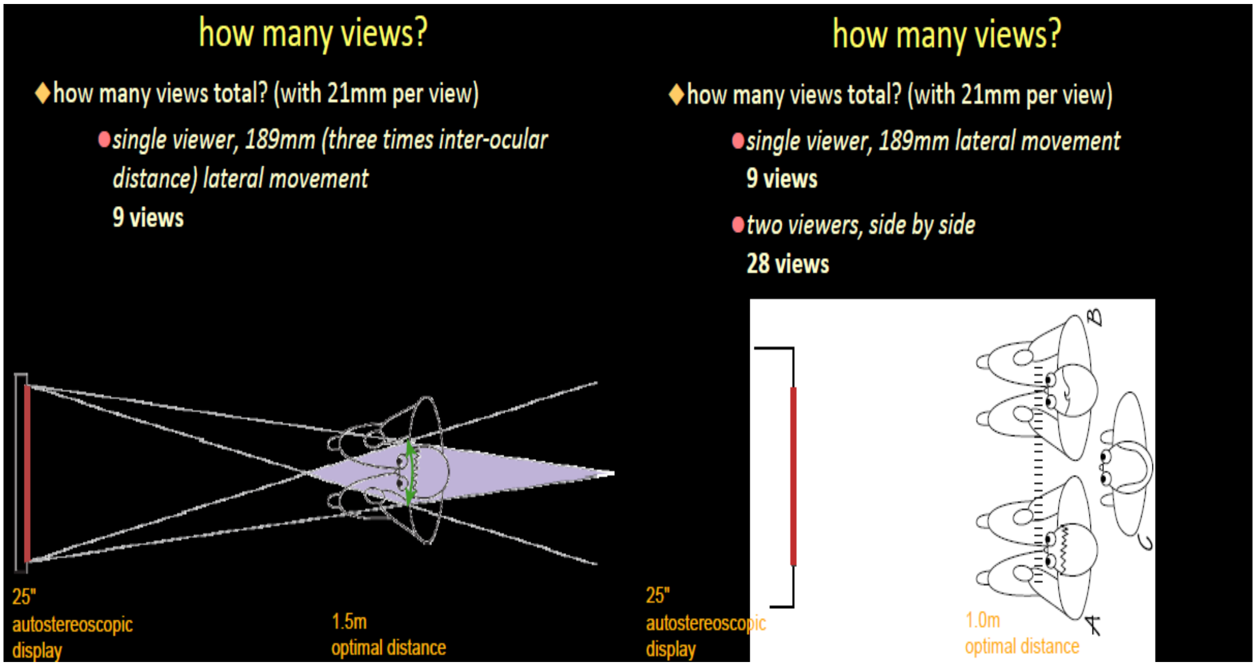
Optimally each viewing zone must be no wider than the entry pupil of the eye. That makes each view only 3mm wide, giving 20 views between the eyes (lower set of bars). Of course, you need views outside the two eyes, so that you permit some head movement. This means that you need a display with at least 30 views, and probably more like 60 views. This is not practical with current technology.

However, if we go to the other extreme and have just one view between eyes, that is, each viewing zone being 63 mm wide, then we have a different problem. While each eye does see a different view, we get a dramatic change in view as we move from one zone to the next. Our experience is that this jump is so dramatic as to be disturbing to the viewer.

Also, the viewer does not get much movement parallax effect when they move their head. Instead they strongly feel as if they are jumping from one view-point to the next.

As a compromise, it was found 21mm per view to be good (upper set of bars). This is three views between the eyes. The differences between adjacent views are sufficiently small that they are not disturbing as you move from zone to zone, and the views are close enough together that you get a fairly smooth effect as you move your head. Indeed, the combination of the two effects leads me to think that the quality of the effect improves quadratically with the number of views between the eyes.

If we assume 21mm wide views, for a single viewer, we should allow some lateral movement. It is not clear how much should be allowed, but about three times inter-pupillary distance seems to be reasonable. This gives good space for head movement for a seated viewer. That calculates to nine views, which matches nicely with the seven and nine views produced by Philips and Stereographics lenticular displays. We appear to have agreement from three different sources that this number of views is some sort of optimum trade-off.



how many views?

- how many views total? (with 21mm per view)
  - *single viewer, 189mm (three times inter-ocular distance) lateral movement*
    9 views

how many views?

