Enhancing research with new and emerging presentation technologies

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Introduction to visualisation

Relevance to this symposium: Leveraging the human visual system

Stereoscopy, immersion and how displays can deliver that.

A “new” way of thinking about displays and their abilities

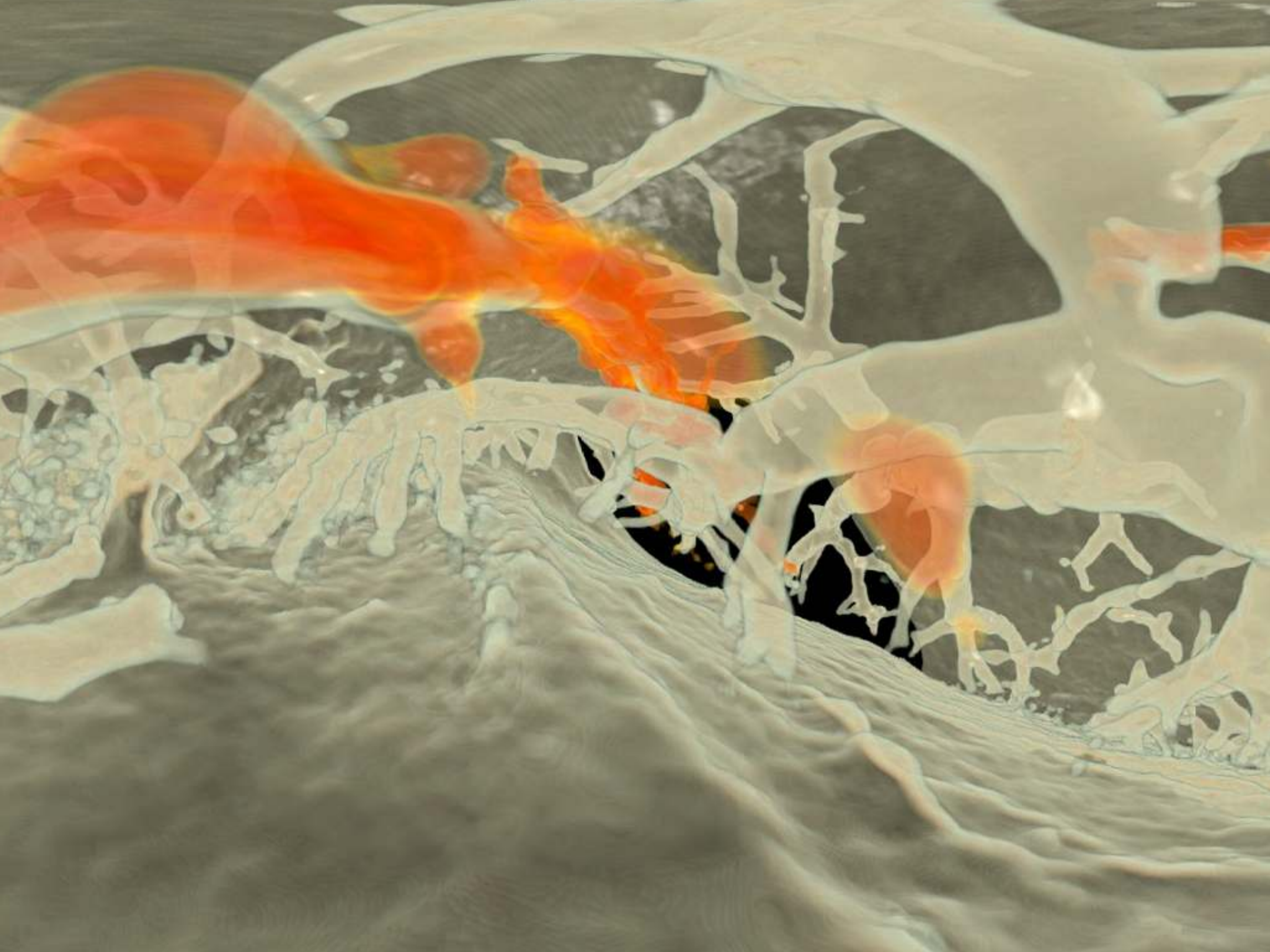
Some other novel visualisation techniques

Visualisation

- The application of computer graphics and advanced algorithms to enhance the understanding of data, to provide insight.
- Key senses employed are the sense of vision (hence visualisation), hearing (sonification), touch (haptics).
- Often leverage key characteristics / capabilities of the human visual system: fidelity (high resolution), depth perception (stereoscopic 3D), and peripheral vision.

