iDome and digital projection into hemispherical domes

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Outline

- The human visual system - what's missing when we view 3D models or world using traditional computer displays?
- Brief introduction to stereoscopic display systems.
  - Single wall
  - VROOM
  - AVIE
- Planetariums and digital fulldome projection.
  - Multiple projectors
  - Single projector and fisheye lens
  - Spherical mirror
- iDome: The upright dome.
- Applications.
- Content creation:
  - CG (Computer generated)
  - Photography / filming
  - More exotic camera systems
- Navigable movies, demonstration.

Limitations of most computer displays

- Both eyes get the same image.
  (Even if the display presents a 3D model)
  This is not how we experience the real world, we get two slightly different views of our 3D environment. These two views are used by our visual system to give the sense of depth we experience when viewing the real world.

- Only a small part of our field of view is utilised.
  The horizontal field of view of our eyes is very close to 180 degrees (albeit not in detail or colour), our vertical field of view is around 120 degrees. Our visual system is tuned to detect motion is the peripheral region (survival capability).

- Displays are small and don't support the ability to have a 1:1 relationship between the virtual and the real. The player looks through a small portal on a miniature world.

Stereoscopic display systems

- Irrespective of the technology, the goal of all stereoscopic systems is to present two (correctly formed) images independently to each eye.
- Most common experience is a single flat screen, most likely either active shutter glasses, linear/circular polaroid, or infitec.
- Most cost effective solution consists of two projectors, polaroid filters, and a polarisation preserving screen. Audience wear low cost polaroid glasses.
- While autostereoscopic (glasses free) displays exist they are still relatively low resolution.

Parkes radio telescope visitors center

Movie example

- “AfterStars”, Swinburne University, Astrophyscs and Supercomputing.
- Stereoscopic animation using alien scientists who discuss the future of a star at the end of its life. Will it become a pulsar or a black hole?
- Original is 2048x768 pixels @ 25 fps.

Left eye Right eye

VROOM: Virtual ROOM

- First conceived by myself and David Barnes in 2001.
  At the time called the VCV: Virtual Containment Vessel, the literal name.
- Currently installed at Melbourne Museum.
- Consists of 8 stereoscopic walls in an octagonal arrangement, the observers are on the outside. Consists of 16 DLP projectors, 8 computers + server.
- With careful design of the stereoscopic rendering a correct sense of depth can be achieved, giving a 1:1 relationship between the virtual and the real world.
- Content creation (movies) is challenging: 1024x768 pixels x 2 eyes x 8 screens x 25fps.

Movie example

- VROOM trailer, RMIT.

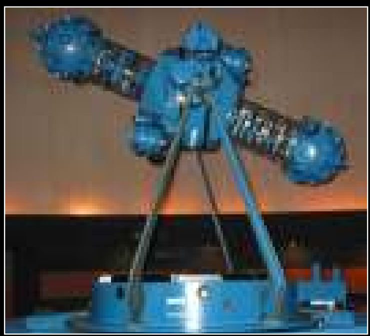
Left eye Right eye

AVIE: Advanced Visualisation and Interaction Environment

- Engages both our peripheral and stereoscopic vision.
- Located at iCinema Scientia Facility, UNSW, Sydney.
- 360 degree cylinder (- door), 10m diameter, 3.5m tall. 6 pairs (12) projectors for a total of 8000 pixels around the cylinder. Passive polaroid stereoscopic projection.
- Can be enjoyed by multiple viewers without headtracking!
  Very uncommon feature not normally possible with stereoscopic environments which only create a correct view for a single observer position.

Planetariums and digital fulldome projection

- Traditionally fixed planetariums had a range of projection hardware:
  - a dedicated star projector (eg: Zeiss or Digistar), usually black and white
  - possibly a laser system building an image up from points and lines, limited colour
  - a bank of slide projectors to give a still colour image over the whole dome
  - some single projectors that can play a colour movie but only on part of the dome.
- Smaller inflatable domes used lower end devices, essentially pin holes in mylar sheets with bright light source.
- "Everyone" is now trying to move to fulldome digital projection. This extends the capabilities of the planetarium to more than star fields, constellations, and planets to essentially any topic. The digital planetarium becomes an immersive theatre.

