Stereographics

Stereoscopic 3D technology, history, principles, and limitations

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Contents

- Depth cues.
- A brief history.
- Principles for creating stereoscopic image pairs.
- Computer generation and photography/filming.
- Mainstream stereoscopic presentation technologies.
- Visualisation and unique environments.
- Current state of affairs and possible future trends.
- Limitations and issues.

Invitation to arrange a meeting to view stereoscopic systems at UWA.

Depth cues

- Single eye.
  - Occlusion: an object blocking another.
  - Perspective: distant objects are smaller.
  - Expectation: we know the size of most objects, if a plane is small then it's probably distant.
  - Motion: closer objects appear to move faster.
  - Lighting: diffuse reflections are a function of depth and curvature.
  - Shadows: implied depth of shadows cast from one object to another.
  - Detail: perceive more detail on close objects.
- Two eyes.
  - Accommodation: muscle tension to change focal length of the lens.
  - Convergence: muscle tension to rotate the eyeball towards an object.
  - Binocular disparity: difference in the views presented to the human visual system.
- While much of the discussion here is around binocular disparity, it is important for the other cues to be consistent.

History: Photography

- Sir Charles Wheatstone circa 1838 used stereoscopic drawings to explain binocular vision.
- Was experimented with by a number of people in the very early days of photography, around 1839.
- Sir David Brewster is attributed with the invention of a widely used stereoscope in 1849.
- First major exhibition was at the first World exhibition in 1851. Featured the first commercially available stereoscopes by Duboscq and Soleil.
- The hand held stereoscope based upon a model by Oliver Holmes (1905) was available in the majority of homes in England at the turn of the century, a commodity item.
- Giving the greater population who could not afford to travel an experience of far away exotic locations.

Camera by Jens Poul Andersen, circa 1895

Viewer by Gaumont

History: Photography

Brewster Stereoscope (1849)

Homes Stereoscope

Museum of Sciences
(1860)

Antarctica Stereo Photography

Newman and Guardia
Used by Frank Hurley on 1912 Mawsons expedition

Left eye

Right eye

John Curtin Gallery exhibition

Samples from an exhibition at the John Curtin gallery by Peter Morse.

Viewmaster

- First released in 1939, viewed stereo images mounted on a circular card, normally 7 pairs.
- Essentially an update on the stereoscope leveraging the advent of 16mm colour photography.
- An alternative to the scenic postcards people purchased from distant lands.
- Camera and mounting system in the 50's that allowed one to make ones own viewmaster disks.
- About 25 different models and 1.5 billion disks, all backwards compatible!

ViewMaster disk

ViewMaster camera

ViewMaster, model E (1950)

ViewMaster, model G (1962)

History: film, early experiments

- 1856 J.C. d'Almeida gave a demonstration to the Academie des Sciences. Called a "stereo lantern" it employed red and green light sources (image as filter), viewed with glasses with matching filters.
- Overlapping presentation of analgyph slides in 1890 by Ducos du Hauron.
- 3D film camera that exposed two reels of film by C. Grivolas in 1897.
  Projected using red/blue anaglyph.
- Motion picture by William Friese-Greene in 1889. Exhibited in 1893.
- "Teleview" (1922) similar to time multiplexed and shutter glasses of today. Based upon mechanical shutters fixed to the chairs synchronised to two projectors and time interleaved frames. Only feature shown was "The Man From Mars".
  Originally conceived in 1903 by C. Dupius but built by Laurens Hammond and William Cassidy.

Almeida's stereo lantern

Teleview

History: film, anaglyph

- Anaglyph presentation became common from around 1922 with the first 3D feature film "The Power of Love".
- Had (has) the advantage that it supports accompanied printed material.
- Most commonly red/blue filters (also red/green), today the most common type is red/cyan.
- Used simpler projection technology (single film) than later polaroid systems.
- There have existed a number of variations
  - ColorCode3D, designed to be compatible with NTSC colour space.
  - Anachrome, gave better perceived colour.
- Colour reproduction is generally poor.
- In more recent times part of a movie has been in anaglyph, for example: Spy Kids (2003). Generally used as a gimmick to compensate for a weak story.