6000 pixel wide, stereoscopic, large scale display. UWA

Rock shelters inhabited by indigenous Australians for up to 70,000 years.



Visualisation, stereoscopy, immersion and displays

- Immersion, "being there" ... around the extent to which one feels like one is really within an imperfectly mediated world (Mimetic Immersion).

- Werner Wolf describes immersion as : "... a feeling, with variable intensity, of being imaginatively and emotionally immersed in a represented world and of experiencing this world in a way similar (but not identical) to real life".

- The focus for data visualisation is often around the extent to the digital delivery engages/leverages the human visual system, and other senses.

- In the case of vision this is relates to:
  - stereopsis (depth perception arising from images from two positions, our eyes)
  - peripheral vision (for humans about 170 degrees by 120 degrees)
  - fidelity (spatial and temporal resolution)

- How do we rate the degree to which a display can support immersion and by implication how it can enhance visualisation?

Visualisation laboratory, UWA

- Displays of different types, how to rate them? None are perfect.
- Can do this qualitatively (user surveys) but would be helpful to have a quantitative basis.
- If none of our displays are perfect, how do we rate the most important characteristics?

The plenoptic function, a new way of thinking (?)

- Plenoptic: (optics) Of or relating to all the light, travelling in every direction in a given space.
- The "light field" is the infinity of 3D points through which innumerable light rays (photons) enter and exit every point.
- The part of the light field we observe (in one eye) are the two spherical images located at the position of our eyes.
- The plenoptic function is a 7 dimensional function of position: (3 variables), polar angle (2 variables), wavelength and time.

$$L(x, y, z, \theta, \phi, \lambda, t) = i$$

Converging rays arriving at any single point of the light field can be imagined as a spherical image of the world seen from that single position.

Plenoptic function

- An ideal immersive display needs to represent this light field intensity "i".
- Any (current) display is only an approximation of the light field, display artefacts include:

Display artefact	Display Feature	Limitation of L()
Monoscopic	Single image	x,y,z
Frame	Limited field of view	θ, ϕ
Pixels	Resolution	θ, ϕ
False colour	Colour gamut	λ
Colour banding	Colour depth	λ, i
Low contrast / brightness	Dynamic range	i
Noise	Signal to noise	i
Lag	Latency	t
Refresh rate / flicker / jitter	Frame rate	t

Case 1: 4K desktop display

Light field parameter	Comments	Rating
x,y,z	Not stereo3D enabled. No head tracking.	
θ, ϕ	Framed view, angular field is limited.	
θ, ϕ	High pixel resolution so low angular discretisation	
λ	Standard display technology capabilities, would be improved by HDR display.	
t	Standard display technology of 60Hz	
i	Standard display technology capabilities.	

Good

Not ideal but current state of technology

Not ideal and limited by nature of system

Poor

Standard tiled display

Tiled display

Light field parameter	Comments	Rating
x,y,z	Not stereo3D enabled.	
x,y,z	No head tracking.	
θ, ϕ	Wider field of view by standing closer, still framed.	
θ, ϕ	High pixel resolution so low angular discretisation.	
θ, ϕ	Bezels add blind spots at certain angles.	
λ	Standard display technology colour capabilities.	
t	Standard display technology of 60Hz	
i	Standard display technology capabilities.	

iDome

- 180 degree field of view, single person dome.

iDome

Light field parameter	Comments	Rating
x,y,z	Not stereo3D enabled.	
x,y,z	No head tracking.	
θ, ϕ	Largely removes framing of human visual field.	
θ, ϕ	Most common variation has modest resolution, so high angular discretisation.	
λ	Standard projector colour specifications.	
t	Standard for projector, 60Hz	
i	Standard for projector but degraded by interrefections and imperfect optics.	

