Digital fulldome for science research and public education

Paul Bourke
WASP / iVEC
University of Western Australia

Contents

- Visualisation at UWA
- Novel display technologies and our visual system
  - High resolution
  - Stereopsis
  - Peripheral vision
- iDome
- Planetariums
- Generating content for hemispherical domes
  - Computer graphics
  - Photography
  - Filming
- Demonstrations

Introduction

- Visualisation of data is an important part of many scientific research projects.
- Present data to researchers and the public in informative ways using computer graphics.
- Visualisation can often benefit from novel display technologies that exploit characteristics of our visual system.
- Technologies that provide benefits over a standard desktop display.
  - Fidelity
  - Stereopsis
  - Peripheral vision
- Displays supported by WASP at the University of Western Australia.
  - Tiled display (visual fidelity)
  - Stereoscopic display (two eyes)
  - Hemispherical dome (peripheral vision)

High definition tiled display

- Exploits the high resolution of our visual system.
- Solves the zoom-in, pan, zoom-out of large images of databases.

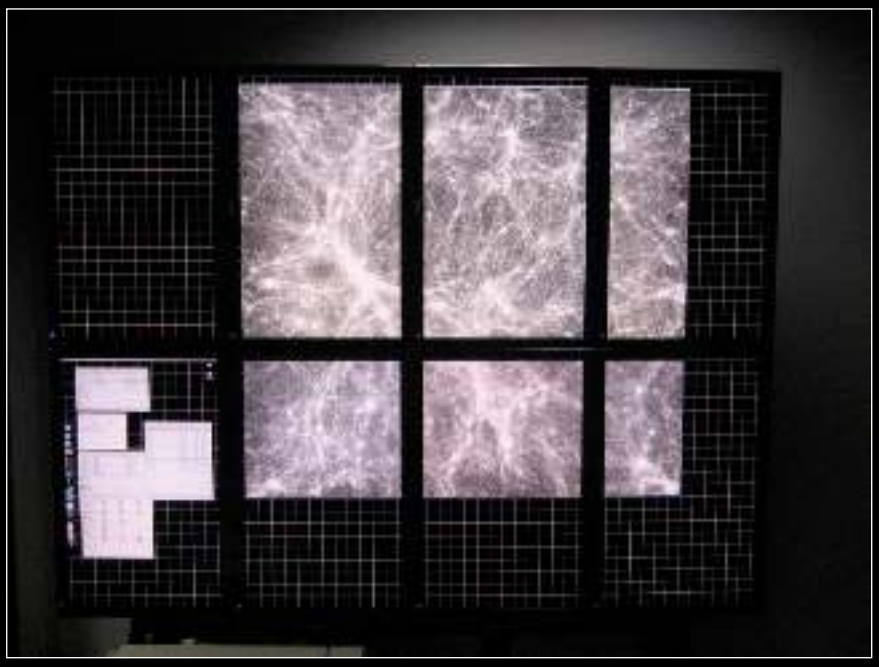
Tiled displays: Example

- Can view high resolution images at (or closer to) 1:1 scale.
- Total resolution count is 6400 x 5120 pixels. 6 x DELL 30inch displays.

Image from repaired Hubble, 2009.

Tiled displays: Example

- Viewing very high density point data (cosmology simulation) in realtime.
- Would look like solid white box on a standard display.



Visualisation of cosmology simulation.

Stereoscopic 3D displays

- Exploits the fact that we have two eyes.
- The two views from slightly different positions is used by our visual cortex to create the sense of 3D we see in the real world.
- The 3D viewing of complicated datasets has clear advantages in
  - Understanding the geometric relationships faster.
  - Seeing new properties and features not otherwise obvious.
  - Detecting possible errors and problems in simulations.
  - Opportunities for public education due to engagement of students.
- While the movie industry has recently started to create movies in 3D, the visualisation industry has been using stereoscopic viewing for over 30 years.
- Today it is possible to create a high quality stereoscopic projection system in a very cost effective way from commodity components.

Stereoscopic displays: Rear projection

- Systems most commonly used are based upon polaroid filters, similar to most iMAX theatres.
- The light from one projector is polarised at +45 degrees, the other at -45 degrees. The glasses have matching polarisation angle.
- Requires a special rear projection screen.
- Low cost glasses are ideal for educational applications.

Stereoscopic displays: Front projection

- Also polaroid based.
- Requires a special screen surface, cannot use a plain wall.
- Suited when space is limited, or where rear projection is not possible.