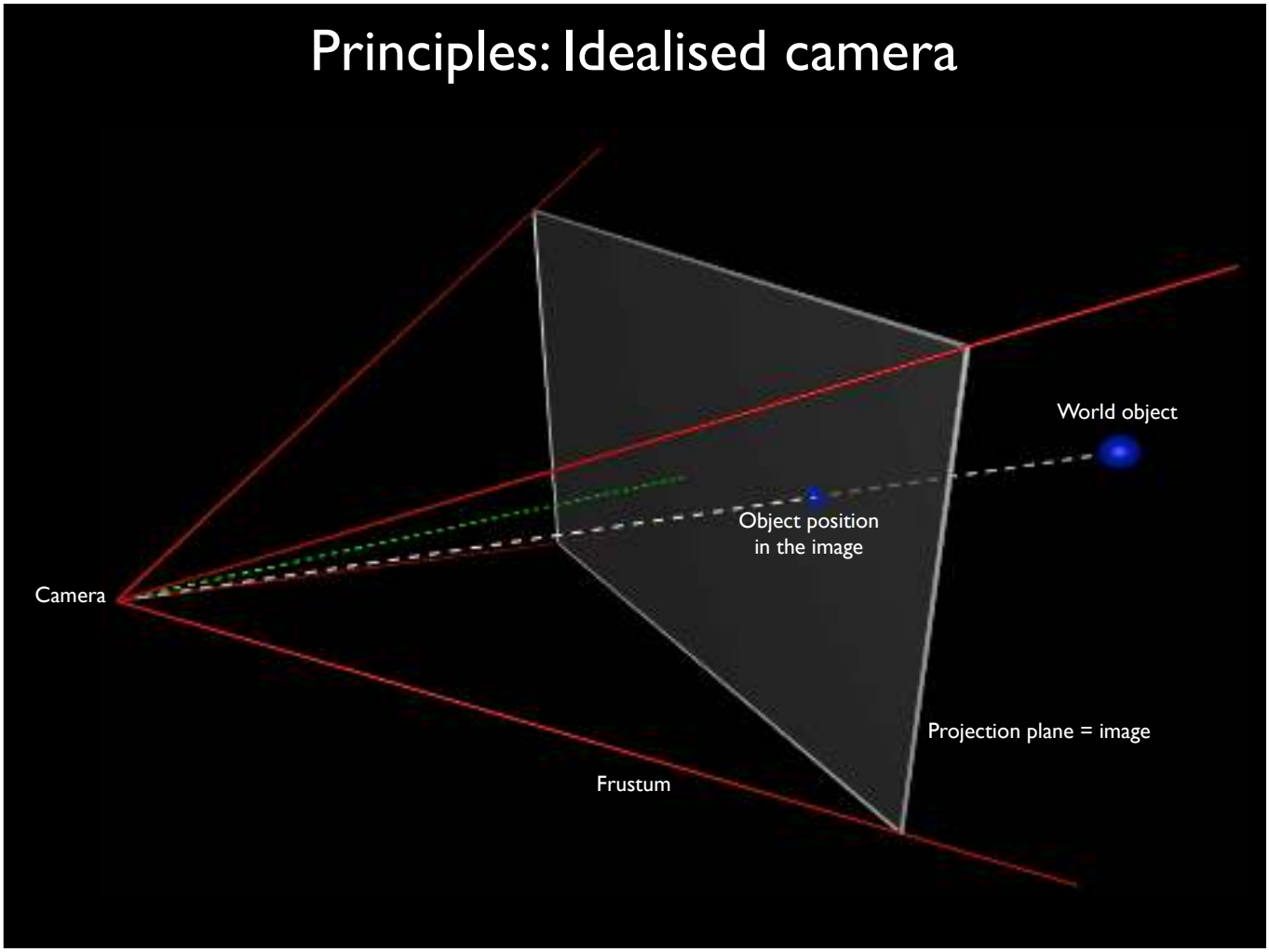
History: film, polaroid

- Based upon lower cost methods of producing polaroid filters in the 1930s, notably by Edwin Land.
- Allowed full colour 3D films. Early example in 1936 titled "You Can Nearly Touch It" (translation from German), presented at the Haus der Technik, Berlin.
- Milestone was a projection by Polaroid Corp at the 1939/1940 world trade fair. The largest audience to date and based upon the production of the Chrysler car assembly line.
- The boom in 3D movies occurred in the 50's the most prevalent method was based upon polarised projection systems.
- First major full length 3D colour production that popularised the technology was Bwana Devil (1952).
- Peaked during the years 1952 to 1955.