Oculus Rift

- One of a number of low cost head mounted displays on the market.

Oculus Rift

Light field parameter	Comments	Rating
x,y,z	Stereo support	
x,y,z	Position (limited) tracking.	
x,y,z	View direction tracking.	
θ, ϕ	Wide field of view but doesn't fill human field of view.	
θ, ϕ	Low resolution, so high angular discretisation.	
λ	Standard projector colour specifications.	
t	Standard for panels.	
t	Poor head tracking latency.	
t	Standard refresh for panels.	
i	Standard gamut for panels.	

Stereo3D tiled display with head tracking

Stereo3D tiled display

Light field parameter	Comments	Rating
x,y,z	Stereo support.	
x,y,z	Position tracking.	
θ, ϕ	Significant portion of the human visual field engaged when close.	
θ, ϕ	High resolution so low angular discretisation.	
λ	Better colour than standard panels.	
t	Standard refresh rate of 60Hz.	
t	Head tracking latency.	
t	Panel refresh of 60 Hz.	
t	Glasses refresh resulting in time quantization.	
i	Standard for panels.	

Other novel visualisation techniques

- Interesting to consider the use of commodised technologies for more serious activities.
- Have explored three technologies more commonly found for merchandising, tourist “junk”.
- Lenticular prints - 3D printing - Crystal engraving.
- You can now judge how well they might represent the plenoptic function.