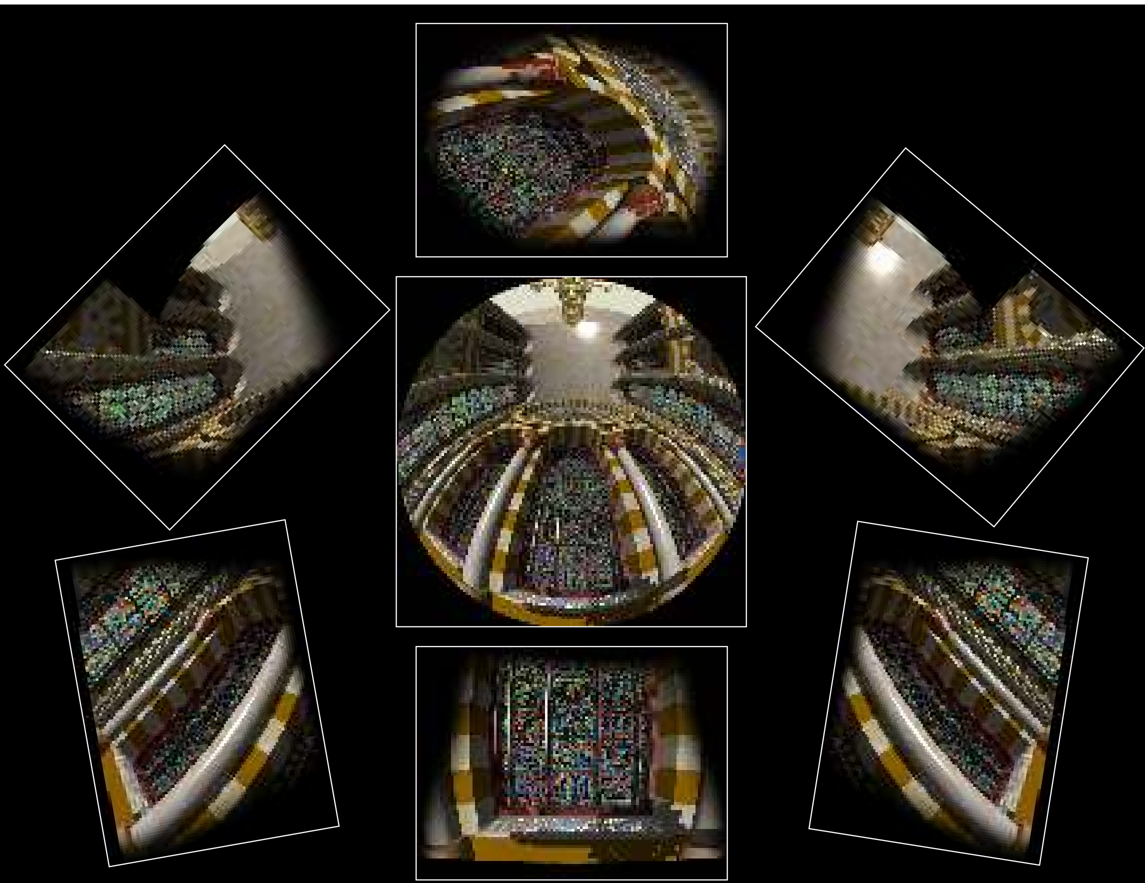


High end Zeiss projector

Do-it-yourself star projector

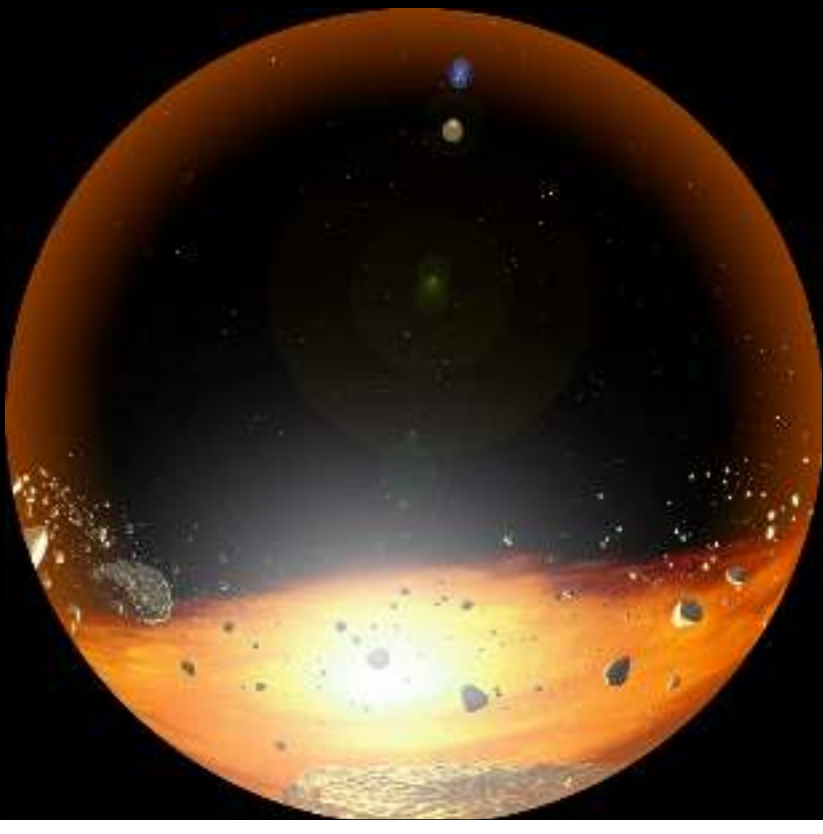
Multiple projectors

- The challenge is getting a high resolution digital image/movie on the dome.
- For large installations the approach is to employ multiple projectors, normally between 5 and 7. Each of these covers an overlapping region of the dome and they are edge blended together to form a seamless image.
- Each frame is a fisheye projection but it is diced up into N pieces, one for each projector. Generally each projector is driven by one computer.
- Projectors conveniently located around the rim of the dome and usually not obviously visible.
- Very expensive operation both initially and ongoing (high cost of ownership).
- Perfect edge blending is very difficult, imperfect edge blending results in an out of focus effect across the seams and at worse an actual image offset.
- Even though one can spend "millions" of dollars on multiple digital projection systems the star fields are rarely as good as a good optical-mechanical star projector. Installations either keep their star projectors or accept the loss in star field quality given the other advantages of a realtime digital system offers.
- The magic happens when you loose sight of the dome surface, when there is no visible frame of reference other than the digital content.



Fisheye movie example

