Capturing Omni-Directional Stereoscopic Spherical Projections with a Single Camera

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Introduction

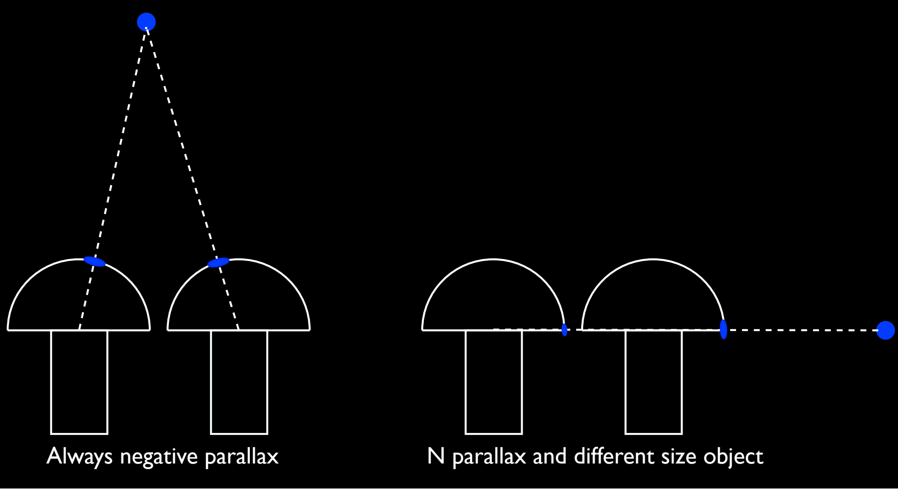
- Presenting visual information to our brains can benefit by leveraging the unique characteristics of our visual system: fidelity (resolution), peripheral field of view, and stereopsis (depth perception).
- Over the years various attempts have been made to engage all these three of these characteristics at once.
- Recently full hemispherical digital domes, once called planetariums, are being installed with stereoscopic 3D capabilities.
- Unlike many previous display technologies a hemisphere can entirely fill our visual field of view and modern digital projection can deliver very high resolution.
- What exactly is a stereoscopic fisheye image pair?
- In what follows I will propose a means of generating stereoscopic fisheye pairs that have the additional advantage of being "omni-direction", that is, they allow one viewer to look around and experience a stereoscopic experience without the need for head tracking, similarly they allow multiple viewers to all be looking in different directions.

One possibility

- One possibility is to simply use two cameras each with a fisheye lens.
  Indeed this is the model currently used for existing stereoscopic planetarium shows.

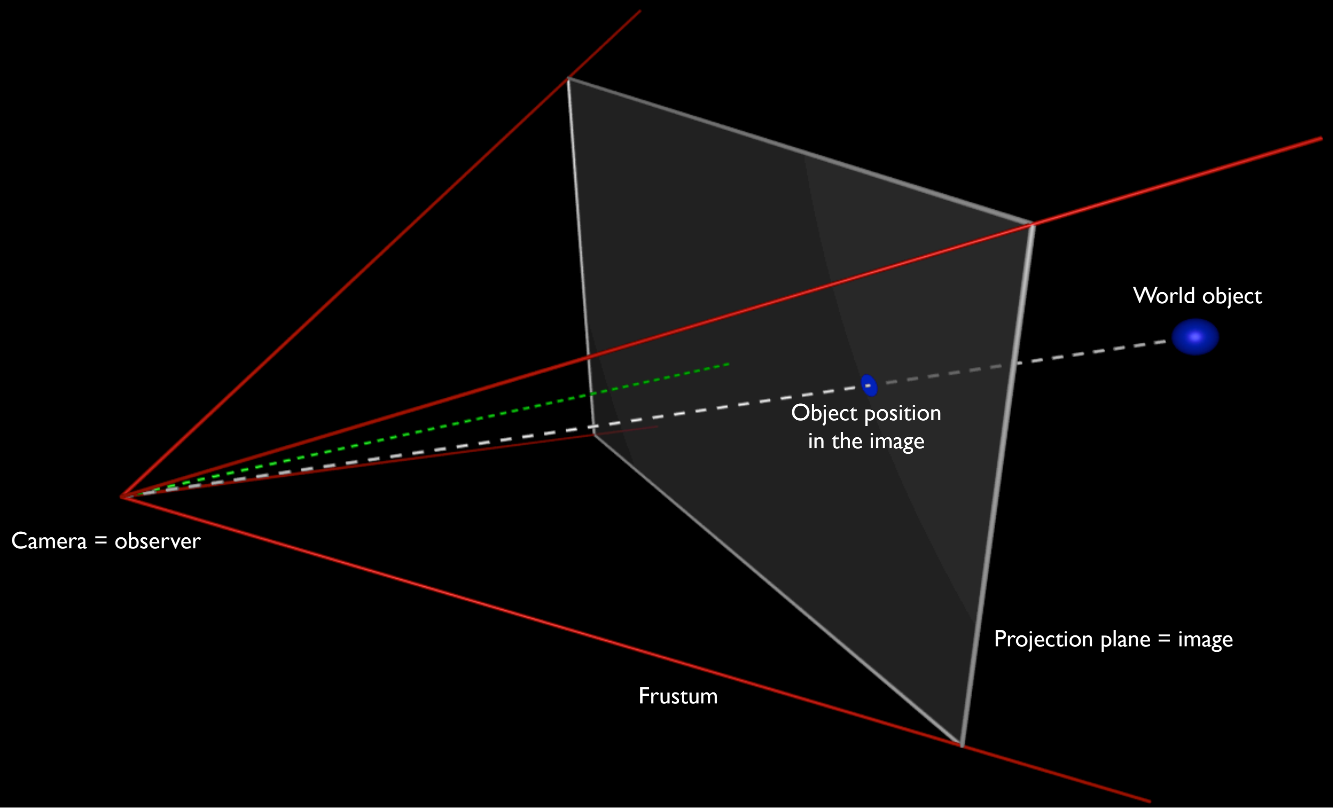
- Problems:
  - The stereoscopic effect only works when the viewer is looking forward.
    There is no stereopsis towards the left or right of the fisheye image.
  - For an audience, everyone needs to be looking in the same direction, forwards.
  - Without some additional distortion, all objects are in negative parallax.
    Infinity is located on the dome radius.