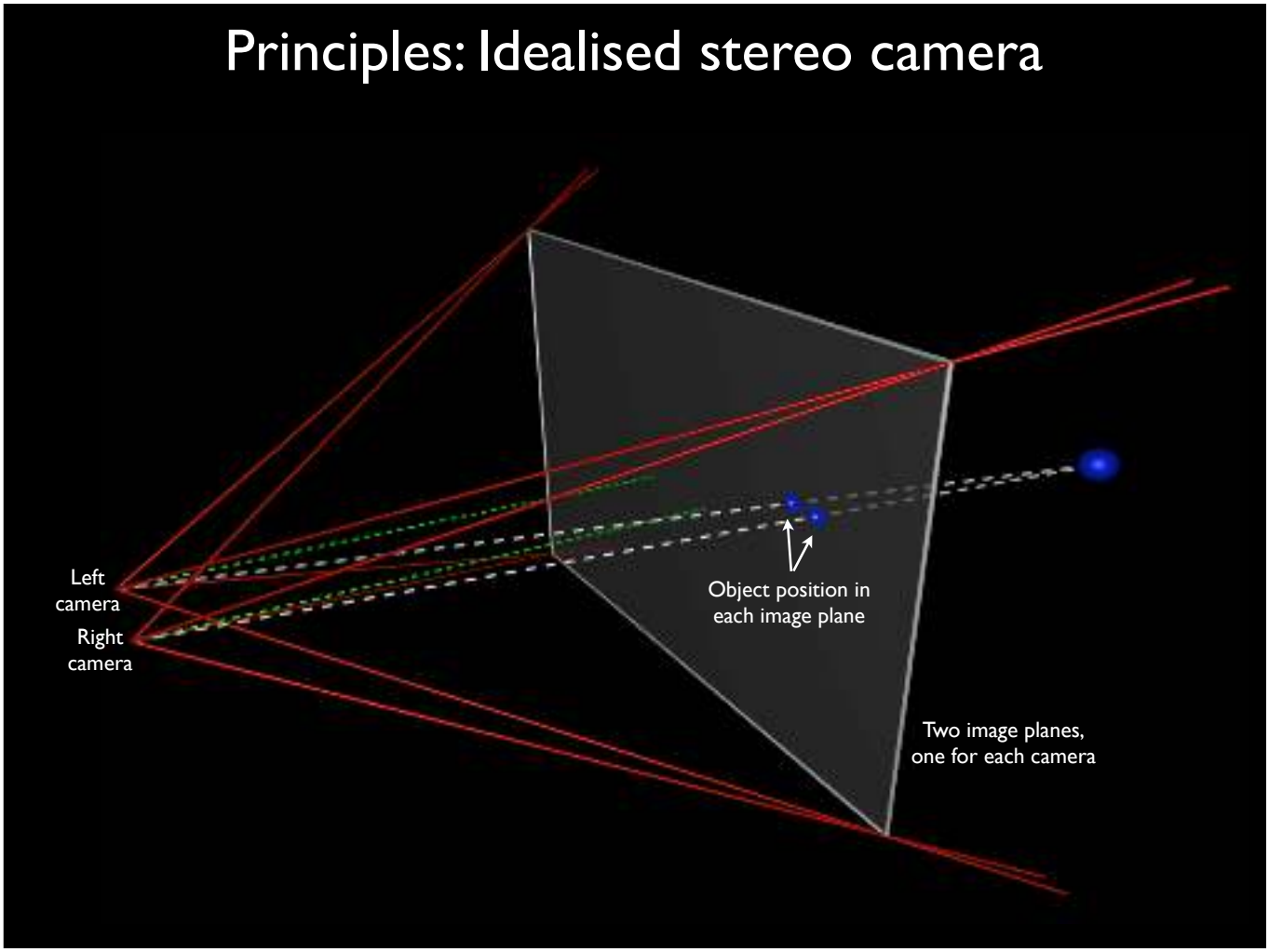
History: film

- Major success by Warner Brothers was "The Wax Works" filmed in 1953 and premiering in New York.
- Also in widescreen format and employed 6 channel stereo.
- Columbia released "Fort Ti".
- Universal designed a new camera and released "It Came From Outer Space", also in 1953.
- Disney produced a few short 3D cartoons, notable "Melody" and "Working for Peanuts".
- During this era all the major film studios were creating 3D films.
- But by the mid 50's 3D was loosing out to CinemaScope. Next resurgence didn't happen until IMAX, first 3D enabled IMAX theatre in Vancouver in 1986.

Principles: Idealised camera



Principles: Idealised stereo camera



Principles - continued

- The correct mental picture is to imagine viewing the world through a rectangular window.
- The consequence for stereoscopic projection is the concept of an offaxis (asymmetric) view frustum.
- Two parallel cameras are not the same as rotated cameras, rotated projection planes results in a keystone type effect.
- Rotated cameras have often been used mainly due to limitation with the underlying technology, introduces vertical parallax towards the corners of the image.

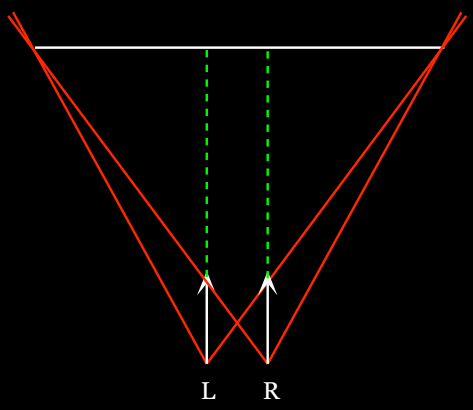


Diagram of offaxis frustum

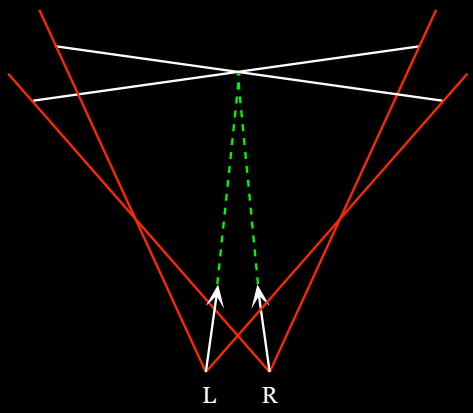
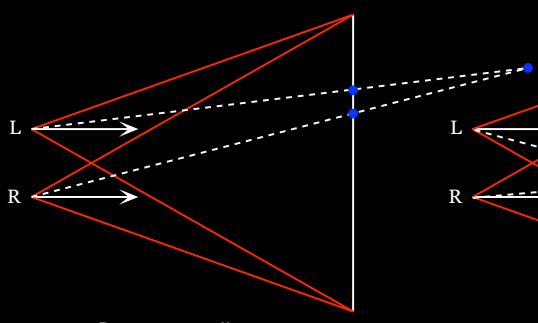