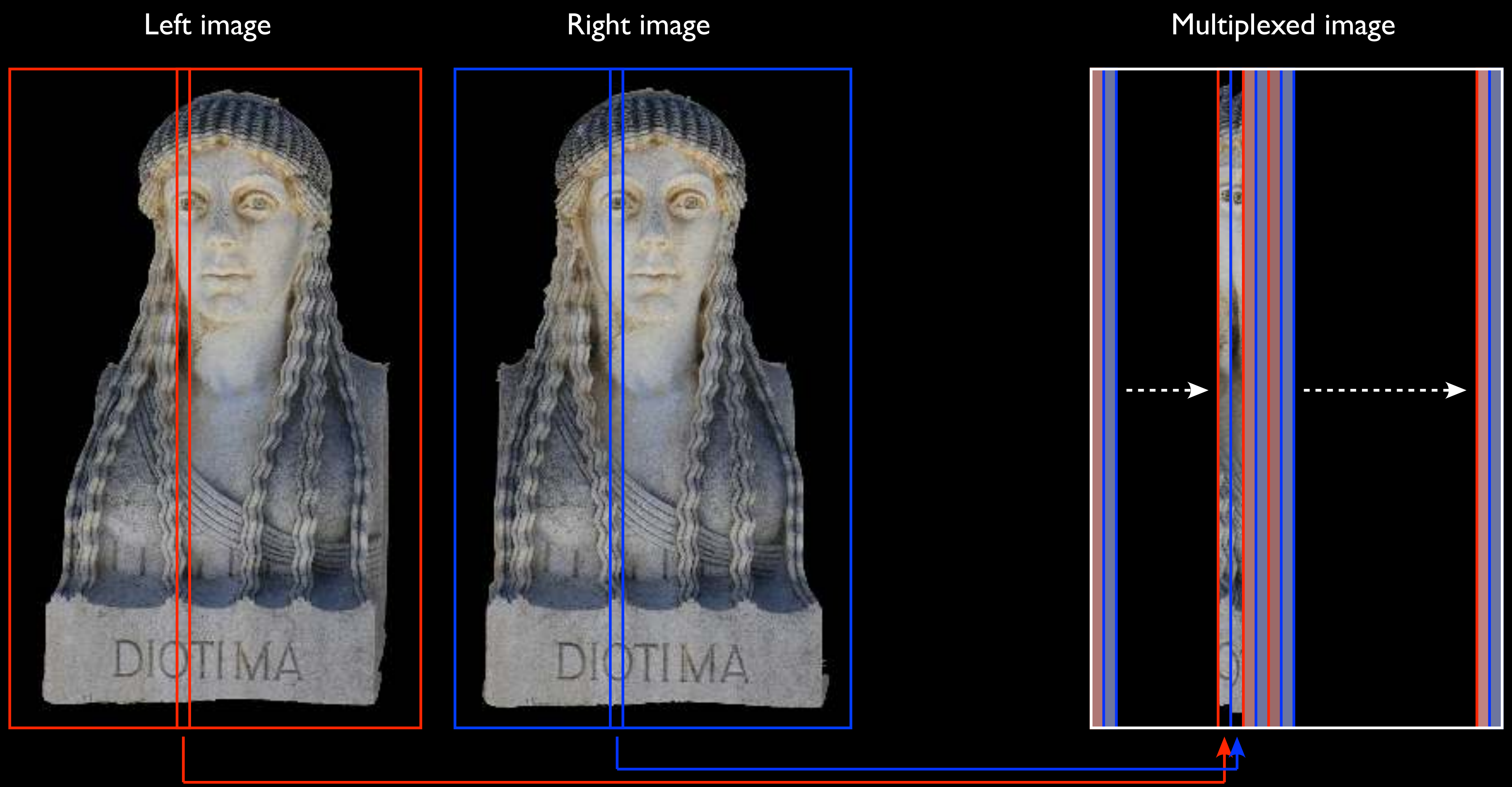
Lenticular prints

3D printing

Crystal engraving

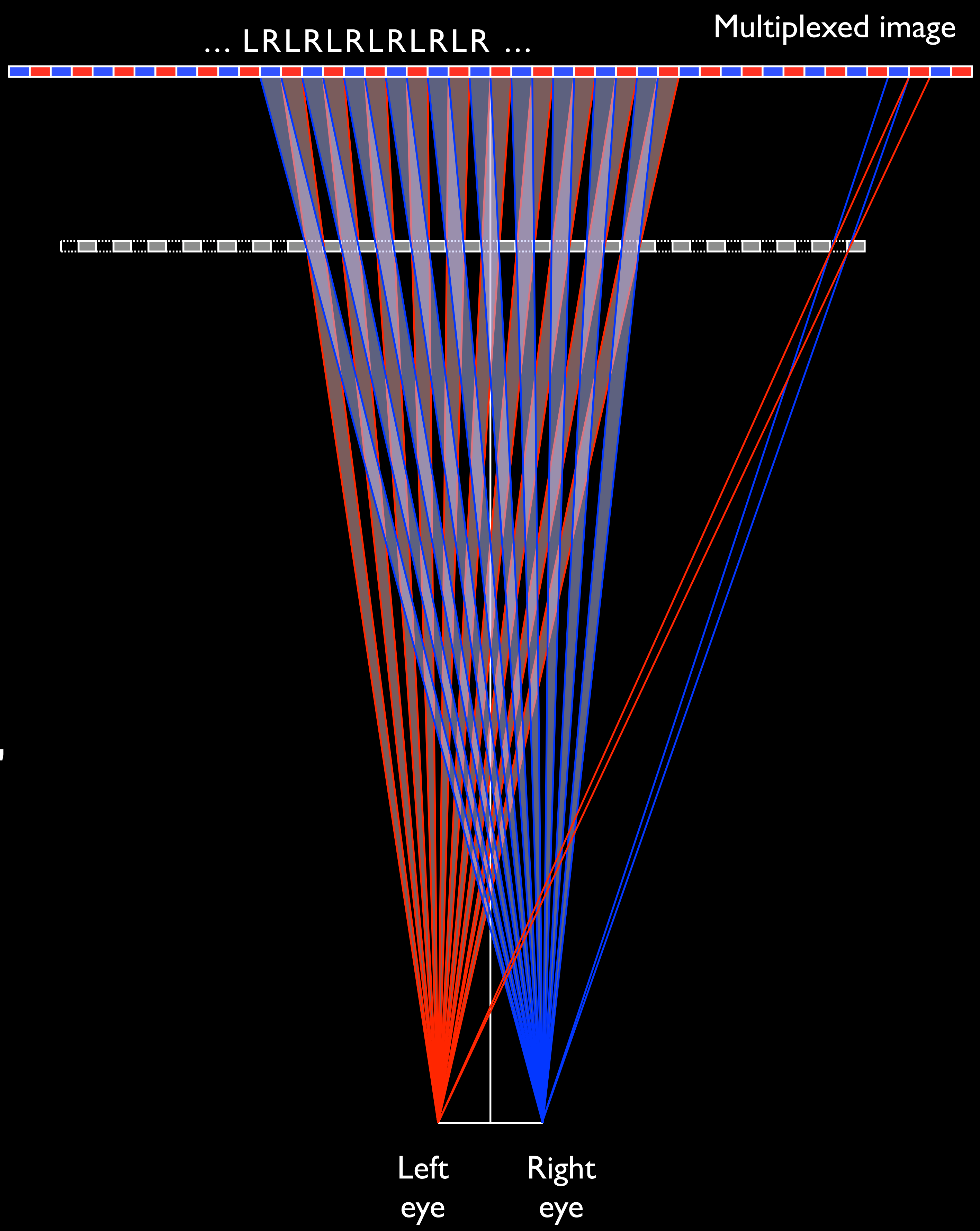
Lenticular displays or prints

- To date barrier strip or lenticular based displays have been low resolution.
  4K lenticular panel coming onto the market will improve this but higher density still required.
- Have been interested in lenticular prints for the presentation of visualisation.



Lenticular prints

- Barrier placed at just the right distance from the multiplexed image.
- Constrains the left eye to see only the left eye columns and the right eye to see only the right eye columns.
- Characteristics
  - Very precise viewing position required
  - Very precise printing process
  - Depth perception but no "look around" parallax.
- These are improved by lenticular rather than barrier strip.