- These are solved with the proposed method for creating stereoscopic fisheye.



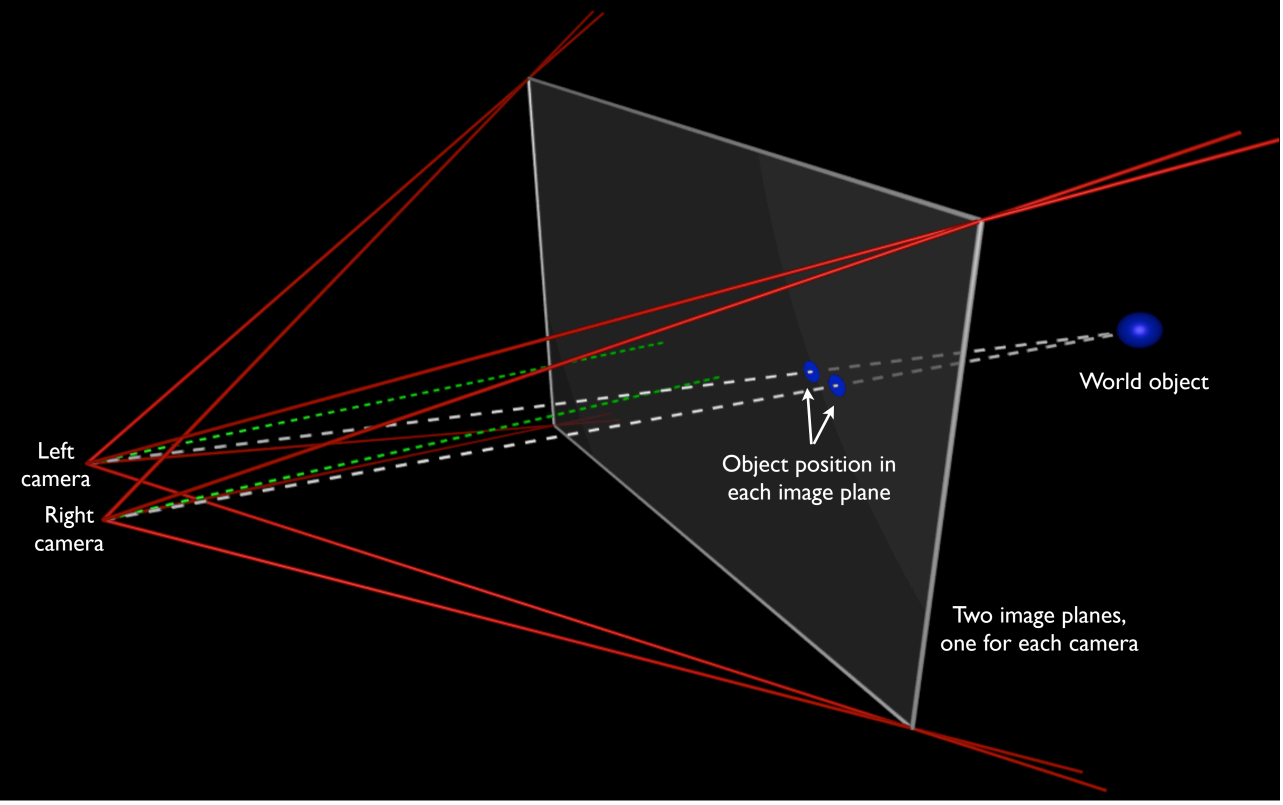
Fundamentals of pinhole camera

The correct way to think about standard idealised perspective projection is to imagine looking through a window on a real, or virtual, world.