- how many views total? (with 21mm per view)
  - *single viewer, 189mm lateral movement*
    9 views
  - *two viewers, side by side*
    28 views

Figure 12.2. Optimal no. of views.

If we want two viewers to sit side-by-side, as was the case for the 1997 25” display, where we needed about 28 views. That gives each viewer some head movement without banging shoulders with their colleague. It leaves a lot of unused views in the middle, but those can provide stereoscopic viewing to a third person standing behind the other two.

The fact that the third person is not at the optimal distance leads us to ask what is visible on the screen to viewers who are at distances other than the optimal. This is also important for home use where viewers are unlikely to sit at exactly the optimum.

Chapter 13

Analysis of optimal density

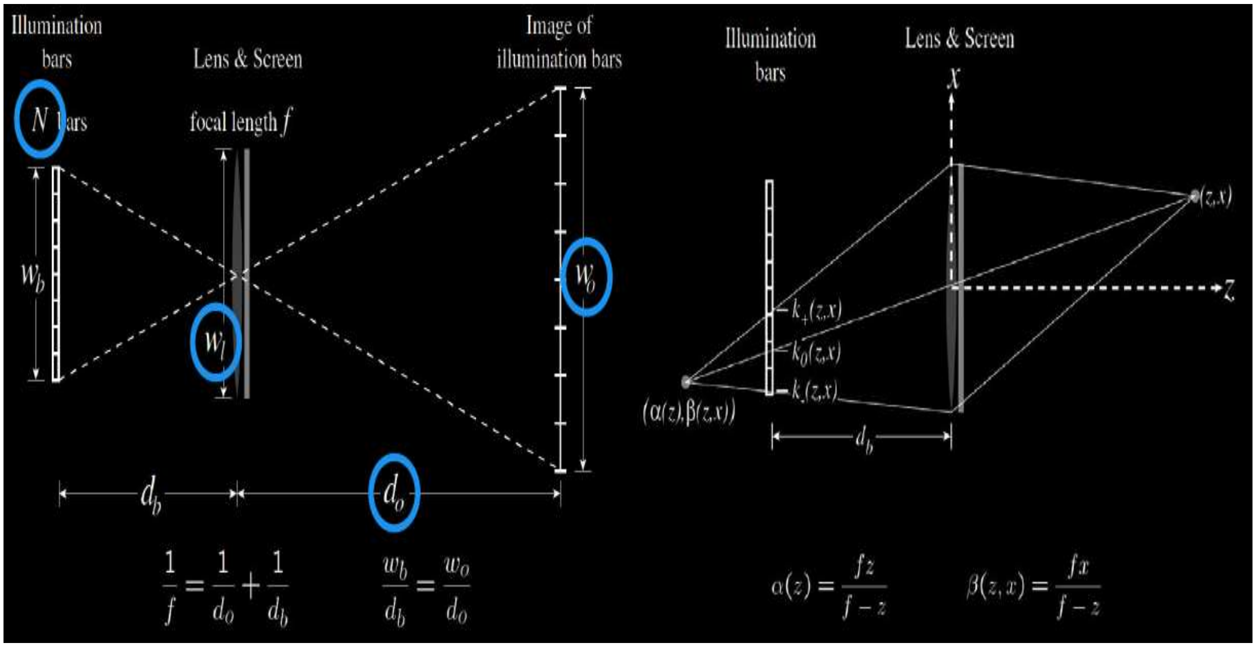


Figure 13. Cambridge theoretical display design.

This analysis[3] generalizes to all types of multi-view auto stereoscopic display and is employed to determine optimal viewing distance and optimal view density.

It turns out that only four parameters determine the characteristics of a display, as seen by the observers. The parameters are:

The width of the screen, *wl;*

The optimal viewing distance, *do;*

The width of the overall viewing zone at the optimal distance, *wo &*

The number of viewing zones within that overall width, *N.*

We can calculate which illumination bars illuminate which parts of the screen for an arbitrary position in front of the display. This allows us to work out what the viewer sees from anywhere in front of the display.