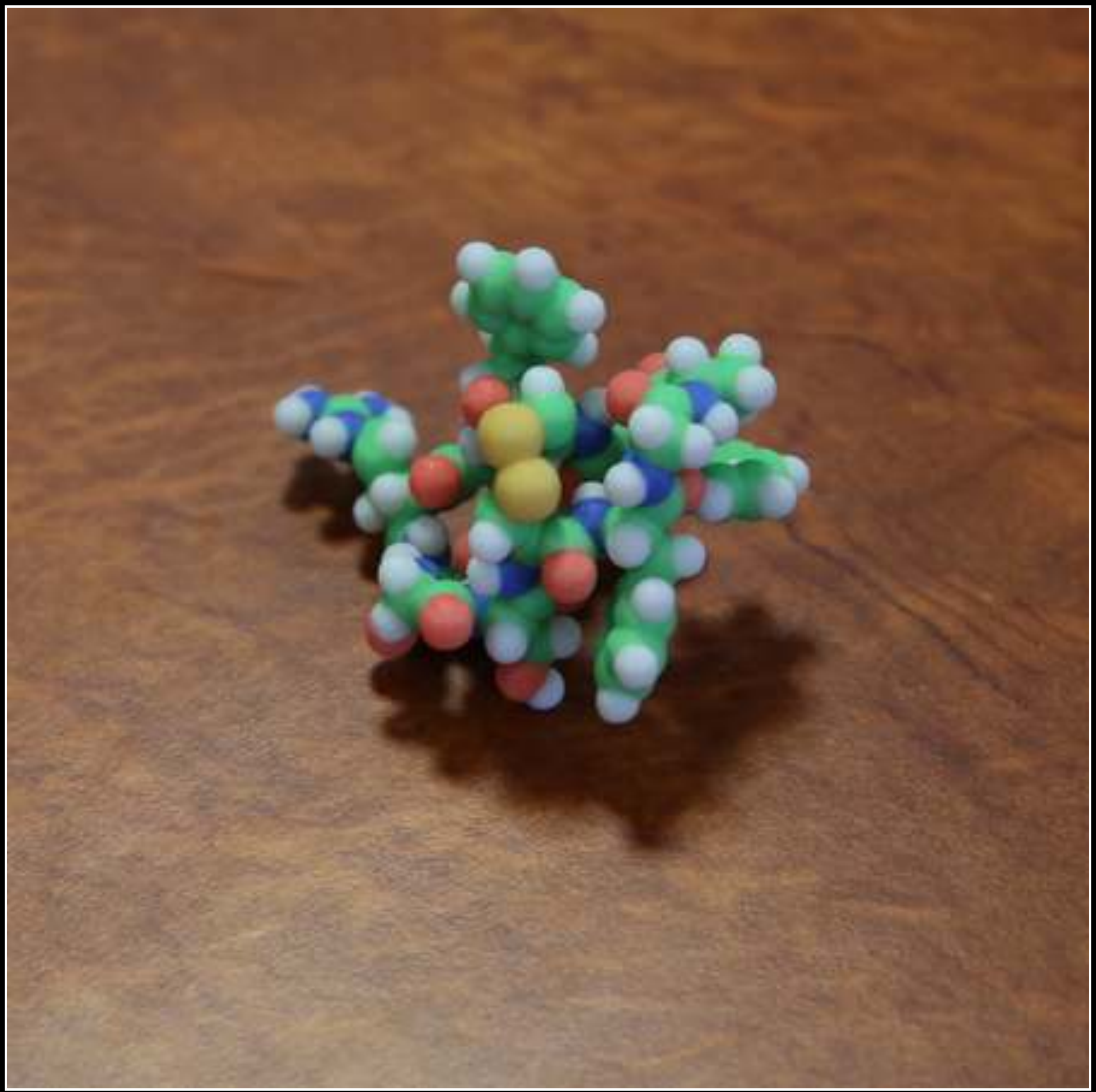
Lenticular prints

- Two photographs of the lenticular print from three different positions.
- Note the parallax difference, sides of objects visible in one photograph and not the othe