Hemispherical dome

- Exploits our peripheral vision.
- Our wide field of view horizontally and vertically is credited with giving us our sense of immersion ... of being somewhere else.
- Examples of hemispherical environments includes planetariums and the iDome.

iDome: examples

Planetariums

- Traditionally planetariums housed some sort of dedicated star projector.
- Capable of very high quality representations of the night sky (stars, planets, constellations, etc).
- Satisfies our fascination with astronomy, the universe, what's "out there".
- With the advent of "digital fulldome" projection the types of content that can be displayed in a planetarium has risen dramatically.
- While many planetariums choose to limit themselves to astronomy education, others extended the material they show to
  - other science topics.
  - artistic expressions and exhibitions.
  - offer the venue for entertainment.
  - corporate events.
  - gaming.

Brief history of planetariums

- 1500BC: Earliest known depiction of the night sky on Egyptian tomb of Senenmut.
- 500BC: First known domed building, called the The Dome of Heaven.
- 1923: First planetarium built in Munich, Germany. Projection using the Zeiss Mark I star projector.
- 1949: Spitz demonstrated their first star projector at Harvard College in the USA.
- 1959: First planetarium and star projector by GOTO of Japan.
- 1965: First star projector by Minolta of Japan.
- 1973: First OmniMax (iMAX) opened in Reuben Fleet Science Centre, based upon 70mm film.

Brief history of digital planetariums

- 1983: Evans and Sutherland develop a vector graphics style projector capable of creating points and lines at the Virginia Science Museum.
- 1997: Spitz install the first ElectricSky system in Canada comprising of 4 CRT projectors and edge blending.
- 1998: SkySkan demonstrates their digital projection system. The first digital video content not reliant on custom projection hardware.
- 2002: First laser projection system by Zeiss demonstrated in the largest digital dome at the time, 24m diameter.
- 2005: GOTO of Japan create the first full sphere projection system.
- 2008: SkySkan installs the first 8Kx8K projection system in the Beijing planetarium.

Digital projection systems

- Multiple projectors: Traditionally CRT due to perfect black capability, today other digital projector technologies are used. Often 5, 6, or 7 projectors.
- Laser based, not very common. Generally multiple units, very high colour fidelity and dynamic range.
- Two projectors with wide angle lenses. Popular configuration for high resolution uses the recent 4K projectors from Sony.
- Single projector with a full or partial fisheye lens. Was the standard solution for small and portable planetariums for many years.
- Spherical mirror (developed by myself). Quickly becoming the standard for single projector installations. With care it is as good as single projector and fisheye systems (4K projectors excluded).
- Comparing projection systems is largely a matter of resolution (number of pixels on the dome). Price rises rapidly with resolution.

Content generation: Fisheye projection

- Standard perspective projection is no longer enough.
- It doesn't capture the field of view required for a hemisphere.
- One cannot take "standard" video and stretch it across the dome without extreme distortion occurring.
- Need to consider the angle of the dome, dome range from 0 degrees like the Kuching planetarium, to 90 degrees of the iDome. Most iMax domes are at a 60 degree angle.
- Need to consider whether the installation has omni-directional or uni-directional seating.
- Most content today for digital fulldome projection assumes a directional seating arrangement.

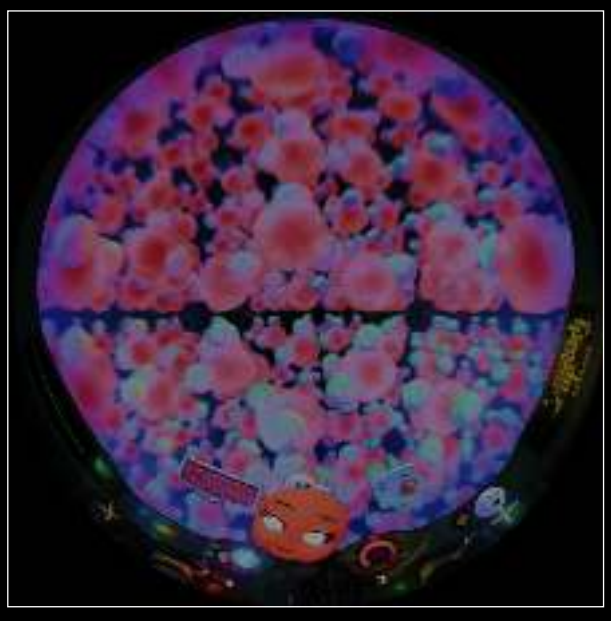
Fisheye projections

Fisheye example.
As if one is looking straight up from the floor.