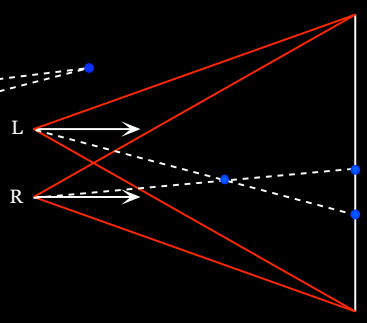
Diagram of rotated cameras

Parallax

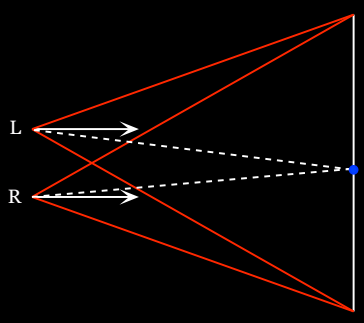
- The difference in position of the projection of a world object onto the left camera and right camera image plane.
- For stereoscopy there is ideally only horizontal parallax, our eyes are offset horizontally not vertically.
- Positive parallax features appear behind the screen, Negative parallax features appear in front of the screen.
- Maximum position parallax is camera/eye separation for objects at infinity.
- Maximum negative parallax is infinite, a key consideration is acceptable negative parallax for acceptable viewing. Dependent (among other things) on the degree of ghosting in the presentation system.



Positive parallax
Object behind projection plane



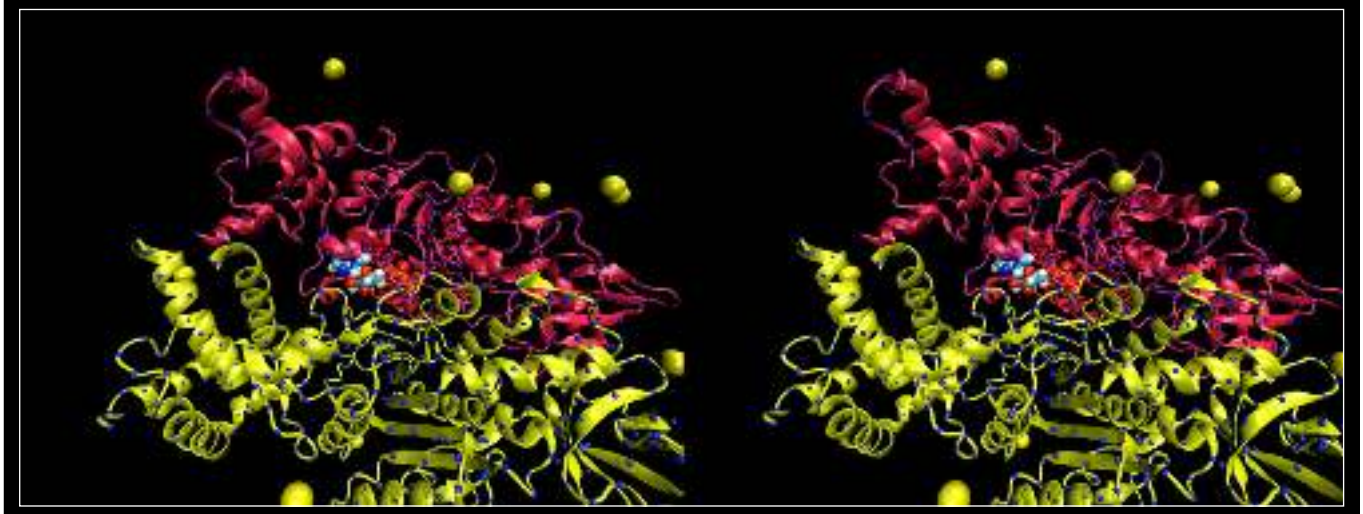
Negative parallax
Object in front of projection plane



Zero parallax
Object at projection plane

Realtime computer generation

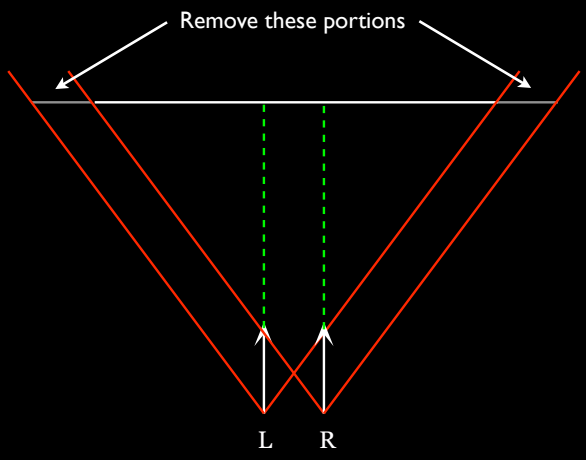
- Computer generated stereoscopic pairs are relatively straightforward due to powerful camera frustum models in OpenGL say.
- The standard computer model for realtime graphics is a pinhole camera without the physical limitations of a real camera.
- Asymmetric view frustums supported in realtime APIs due to the history of stereoscopy in computer graphics and visualisation.



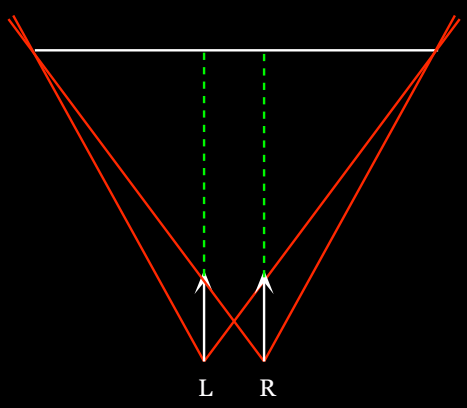
Unbinding of ATP

Rendered computer graphics

- Traditionally rendering packages haven't supported general asymmetric view frustums.
- Native stereo support is now quite common either as part of the base product or as a plug-in.
- There is a simple solution to creating asymmetric frustums in software that only supports symmetric frustums by over rendering the width and trimming the resulting left and right eye images.
- This is a similar process involved in stereo photography with cameras that generally don't have offaxis lens/sensor arrangements.