Chapter 14

Different areas in space are illuminated by different sets of views

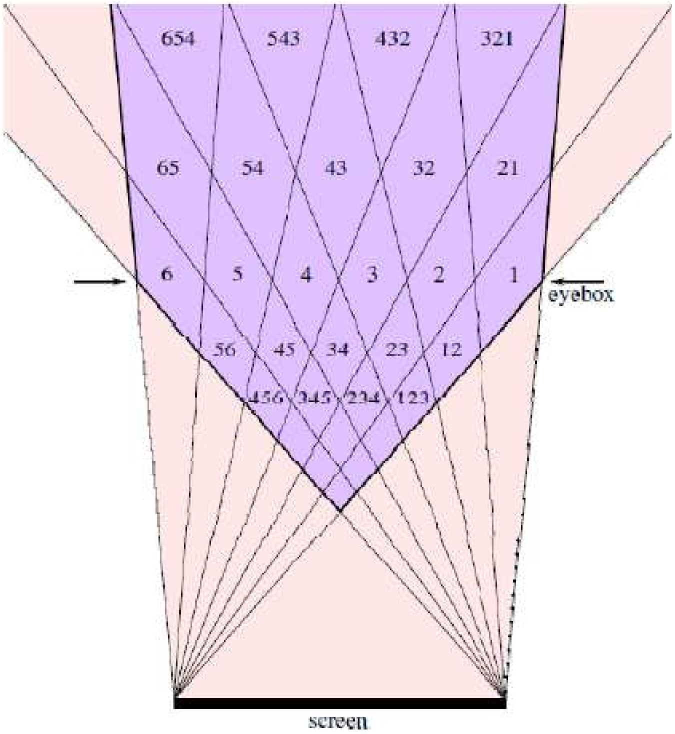


Figure 14. different sets of views.

It transpires that, at the optimal distance (the “eyebox”), an eye sees the whole screen showing exactly one view. Forward or backward from the optimal distance the image is made up of parts of various views, with increasing numbers of views contributing as we get farther from the optimal distance For a small screen (10”, 8 views), we get a viewing zone that allows multiple people to stand one behind the other to see stereoscopically. This is typical professional use of a display: single operator with occasional collaborative work.

If the screen is enlarged but not the number of views (25”, 7 views) then the viewing zone becomes a diamond. This is essentially a single-viewer system as it would be hard for a second person to have their head in a position where they can see stereoscopically without having the first viewer’s head in their way.

Chapter 15

Comparison of various displays

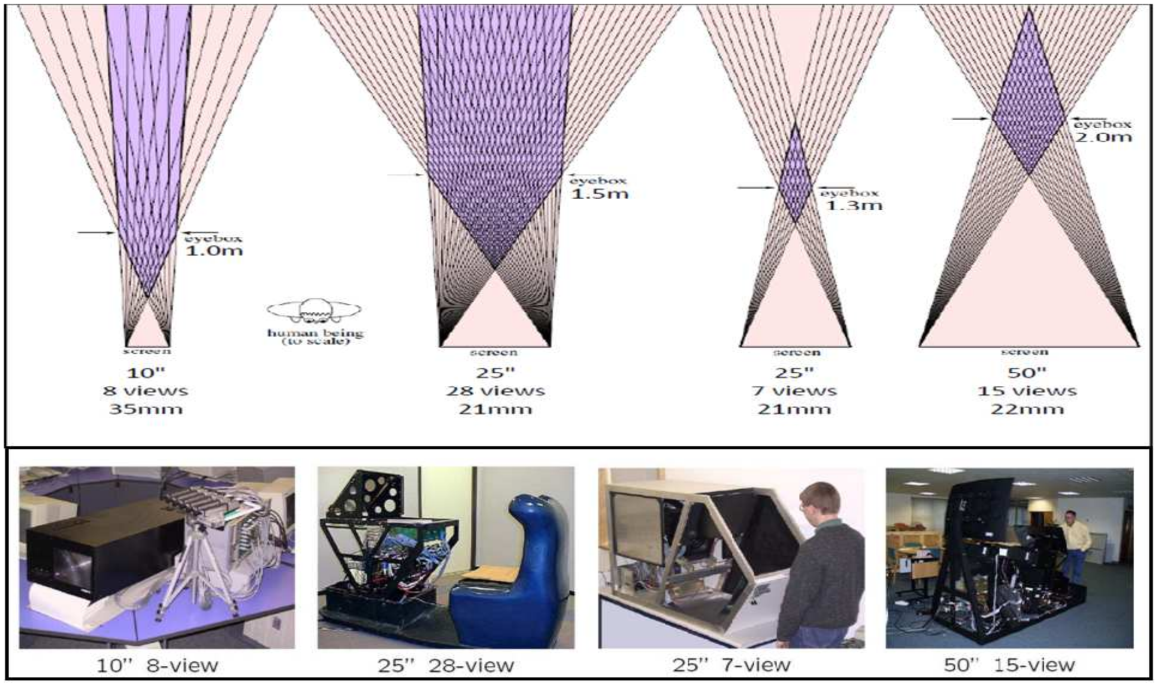


Figure 15. Comparison of multi-view displays.