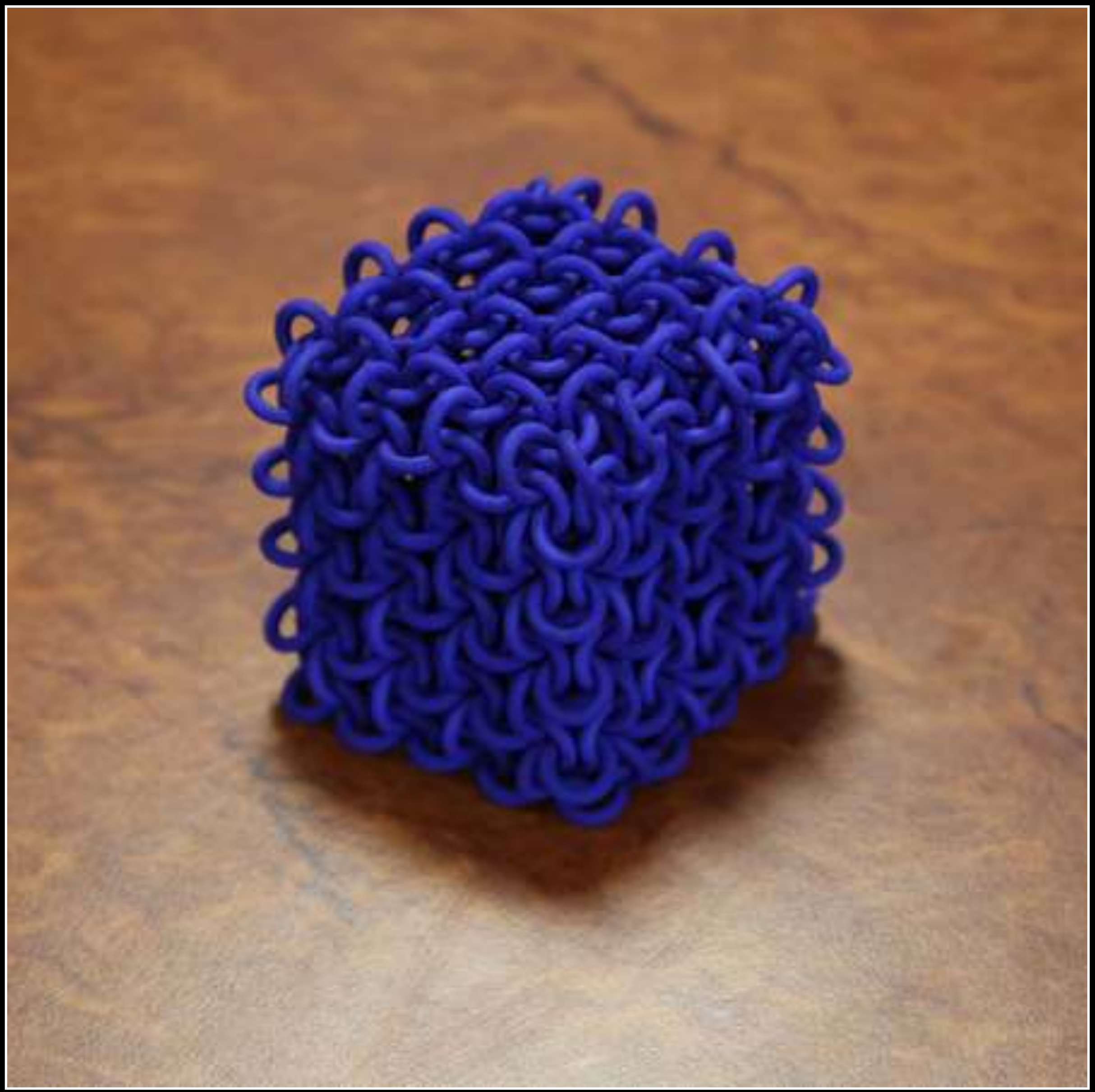
Physically realised data

- 3D prints and crystal engraving.
- These create solid objects of data which can then be explored in the same ways that we explore objects in real life, using our tactile and vision sense together.
- The ultimate stereo3D means of presenting data?
- Examples of a project to explore the use of technologies normally used for frivolous activities.
- In a sense these fully represent the plenoptic function but are limited in the types of data they can represent.
  - No time variation
  - Poor colour reproduction
  - Structural limitations