Two symmetric frustums



Equivalent to two asymmetric frustums

Eye separation

- Camera separation is not always human eye separation although it generally is for human scale objects and viewing experience.
- For visualisation the camera separation is related to the scale of the subject matter.

Camera separation ~ 1mm

Camera separation ~ 30m

Galaxy survey visualisation.
Camera separation
~ million light years

Stereo photography

- Many early (and contemporary) stereo photographs are captured with a single camera, the second photograph being taken from a horizontally offset position.
- There have been a multitude of dedicated commercial stereo cameras over the decades.
- Many units constructed by individuals from two standard cameras.

Famous Rolleidoscop (circa 1926)

Minolta (1960)

(2000)

Stereo photography

Beamsplitter add-on lens

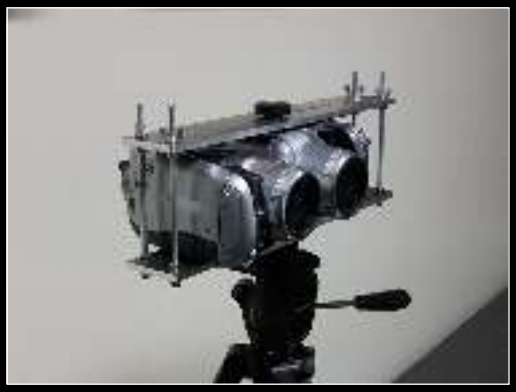
Commodity cameras and genlock trigger

Add-on lens to Lumix cameras (2010)

Fujifilm Finepix Real-3D (2010)

Stereo filming

- Many people have chosen to create their own camera rigs with commodity or semi-professional cameras.
- One issue has often been the dimensions of the camera have precluded human eye separation, generally taken as 6.5cm.
- Not uncommon to use a beamsplitter to reduce the separation, some of the commercial cameras use this technique.



Various rigs by the author

IMAX underwater camera

Stereo filming

Toshiba camcorder (1990)

Canon DV camcorder (2000)

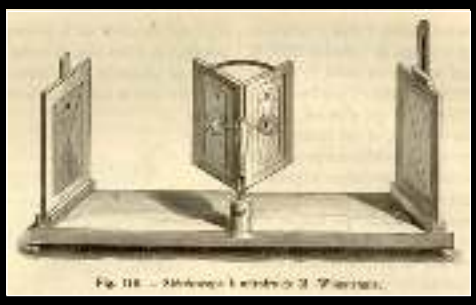
21st Century 3D camera using a beamsplitter (2010)

Panasonic semi-pro video camera (2010)

Presentation technologies

- Irrespective of the technology the goal is to present each image of the stereo pair independently to its intended eye.
- Image splitting.
- Head Mounted Displays (HMD) are a modern day equivalent of the stereoscope.
- Anaglyph uses colour filters.
- Time multiplex, typically uses LCD shutter glasses.
- "Passive stereo" uses polaroid filters.
  - Linear.
  - Circular, allows head tilt.
- Infitec (interference filter technology) uses narrow band colour filters.
- Autostereoscopic
  - Barrier strip.
  - Lenticular lens.

Image splitting



Physical separation: Wheatstone stereoscope

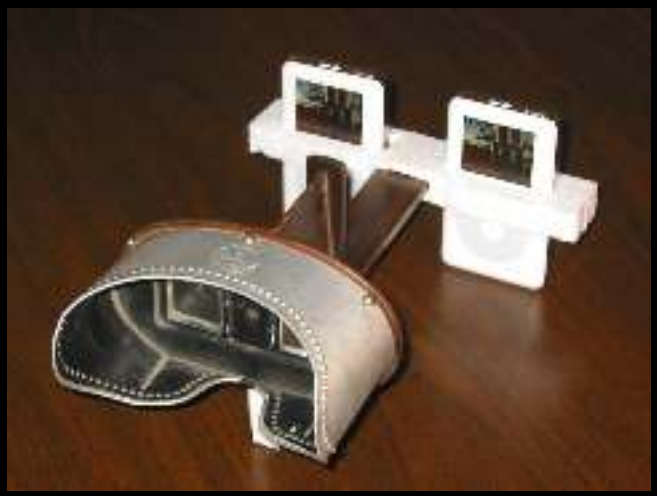
Slide viewers

Modern equivalents

iPod Stereoscope

100 years of stereoscopy

1905



2005

Head mounted displays

- Most prevalent for virtual reality and training/simulation applications.
- Typically low resolution.
- Generally feels like tunnel vision. Tiled units that provide peripheral vision are relatively expensive.
- Generally includes head tracking so the virtual environment can be adjusted as the wearer turns their head.

Cybermind: digital stereoscope

Projection: Time multiplexed

- CRT projectors were the standard in the virtual reality, simulation, and visualisation world up to about 15 years ago. The only technology at that time that could achieve 120Hz.
- Similarly CRT displays were the main desktop 3D viewing environment.
- Used today in LCD TVs, often employing high refresh rates, eg: 240Hz.
- Similarly used for plasma displays (PDP). Advantage of modern plasma displays is the fast switching and therefore lower ghosting levels.
- DLP displays typically interleave the left and right image pixels, these days usually in a checkerboard array.
- Glasses synchronised to the display using cable or IR emitter, more recently DLP link.