- Origins of Life, Mirage 3D



Fisheye lens

- Can place a fisheye lens on a single projector and get fulldome coverage.
- Some solutions use two projectors each with a half of the fisheye image and a single edge blend down the middle.
- Most common arrangement in small or portable (inflatable) domes.
- Problem is that most projectors have a 4:3 aspect ratio (or worse 16:9), this limits the pixel efficiency for a full fisheye. For this reason many products use a truncated fisheye and simply don't project in the back half of the dome, usually acceptable for directional seating.
- Fisheye lens is typically tightly coupled to the projector.
- Additionally some unresolved patent issues.

Inscribed fisheye in a 4:3 frame

Back truncated fisheye

Fisheye lens, continued ....

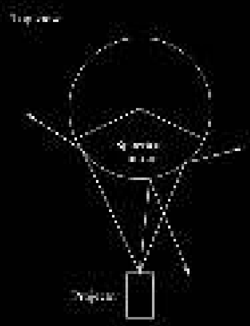
Elumens / Edmund optics

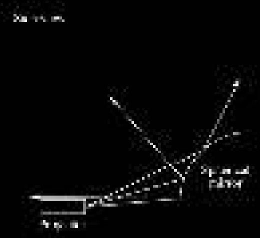
Digitalis

Elumens Visionstation

Single projector and spherical mirror

- A single projector and a spherical mirror can scatter light across a wide field of view.
- Note the parallels between refractor and reflector telescopes.
- Originally conceived by myself in 2003, first tested last in 2004 in the Wollongong planetarium.
- First used seriously in 2005 for digital projection into inflatable domes.
- The images/movies used are still fisheye but they are “warped” before projection in just the right way that they appear correct on the dome.