3D printing



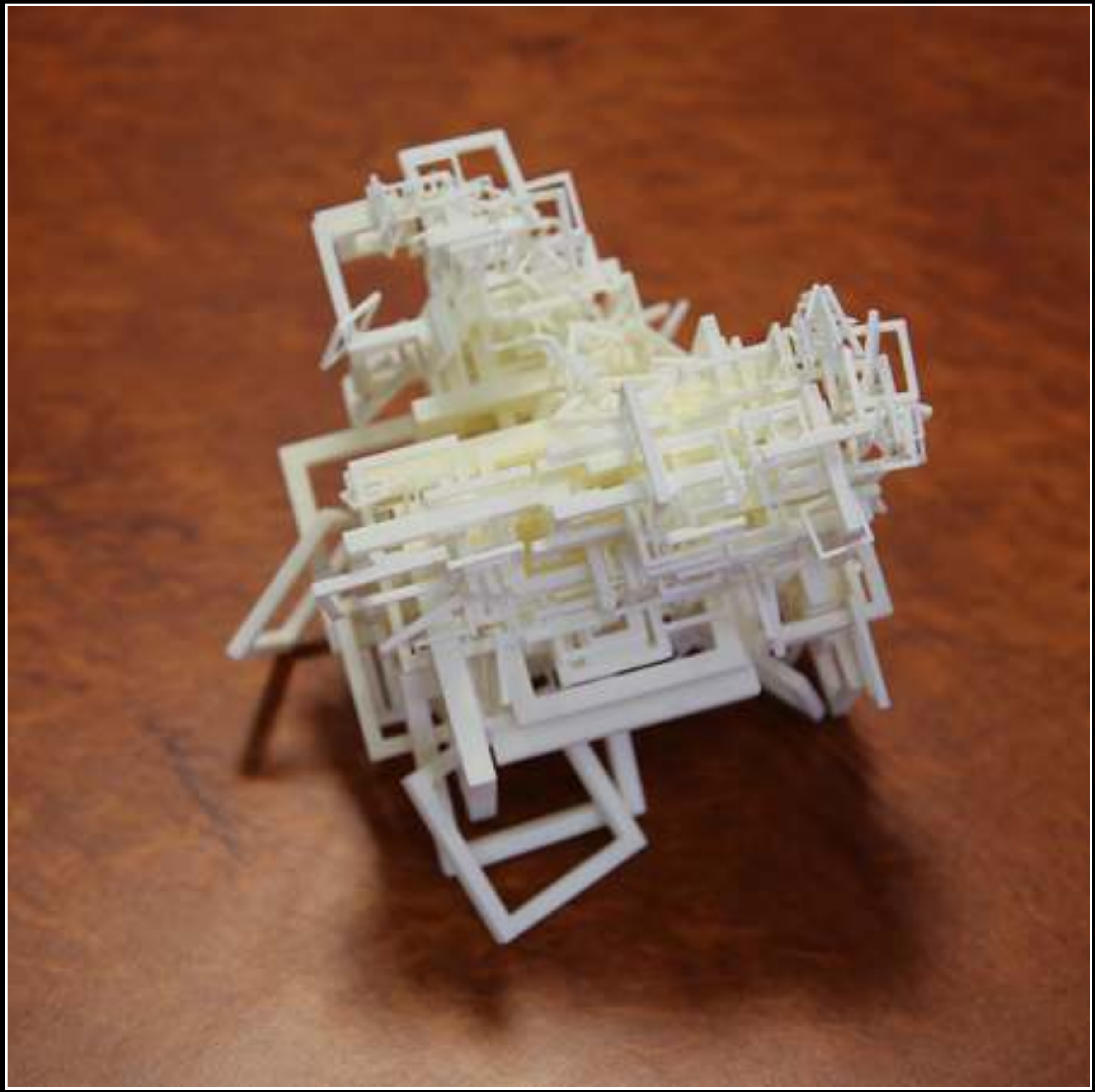
One of a series of 12 peptides.
A flaw in a claim being made by the researchers of the cyclic nature was discovered within minutes of them holding these. Despite viewing them on computer screens for some time.



Studies in topology, in this case three dimensional chain mail. Objects being realised using 3D printing that would be hard to create by other means.

3D printing

Radula (tongue like) from an ancient snail. Portion of the tongue derived from a microCT scan, original object 2mm in length. The cup like structures scrape at rock to derive minerals.



Packing theory in mathematics. The 3D print is not just for visualisation but also analysis. Determining if the packing is a single entity is very difficult in software. The 3D print makes it obvious whether it is a single or multiplicity of separate objects.

Crystal prints

- 3D prints are limited to largely connected objects.
- Crystal engraving provides an alternative supporting extreme resolution of 1/100mm.
- Limitations
  - Monochrome
  - Size limitations
  - Limitation on bubble density
    Too low and object is indistinct, too high and cracking can occur.

Egyptian mummy, CT scan

Human heart, MRI scan

Crystal prints

- Example from astronomy, 2dF galaxy survey data. Determining the 3D position of galaxies in two wedges, Earth and our galaxy in the center.
- 250,000 points, each one represents a galaxy in 3D space. Reveals the large scale structure of the Universe.
- Obviously cannot 3D print or result would be a collection of dust on the table.

Questions