Typical emitter and frame sequential shutter glasses

Projection: Polaroid

- Screen requirements: must not depolarise the reflected or transmitted light.
- Generally "silver" front projection screens or custom rear projection surfaces.
- Generally two projectors. (See "zscreen" for an alternative).
- Still the main means of stereoscopic projection for large public audiences due to the economics of the glasses.
- Linear and circular polaroid options, later allows head tilt. Linear acceptable for seated audiences, circular for VR style applications.
- There are polarisation based displays employing a number of technologies.

Parkes Radio telescope
Visitors Centre

Past installations

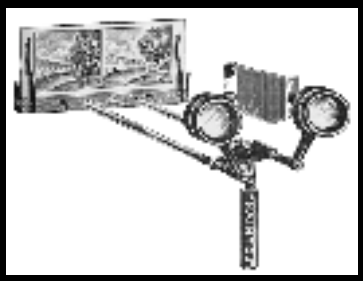
Public education
Swinburne University
Active -> Passive

Sydney Observatory

Tasmania Museum and Art Gallery

Projection: Infitec

- The hardware installed in this theatre.
- Employes a pair of projectors with (generally) an internally mounted filters.
- Left and right eye images are projected with non-overlapping narrow band rgb filters.
- Requires careful colour calibration to correct the colour distortion.
- Glasses susceptible to glancing incident light creating rainbow effects.
- Key redeeming feature is essentially zero cross talk (ghosting) and doesn't require a special surface.



1895

1995

2005

Autostereoscopic

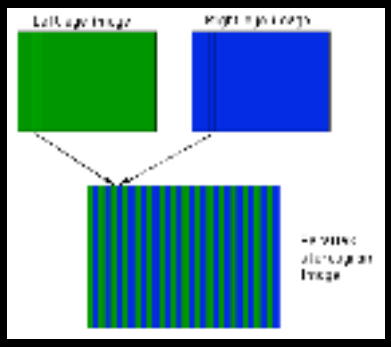
- Term that refers to glasses free stereoscopic viewing.
- First products released around 1999.
- Flurry of activity and products around 2003.
- Two main display technologies are
  - Barrier strip.
  - Lenticular lens.
- Volumetric displays are still mostly in research laboratories, usually involve a rapidly rotating mirror with sychronised image projection.
- Also synthetic holograms and various other techniques outside the scope of this presentation. Many are still promised products rather than shipping.
- "Deep video" uses layers of LCD.
- Sony demonstrated a 360 degree autostereoscopic display at Siggraph 2010.
- (Personal opinion) These devices have not matured and many would seem to have technological limitations that would restrict their usefulness to a narrow range of application areas.

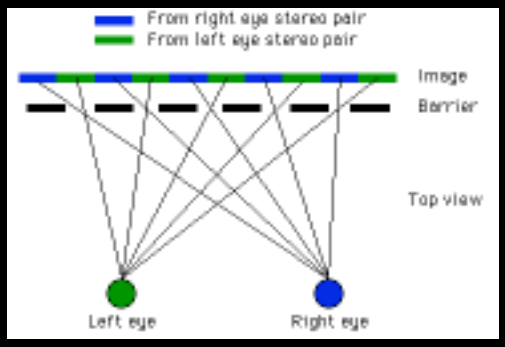
Dimension Technology

Swept volume displays

Autostereoscopic: Barrier strip

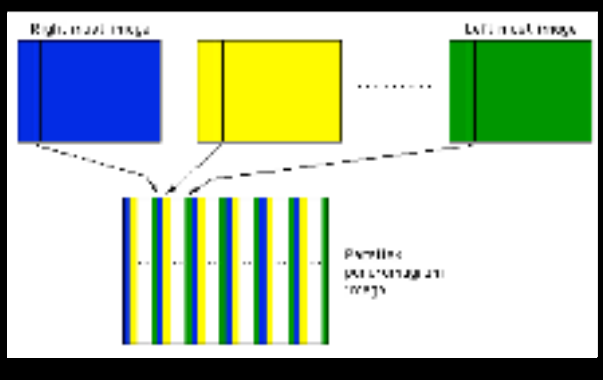
- Based upon work by the Russian Semyon Pavlovich Ivanov back in the 1930s, called "parallax stereogram".
- Main issue is it requires precise head positioning.
  Some products provide head tracking to achieve correct phase of slits.
- Have been available in laptops by Sharp (2003). Mobile phones by a number of companies but notably Hitachi.
- The Fujifilm stereoscopic camera has a barrier strip LCD viewer.
- Many LCD based displays construct the barrier from LCD layer.