If the number of views (25”, 28 views) are enlarged then things improve enormously. We can now have several people all seeing stereoscopically. It is obvious that increasing the number of views increases the size of the viewing zone. This analysis shows that increasing the screen size can quite dramatically reduce the size of the viewing zone. each image of the screen shows which illumination bars illuminate which parts of the screen for an eye at the centre of the rectangle screen images are 64mm apart horizontally. These charts are useful in understanding what the viewers saw on the screen. At the optimal distance, an eye sees exactly one view. As we move forward or back from that distance, you can see that the image on the screen is made up of stripes taken from the correct portions of different views.

Shown above are four Cambridge displays[3]: they have different sizes (10”, 25”, 25”, 50”), and different numbers of views (7, 8, 15, 28).

Chapter 16

A PROPOSED INFRASTRUCTURE SUPPORTING THE CAPTURE OF MULTI-VIEW CONTENT

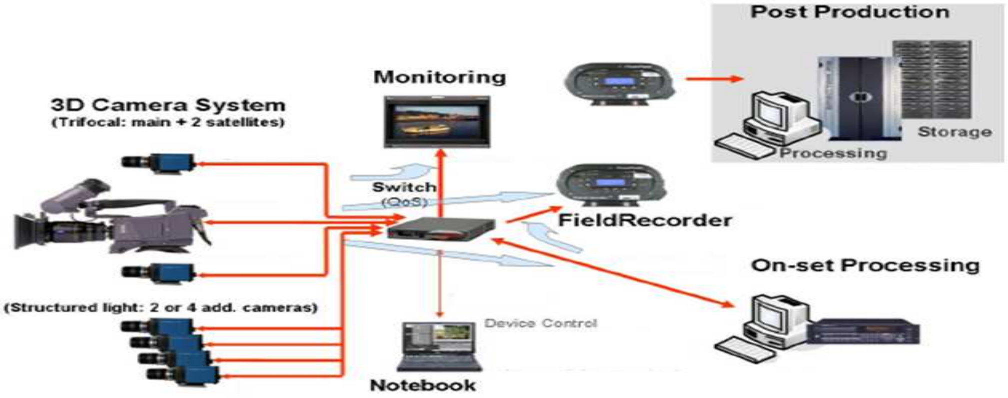


Figure 16.1. INFRASTRUCTURE FOR CAPTURE OF MULTI-VIEW CONTENT.

Today, stereoscopic image capture and play-out produces depth impressions for the spectator. Disadvantageous of the stereoscopic approach is that play-out for multi-view devices is not addressed natively. Multi-view content can be created by means of a depth map of the captured scene. To gain high confidence depth maps, the 'trifocal' capture method is combined with a 'structured light' approach[4].

16.1 Trifocal Capture for Triangulation Processing

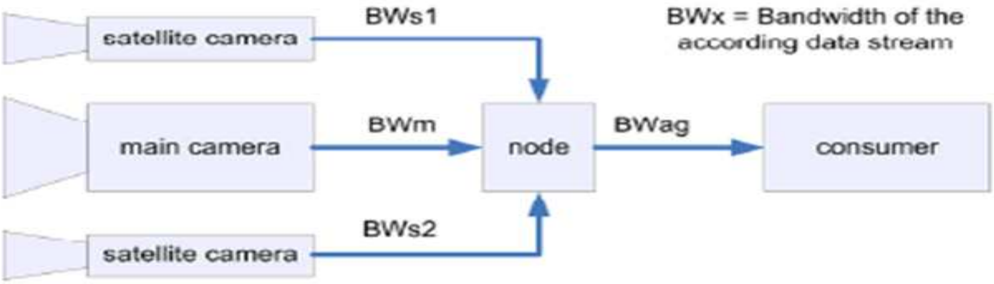


Figure 16.2. Trifocal capture.