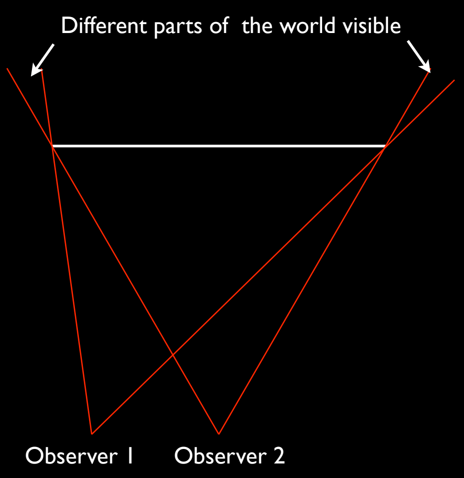
Fundamentals of stereoscopy

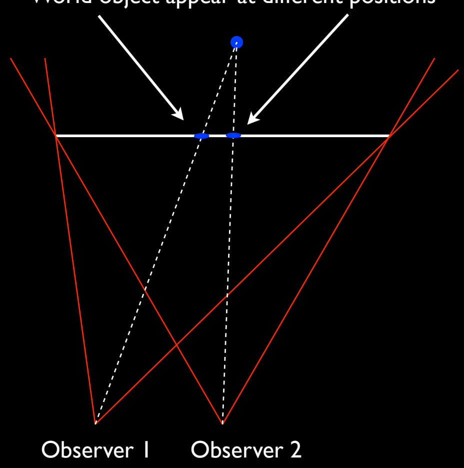
Extension to stereoscopic projection is straightforward.
The cameras are parallel (only horizontally offset) but have asymmetric frustums.



Consequences

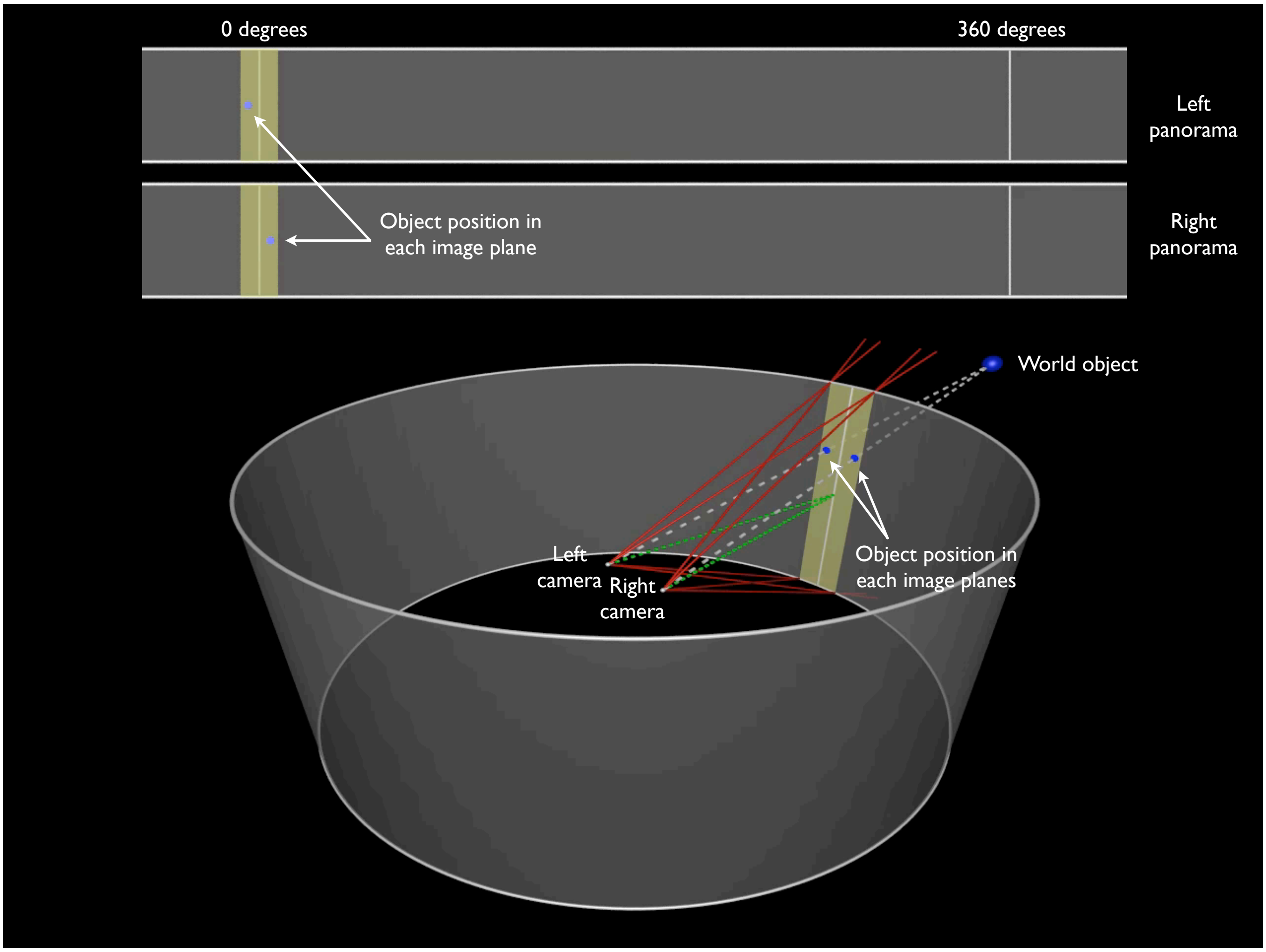
- A stereoscopic image pair is only strictly correct from a single viewer position with respect to the display surface.
- Viewing from all other positions results in a distorted view.
- In a stereoscopic display that occupies a significant field of view, the correct stereo image also depends on the viewing direction, obviously an issue for an audience.
- In virtual reality realtime environments this can be corrected for by head tracking and adjusting the frustums to preserve the correct view through the window.