Typical arrangement in a planetarium

Single projector and spherical mirror, continued...

- The exact warping is generally derived by a simulation application that takes all the physical parameters into account and creates a mesh with the correct texture coordinates onto which the fisheye images are applied.
- This warping can now be performed “on-the-fly” for quite high resolution movies, eg: 2000x2000 pixel fisheye frames.
- As with a fisheye lens one attempts to use as many pixels as possible. Unlike fisheye however, for spherical mirror projection 16:9 projectors are a better fit.
- Common to require an intensity mapping as well to compensate for the different light paths and pixel densities.

Fisheye view

warp →

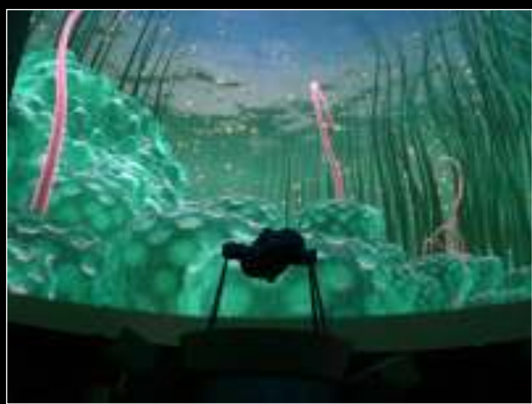
Typical planetarium warp (4:3)

Single projector and spherical mirror, continued...

- Obviously suited to inflatable/small domes due to cost but also, compared to fisheye, the hardware is located on the edge of the dome.
- Separates the optics from the projector allowing one to take advantage of better projectors as soon as they are released.
- Adoption is increasing by fixed planetariums.
- Recent innovation by some is to further fold the light path with an additional first surface mirror.

Adelaide planetarium

Bangalore Planetarium (15m)



Mueller planetarium, Nebraska

Graphite (2005)

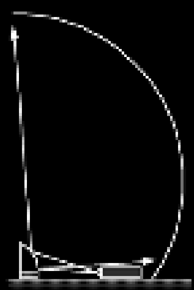
Cosmology Gallery, Gin Gin

- Australias largest projection dome is here in WA at the Cosmology Gallery, Gin Gin.
- Bucky ball geometry (Carbon 60).
- 20m diameter dome, 2.5 storeys above the gallery floor.
- This is also the largest dome (to date) where the spherical mirror has been used to create a fulldome projection.

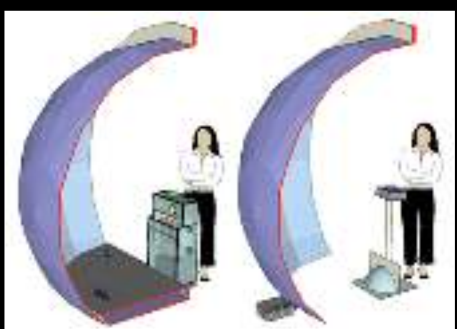
Cosmology simulation

iDome using the spherical mirror

- Dome orientated 90 degrees to the traditional planetarium. More suited to virtual reality, standing upright environments.
- First version was 3m in diameter, there is now also a mold for a 4m version (iCInema).
- The spherical mirror has the same key advantage over fisheye lens system in that the projector/mirror are out of the way. A projector with a fisheye lens would be exactly where the observer should be, in the center of the hemisphere.



Typical orientation

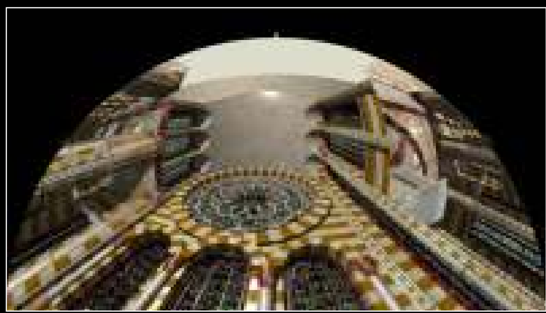


Courtesy iCinema

Origins of life

Calibration

- No (current) closed solution for the image transformation required to warp a fisheye image.
- A raycast simulator takes as input all the physical variables: dome/mirror size, dome/mirror/projector position, projector throw and offset. Some of these are easy to measure accurately, others are not.
- The user adjusts the less well known variables within the calibration software until the result in the dome looks correct. A polar grid is the usual calibration image since one knows where the pole should be and that the lines of longitude and latitude should be radial and circular respectively.
- A texture mesh is saved and used for all subsequent software.