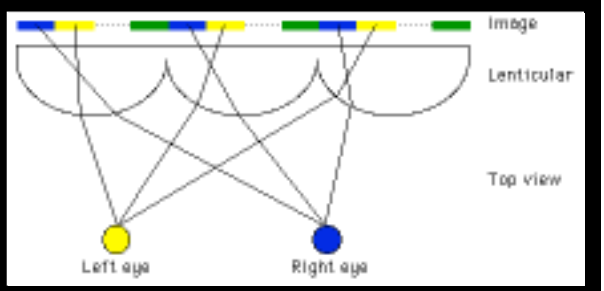




Autostereoscopic: Lenticular

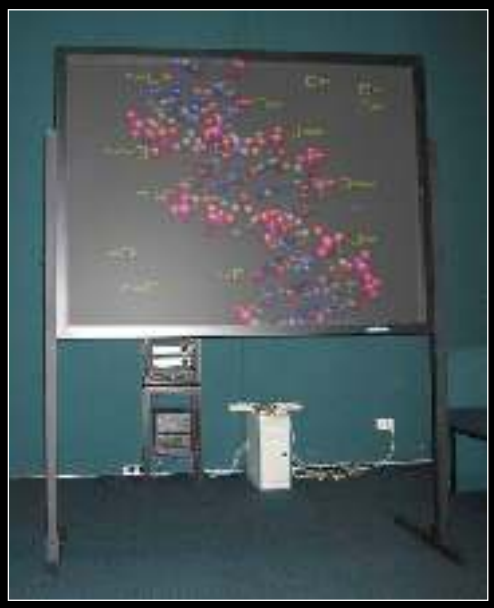
- Can be used to reduce the sensitivity to eye position by using more images, result is a wider viewing angle.
- A lenticular lens presents a stereo image pair from the selection of a number of possible pairs.
- Still a dead viewing zone where the images wrap around.
- Main issue is they are still relatively low resolution, made worse as the number of views increase.





Stereoscopy in visualisation

- Very old and rich history.
- Stereoscopic displays of some sort are essentially standard equipment for visualisation laboratories.
- Easy to understand why the depth perception more quickly allows one to understand complicated geometric/topological relationships in datasets.
- Unlike the movie industry stereoscopy in visualisation has largely been interactive / realtime.



Single screen portable system

Wedge (Drew Whitehouse) ANU

Special mentions: CAVE

- "Big budget" stereoscopic immersive environment.
- Typically need 4 side (wall, floor, ceiling combination) to be called a CAVE.
- Rear projection and small room size.
- Head tracking a requirement, both position and viewing direction.
- Arguably the most immersive display available.

Special mentions: Virtual Room

- Conceived in 2001 by the author.
- Installed at Museum Victoria 2002-2009.
- An "inside-out" CAVE, consisted of 16 projectors (8 pairs). Each wall presents the correct view of the virtual interior (Virtual Containment Vessel).

Museum Victoria

Re-Actor, City University Hong Kong

Special mention: AVIE

- 360 degree cylindrical stereoscopic display.
- Has the unique ability to present stereoscopic images that can be viewed by multiple people all looking in different directions.
- Known as omni-directional stereoscopic panoramas.

Roundshot camera

City University Hong Kong

Left eye

Right eye

Ephesus. Courtesy Sarah Kenderdine, Jeffrey Shaw

Special mention: Stereoscopic planetariums

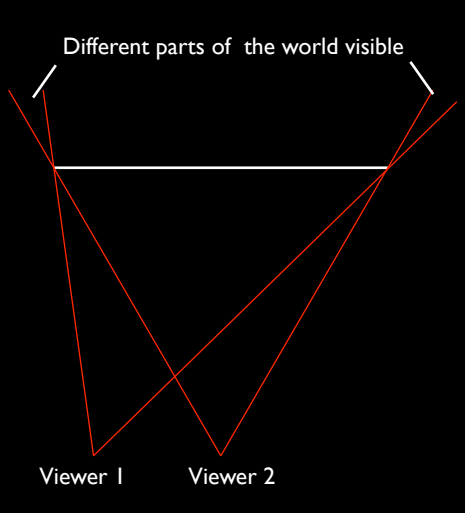
- Starting to see the installation of stereoscopic planetariums.
- For example, Macau planetarium has 12 (6 pairs) of Sony 4K projectors.
  Uses Infitec based projection.
- Exactly what does a stereoscopic fisheye mean?
  Can it give other than a correct result in a single view direction?
  What is the point if ones peripheral vision is blocked due to glasses?

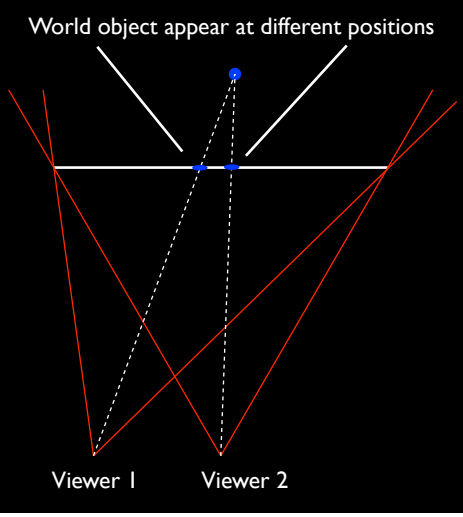
Current state of the market

- Blu-Ray format in place.
- TV channels are coming on line, eg: DirectTV.
- HDMI 3D format in place (1.4a).
- Stereo aware compression: MVC (MultiVariant coding).
- Almost all TV manufacturers have 3D products in the market.
- External sync for emitter and DLP-Link seem to be standard.
  DLP-Link not supported by LCD or Plasma.
- There are a number of emitter/glasses to choose from. IR, BlueTooth, RF ...
  There is a (old) VESA standard.
- Most video production tools now support stereoscopic aware editing.
- The pieces of the puzzle are in place ... will it become pervasive?