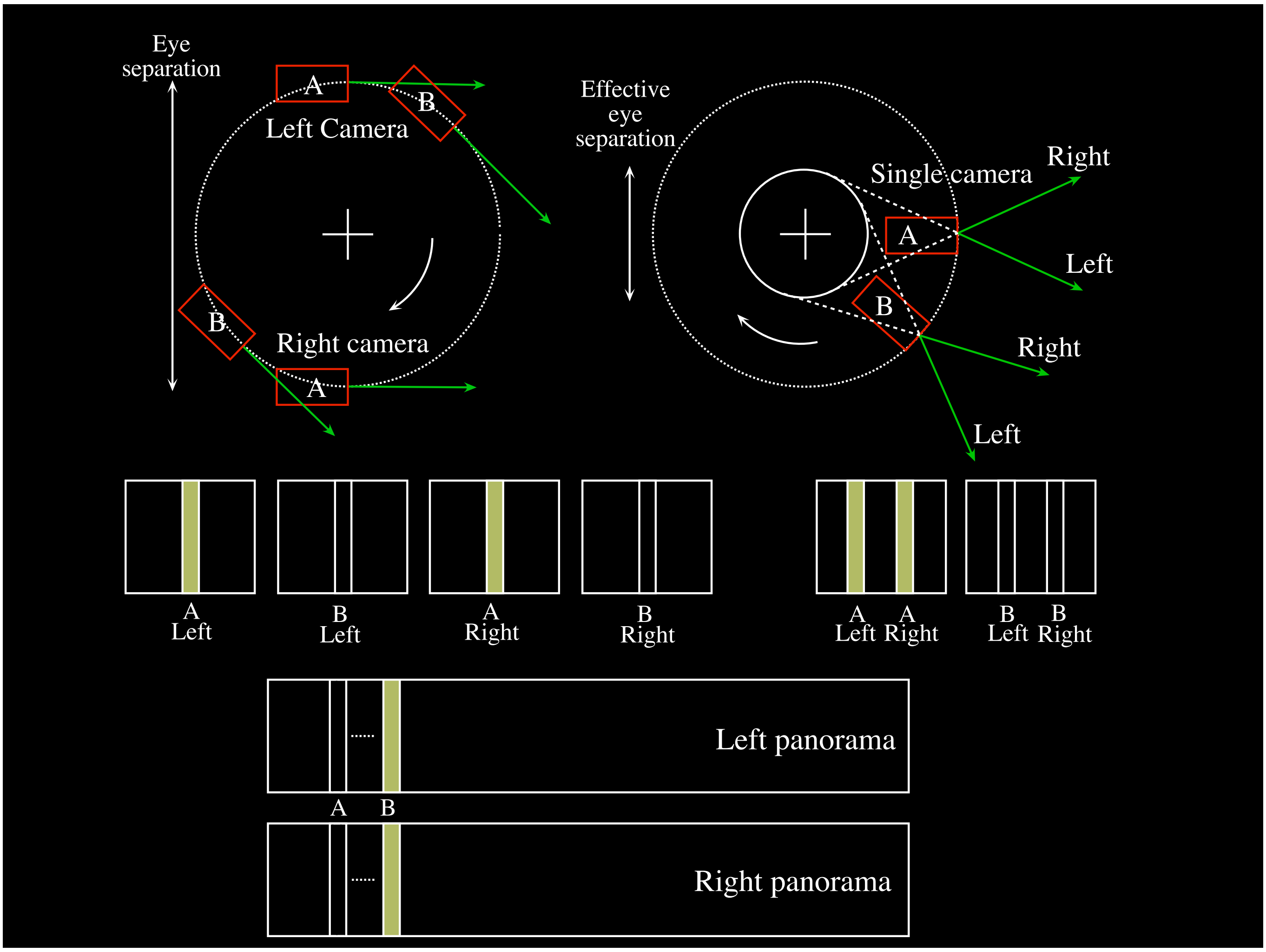




Omnidirectional cylindrical stereoscopy

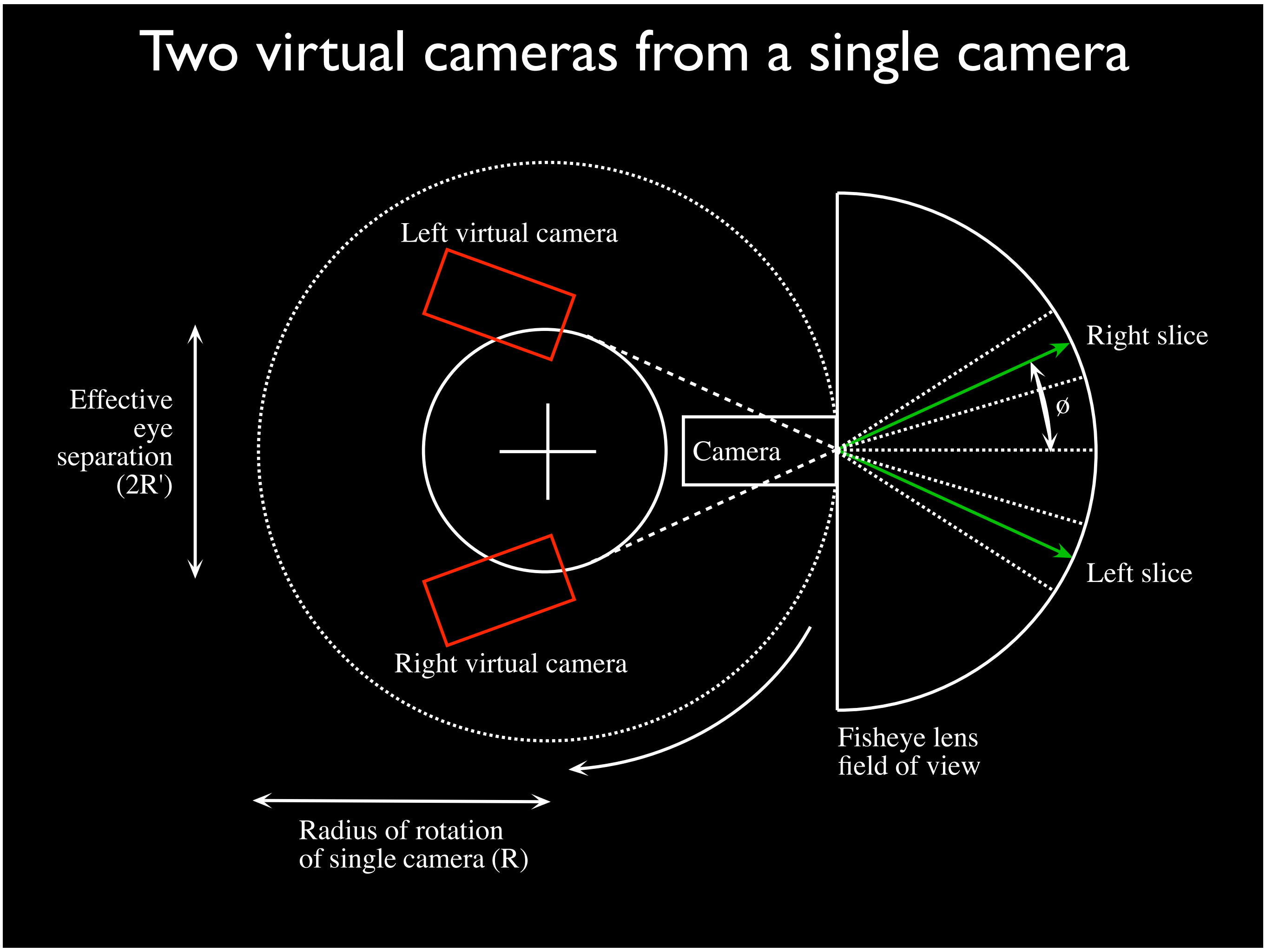
- By making a small concession it has been known for some time that one can create stereoscopic cylindrical image pairs that can be viewed without head tracking or viewed simultaneously by multiple people all looking in different directions.
- Still only strictly correct for a single viewing position but have relaxed the view direction constraint.
- See "Synthetic Stereoscopic Panoramic Images" presented at VSMM 2006, Xi'an. Includes a discussion of twin and single camera capture.
- The stereoscopic imagery is only strictly correct directly along a vertical strip in front of the viewer and is increasingly incorrect away from this strip.
- Acceptable because the frames of the glasses limit the field of view to this region.
- An immersive effect is still be achieved because one can still perceive imagery on the extreme left and right, past the glass frames. Not in stereo but neither is it in real life.