Fisheye with the sweet spot
30 degrees up from the front dome edge.

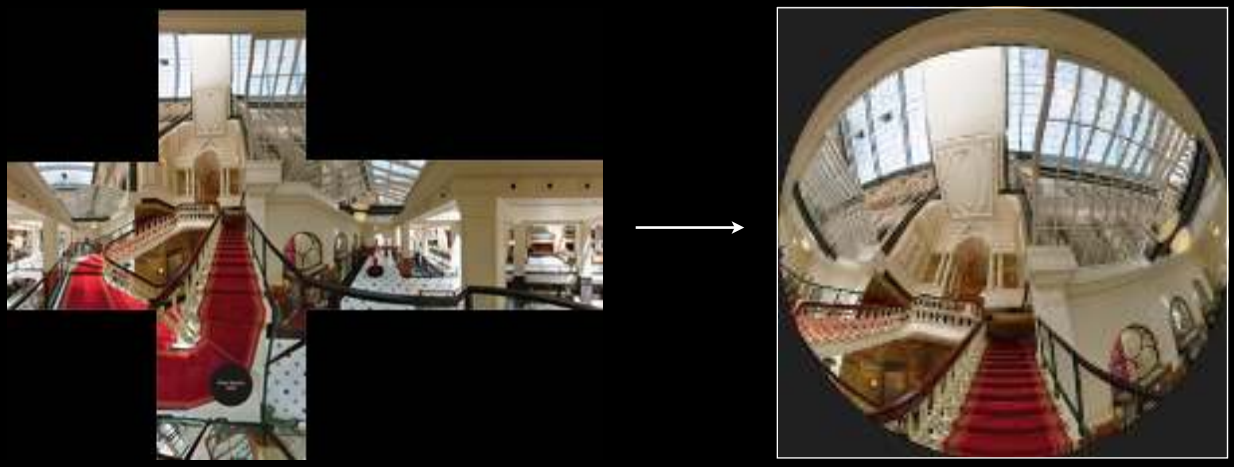
Content creation: CG, direct fisheye

- Many 3D modelling and animation packages now support direct fisheye rendering.
- Either natively or through plugins.
- For example: 3DStudioMax, Lightwave, Maya ....



Content creation: Cube maps to fisheye

- Standard technique when the rendering software does not support direct fisheye.
- Render 4 x 90 degree field of view ... stitch the result into a fisheye projection.
- There are a number of stitching packages available, eg: GLOM, and my own "cube2dome".



Content creation: Fisheye photography

- Many professional cameras have fisheye lenses available.
- "Fisheye lens" for photographers is often just a very wide angle lens. Term used in photography circles is "circular fisheye".
- Sunex have a 185 degree fisheye lens for Canon and Nikon SLR cameras.
- Sigma 4mm fisheye lens for Canon cameras, such as the Canon EOS 5D MkII.
- Capable of capturing at sufficiently high resolution for all but a few high end planetariums.

Content creation: Fisheye filming

- Much more difficult to get sufficient resolution.
- A fisheye image within a HD video camera creates at best a 1080x1080 fisheye image. This is generally not high enough resolution.

Fisheye filming example in the iDome

Content creation: Spherical filming, Ladybug

- LadyBug-2 and LadyBug-3 camera captures video as full spherical images.
- 360 degrees in longitude and about 150 degrees in latitude.

LadyBug-3: Example

- The spherical projection contains all the visual information from a single position.
- Resolution of spherical projection: 5400 x 2700.
- Resolution of fisheye: ~2500 x 2500.
- Fisheye projections can therefore be created in any direction.

Full spherical projection
Sample frame from the LadyBug-3 video

One possible fisheye projection
from the spherical projection

LadyBug-3: Example

LadyBug-3: example in iDome

Examples

- Fulldome demonstrations
  - Cosmology (simulation vs survey) [4 min]
  - Tornado visualisation [1 min]
  - Mathematics (fractal geometry) [3.5 min]
  - Volume visualisation [8.5 min]
  - Public education (nanotechnology) [1.75 min]
  - Virtual heritage (Antarctica) [6.75 min]
  - Photography (Great Barrier Reef) [3.5 min]
  - Science education/entertainment (Molecularium trailer) [3.25 min]
  - Artistic/entertainment (Starlight) [4 min]
  - LadyBug-3 example (Dervishes, Istanbul) [0.74 min]

- Children of the Water [6 min]