What are these environments used for?

- I am involved in science/data visualisation.
  Using computer graphics to assist researchers:
  1. reveal new relationships or understanding of their data
  2. all more rapid understanding of data sets
  3. indicate errors not obvious from lower dimensional representations
- Visualisation is often required for large datasets and high dimensional data.
- Fully exploiting the capabilities of the human visual system can assist in meeting the above goals.
- Stereoscopic projection offers clear benefits for high dimensional data.
- The proposition is that immersive environments such as the iDome will provide benefits when one needs to be ”inside” the data,, something often difficult with stereoscopic projection.

Cosmological simulation

Molecular representation

Other applications.

- Visualisation of scientific data often leads to opportunities in public outreach and education.
- Immersive environments act as engaging ways of presenting all sorts of content.
- Simulators, for example, mine truck driving simulator (iCinema).
- Museum and visitor center exhibits.
- Entertainment.

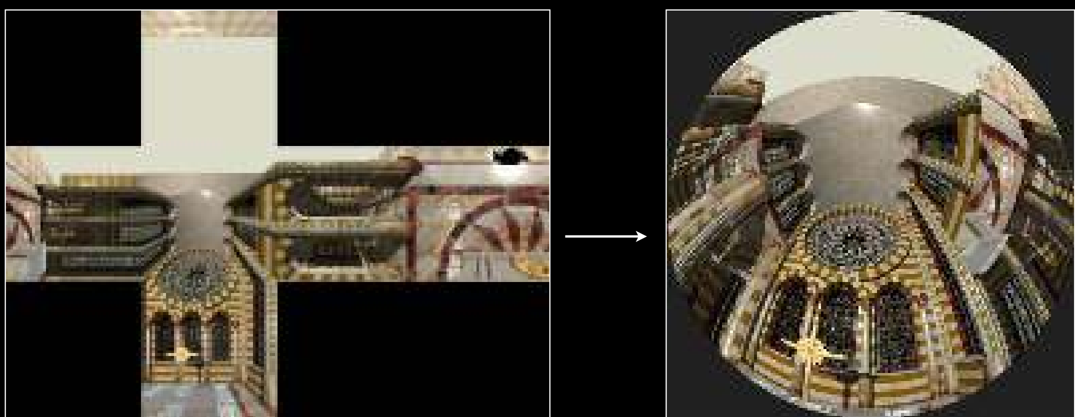
Virtual heritage

Truck driving simulator

Gaming (HalfLife)

Content creation

- Irrespective of the method, a circular fisheye projection (strictly speaking an angular fisheye) needs to be created.
- A fisheye image is the most efficient projection that contains the visual field required to fill a hemispherical dome.
- Many animation packages support a fisheye lens directly. If a package doesn't then the standard method is to render N perspective projections corresponding to the faces of a cube. N=4 is the minimum for a full fisheye.
- If all 6 faces are rendered then any arbitrary orientated fisheye projection can be formed.



Photography / filming

- The trick/problem is resolution. A large planetarium with a multiple projector arrangement (eg: Horizon - The Plaanetarium) can support at around a 3000x3000 pixel fisheye image. Even the projection system on my dome can represent 1500x1500 pixels before the projection system starts to limit the image quality.
- Relatively straightforward to capture single images of sufficient resolution. SLR camera and good circular fisheye lens.
- Filming is much more difficult. Current commodity HD projectors can give 1080 lines (progressive) but this still only gives a 1080x1080 pixel fisheye images.