Issues / Imperfections

- The stereoscopic view is only strictly correct for one viewing position.
- The way to think about this is to consider the screen as a view through a window.
- If you shift left/right while watching stereo you will see the world shearing.
- If you move closer or further away from the screen the world will compress or expand.
- Can be compensated for in realtime systems by head tracking but then an inherently single person experience.





Issues / Imperfections

- Time multiplex flashing.
  Typically 60Hz so not generally considered an epilepsy risk.
  Less of a problem from the CRT days when there was a longer blanking period.
- Ghosting.
  Major source of eye strain on many systems, especially for negative parallax.
  A major consideration for the technology choices and for content development.
- Depth conflict for negative parallax at edges.

Negative parallax OK

Negative parallax planet conflicts
with the zero parallax screen frame.

Issues / Imperfections

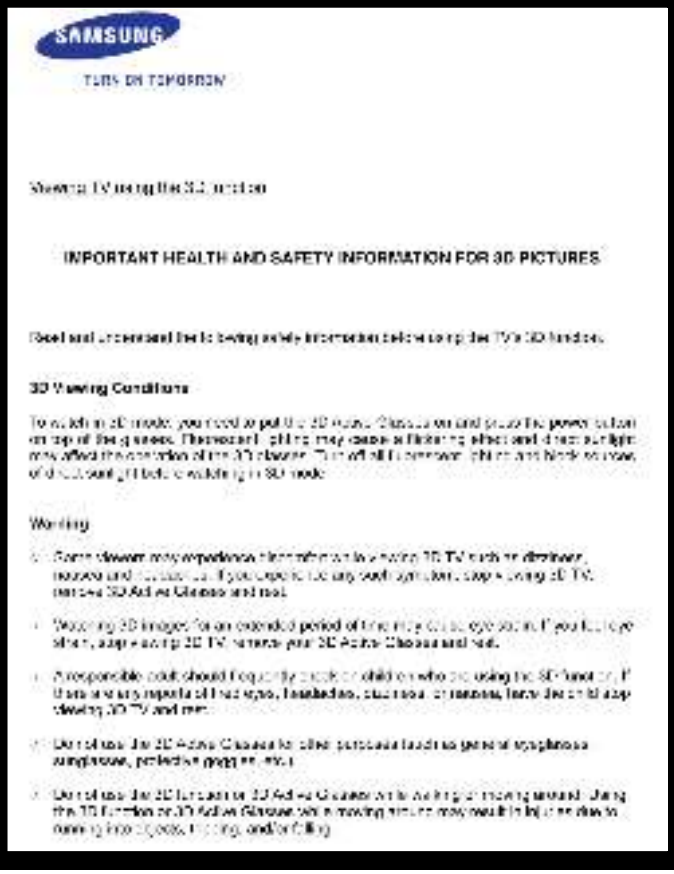
- Content only strictly correct for the screen size and viewing conditions it was design for.
- Divergence at infinity when viewing (on a larger screen) material designed for a small screen.
- For example, on a 2m wide screen object at infinity should be separated by 6.5cm. If the same content is moved to a 4m wide screen the objet at infinity will be separated by 13cm. Requires unnatural divergence of viewers eyes.
- Many considerations to good stereoscopic production
  - Texture and detail: parallax information is carried in vertical detail.
  - Similarly low resolution stereoscopy gives a poorer result.
    Depth resolution is determined by pixel resolution, that is where parallax is "stored".
  - The human eye is very sensitive to differences in brightness or colour space between eyes.
  - Specular hilights can be problematic since they are highly dependent on camera position.
  - .... many more
- In summary, easy viewing stereoscopic content requires skill.

Dangers?

- Convergence and accommodation.
- Presenting imagery to our visual system differently to how it has evolved, is that necessarily dangerous? We do need to revert to experiencing depth perception of the real world in the way our visual system evolved.
- Development of the visual system in young children.
- There are those who have limited depth perception in real life.
- Binocular rivalry is one reason why people who experience depth in real life may not experience it on frame sequential displays.
- Unlike displays for employment, for recreational use people will simply not watch stereo if it is uncomfortable.
- Unlikely to have permanent effects in adults, our visual system is extremely flexible.
- Extended use of standard displays causes plenty of problems as it is.
- Surprisingly little research on the effects of short or long term exposure!

Manufacturers warnings

- The dangers hit the press in a big way near the start of 2010 with the warning by Samsung.
- Initial warning included mention of pregnant women, alcohol affected, sleep deprived, and the elderly.
- Recommended staying away from stairs and balconies after watching 3D.
- Many practitioners in the industry are just waiting for the first class action ... a reflection of our litigious society more than anything else.



SAMSUNG

TURN ON TOMORROW

IMPORTANT HEALTH AND SAFETY INFORMATION FOR 3D PICTURES

3D Viewing Conditions

Warning

Other comments

- Current lack of content ... will improve.
- Poor quality content ... will (hopefully) improve.
- Need glasses for everyone in the room.
- If there is one person in the room who is sensitive to motion sickness or is affected in other ways by stereoscopic viewing, they will not want the display in stereoscopic mode.
- Experience with gaming, as a rule very few gamers use stereoscopy for gaming even though it has been affordable and there have been stereo enabled games for many years.
- Have we chosen the wrong horse? Would we get a more engaging experience with by exploiting our peripheral vision, noted in the virtual reality community as giving a sense of immersion, of "being there".

Comments / Questions