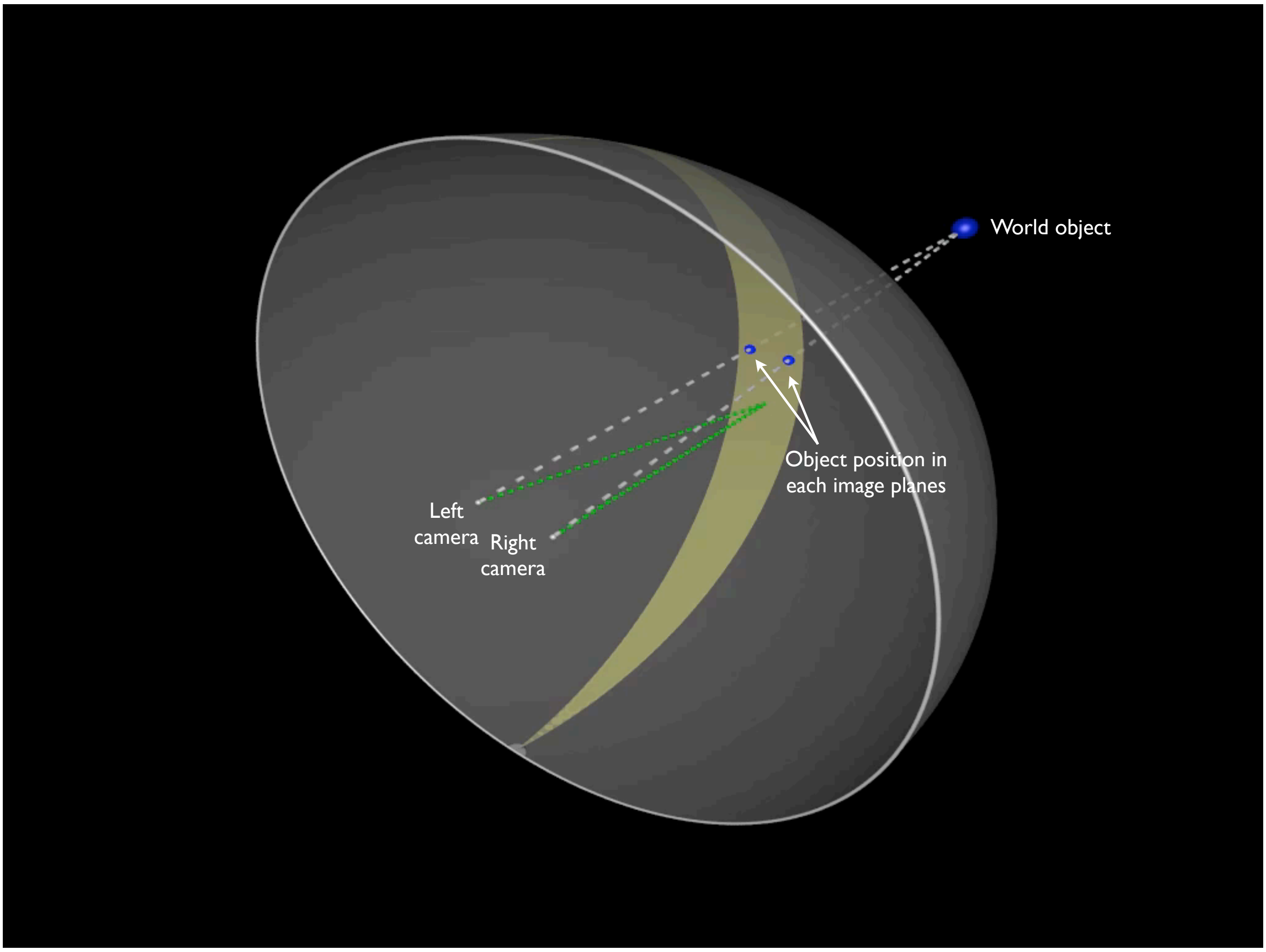




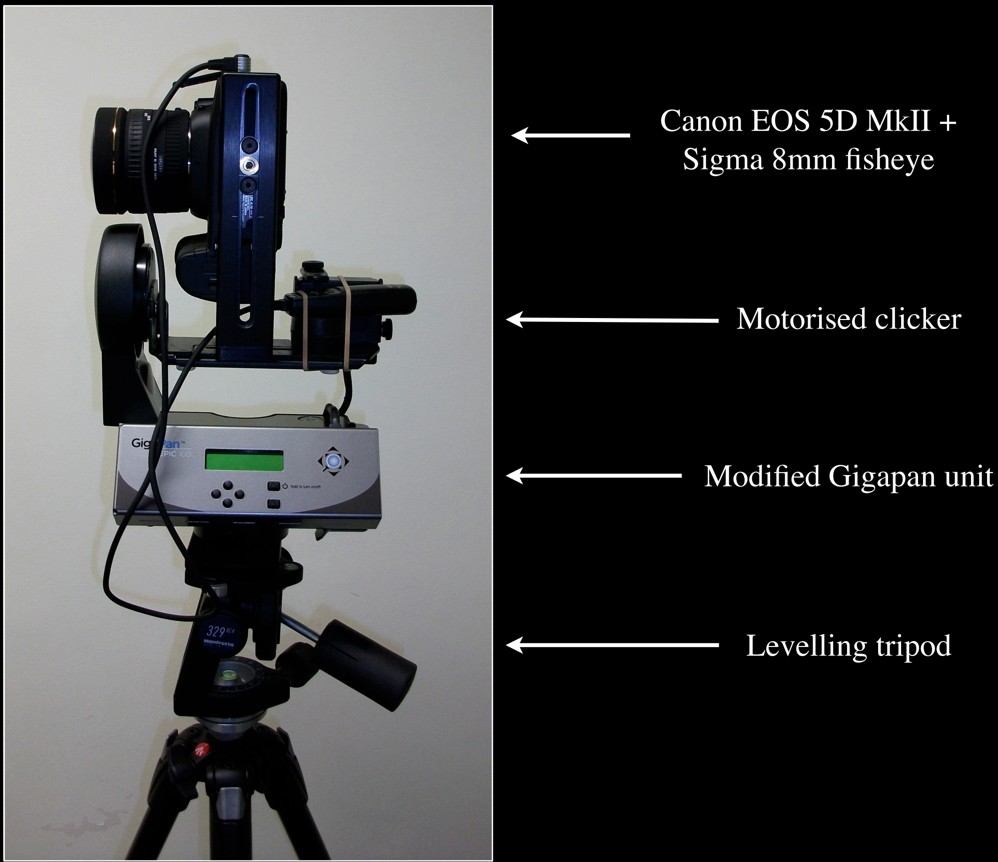
Extension to omnidirectional fisheye stereoscopy