Canon HV20 HD 1080p

Still photography capturing the entire visual field

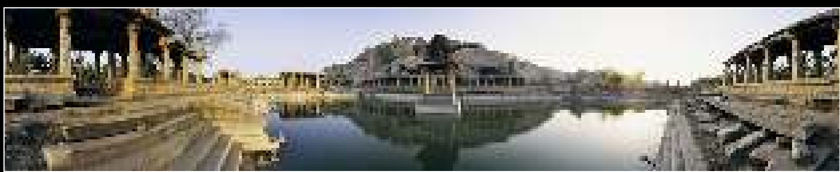
- If nothing is moving in the scene it is possible to capture the entire visual field using a single camera and take many shots that are then stitched together.
- Time consuming but very high resolution is possible. Following example from the Cathedral at Geraldton is almost 1GPixel, captured from over 120 separate shots.
- There are mechanical rigs designed to make this process more automated, they generally provide more consistent images to the stitching software.

Still photography capturing the entire visual field, continued...

- There are specialised cameras designed to capture panoramic images, these can be fitted with a wide angle or even fisheye lens.
- Capture the scene very quickly but more importantly the panorama is captured as a rotating slit so some movement within the scene isn't necessarily a problem.
- RoundShot have film and now digital versions of their rotating cameras, can additionally be configured for stereo.

Left eye

Right eye



More exotic camera rigs

- If a single camera isn't high enough resolution then use multiple cameras and stitch the result.
- Stitching is hard to get perfect because of parallax differences between the cameras, namely, they all have a different nodal point.
- Certainly not portable due to hard drive capture requirements, often a computer ... and associated power supply.
- Currently the only solution for the highest resolution results.

iCinema

iCinema

Micoy

More exotic camera rigs, continued....

- The Ladybug camera and associated software is a compact 6 camera system that captures and then stitches the results to form a partial spherical projection. 360 degrees horizontally to about 150 degrees vertically.
- Native resolution is about 3600x1800 pixels @ 30fps (LadyBug 2).
- Once we have a wide field of view, other projections can be derived, for example, we can pan around within the image.

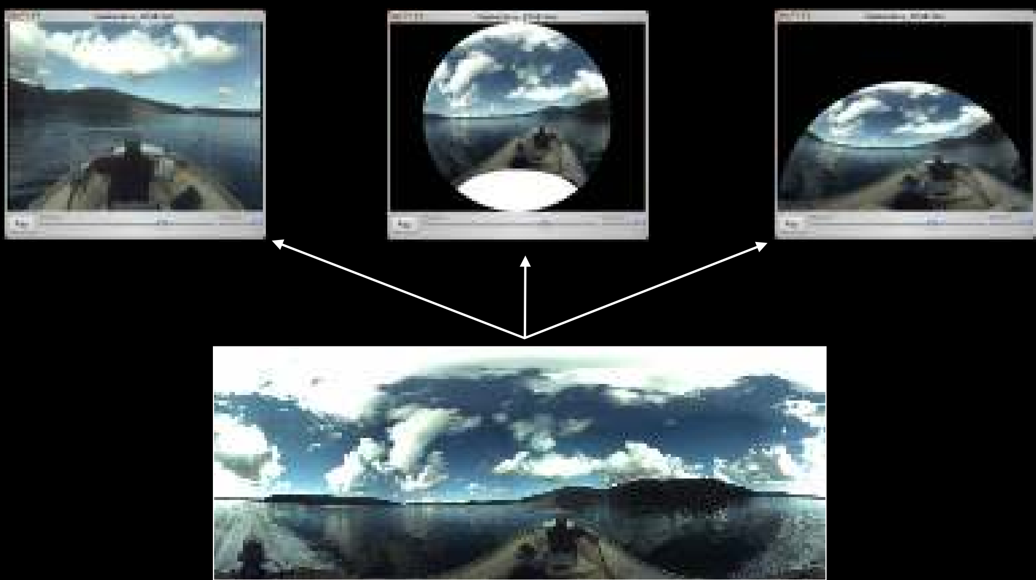
Ladybug camera

Spherical projection (single frame)

One possible derived fisheye

Navigable movies

- If we capture the entire visual field then we can
  1. view the movie in multiple formats
  2. navigate in real time while the movie plays
- Each time the movie is played one could get a different experience.



Examples of navigable moves....