A trifocal system based on three cameras with common resolution is used to capture three synchronized video streams . A post processing step performs a two-fold triangulation analysis based on the three captured video streams following by a consistency check between the two analysis results. The output is a depth map accompanying the video of the central camera featuring the same resolution, with frame speed of 25 or 30 frames per second (fps) respectively. The data flow and annotated bandwidths of the current demonstrator setup is depicted in above Figure. The setup[4] contains one high end center camera as well as in addition two lower quality satellite cameras employing Bayer-patterns and 8 bit resolution. All three cameras feature HD resolution. The triangulation post processing takes place at the 'consumer's side.

16.2 Structured Light Capture

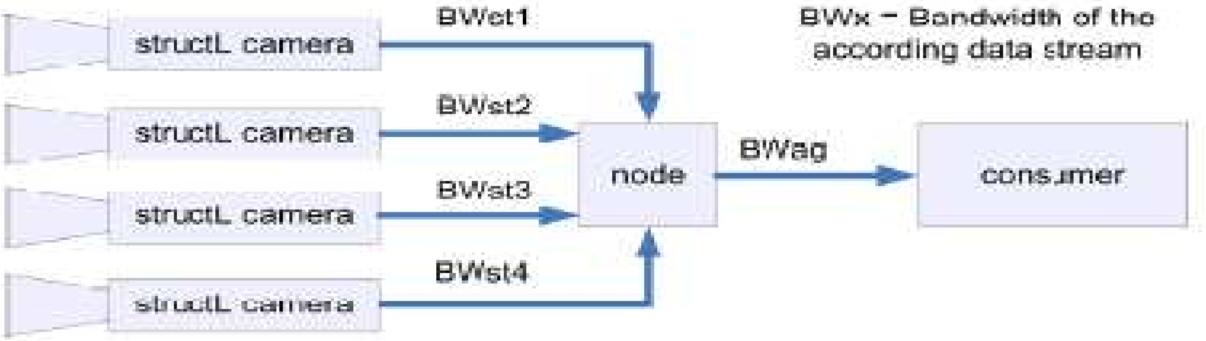


Figure 16.3. Structured light capture.

A 2D deformation analysis of regular pattern structures projected upon voluminous objects can be used to calculate depths of a scene. For capture of scenes applied with such patterns, setups with multiple HD camera arrangements are currently under investigation to detail the resulting depth maps. To capture a scene with the 'structured light' approach one has to separate between the images of the pure scene and the images of the pattern projected on the scene. To cope with movements of objects the capture of the pure scene and the scene with applied projection has to happen in a close series. One solution is to capture the pure scene and the pattern applied scene in a time multiplex manner with double frame rate according to Figure. Every even frame is captured pure and every odd frame is captured with applied pattern (grid). The depth map is processed in a post processing step based upon the four video streams at the 'consumer' site.

CONCLUSION

- It was discovered that 3D is needed in two particular places: visualization of complex scientific and medical structures; and remote manipulation. These are niche markets.
- On investigation in other markets, video arcades and theme parks in particular also seem to present promising results.
- It is evident that multi-view time sequencing technology presents itself as a far more effective technology in comparison with other 3D autostereoscopic technologies.
- The proposed supportive infrastructure for capture of multi-view content incorporates structured light capture with trifocal triangulation processing capture technology, would increase overall efficiency of 3D imaging.
- A range of autostereoscopic displays exist today that can be used in applications ranging from advertising tools to air traffic control consoles and publishable images for scientific visualization.
- Sensible image design, selection of an appropriate display device, and adherence to its limitations can yield realistic, understandable and uniquely effective three-dimensional images.

Future work:

The MAPSCAN (Manual And Portable Scanner)[1], a compact and portable 3D camera for space applications, is being designed to assist space exploration. Researchers are currently involved in the development and integration of a software tool that can convert raw profile data into solid polygonal models.

Switchable displays which can switch between 3D and 2D modes on the press of a button are being developed, which will form an interface to allow 3D displays to reach the consumer market.

Mobile TV is now emerging as a significant new application of cell phones. This is driving a variety of developments in the base display including increased resolution, reduced thickness and 3D capability.

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