- Extend to fisheye by using a lens with a 180 degree vertical FOV, generally known as a fisheye lens.
- The requirements for computer generated stereoscopic fisheye was published in Proceedings of CGAT'09 and presented at CGAT'09. This assumed a versatile rendering engine, such as a raytracer, where camera rays can be controlled directly.
- The extension of that process to camera capture is the subject of this paper.
- Limitations of previous work is mostly related to it being a manual post production process which in turn limited the number of camera images captured and subsequent errors towards the poles and for objects close to the camera.
- Processing pipeline
  - Capture fisheye images by rotating a motorised camera around an axis of known radius.
  - Automatically extract 2 lune wedges from each image.
  - Convert each pair of lune wedges to slits of a spherical projection.
  - Stitch/blend the slits together to form a spherical panorama or stereo fisheye.

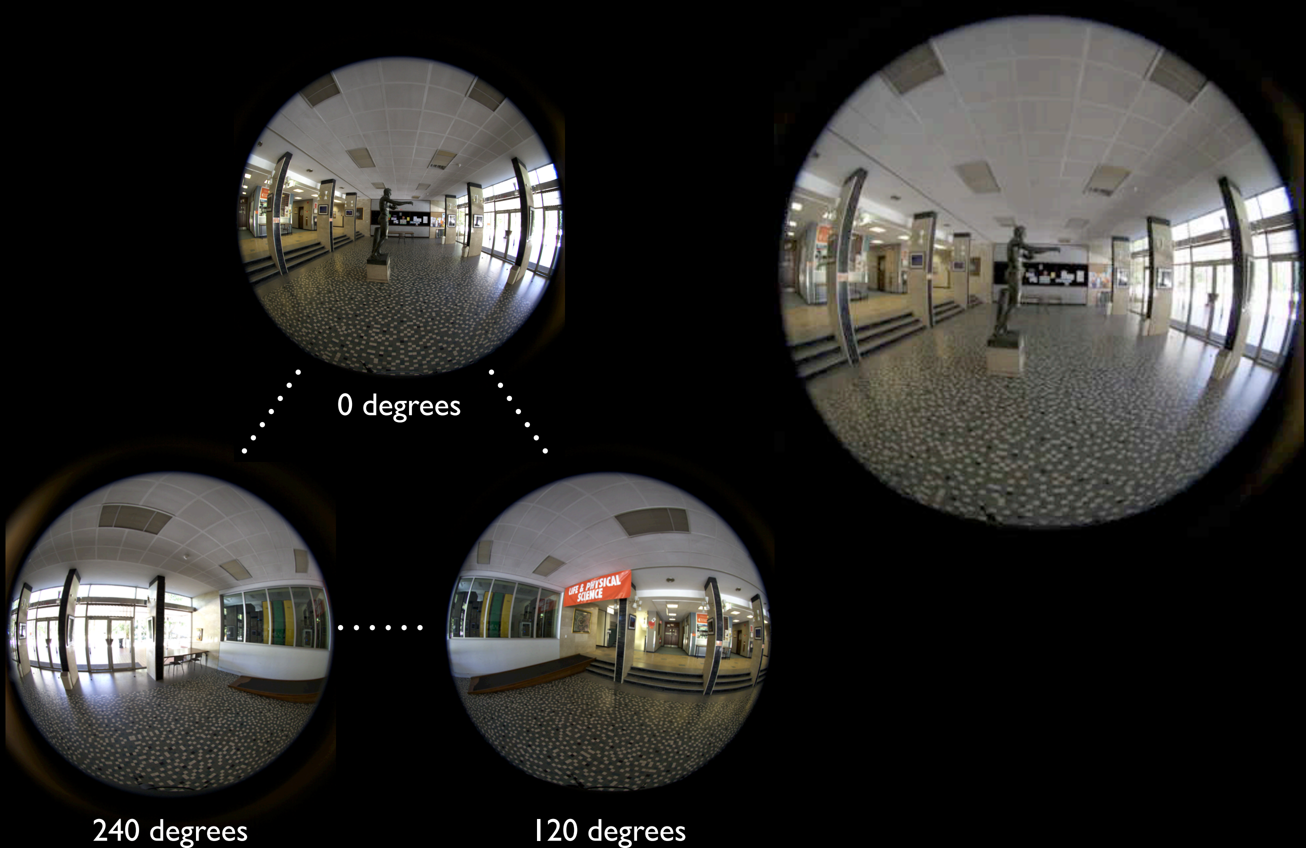

Two virtual cameras from a single camera
Left virtual camera
Right slice
Effective
eye
separation
(2R')
ø
Camera
Left slice
Right virtual camera
Fisheye lens
field of view
Radius of rotation
of single camera (R)

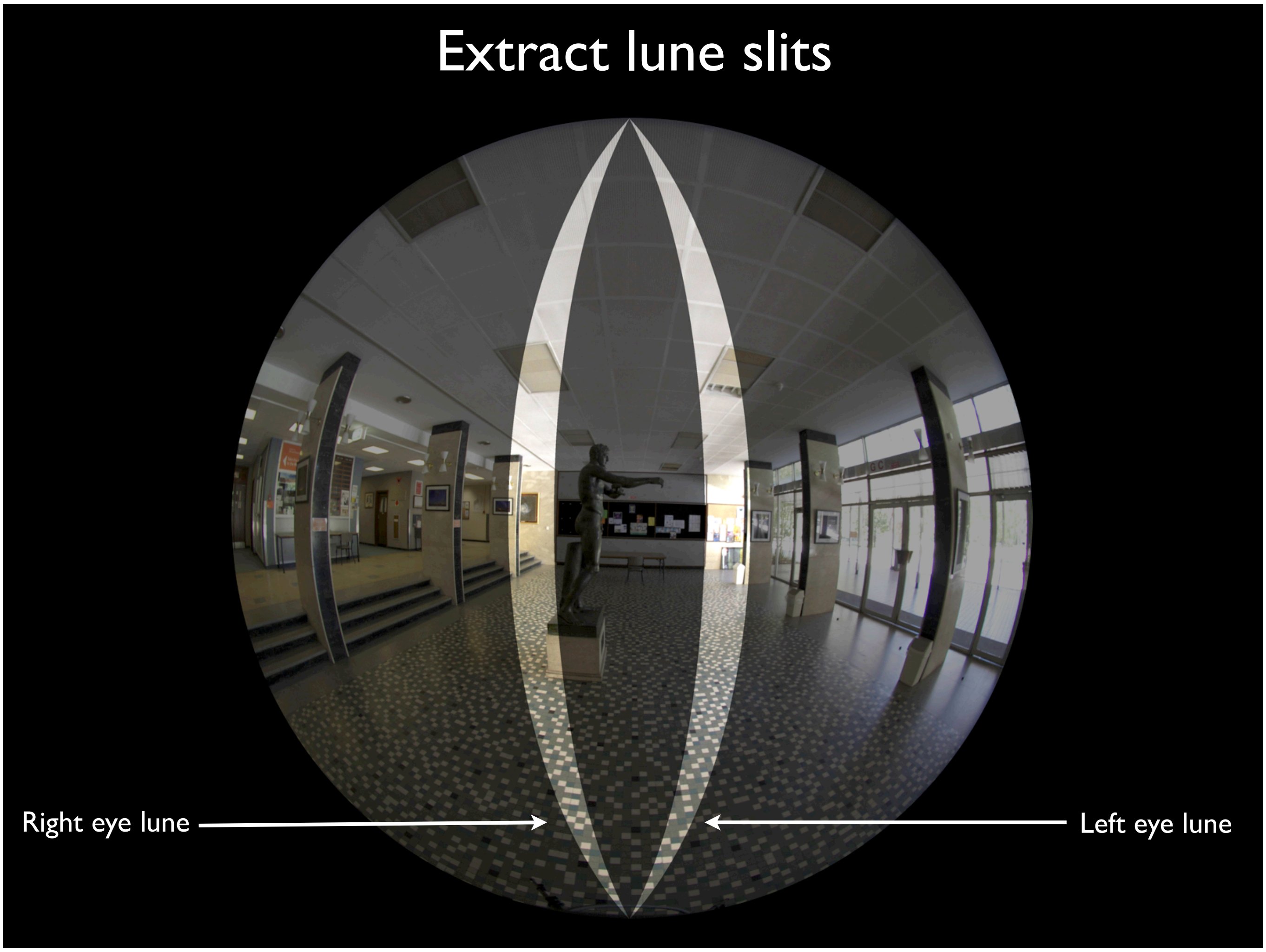

World object
Object position in
each image planes
Left
camera
Right
camera

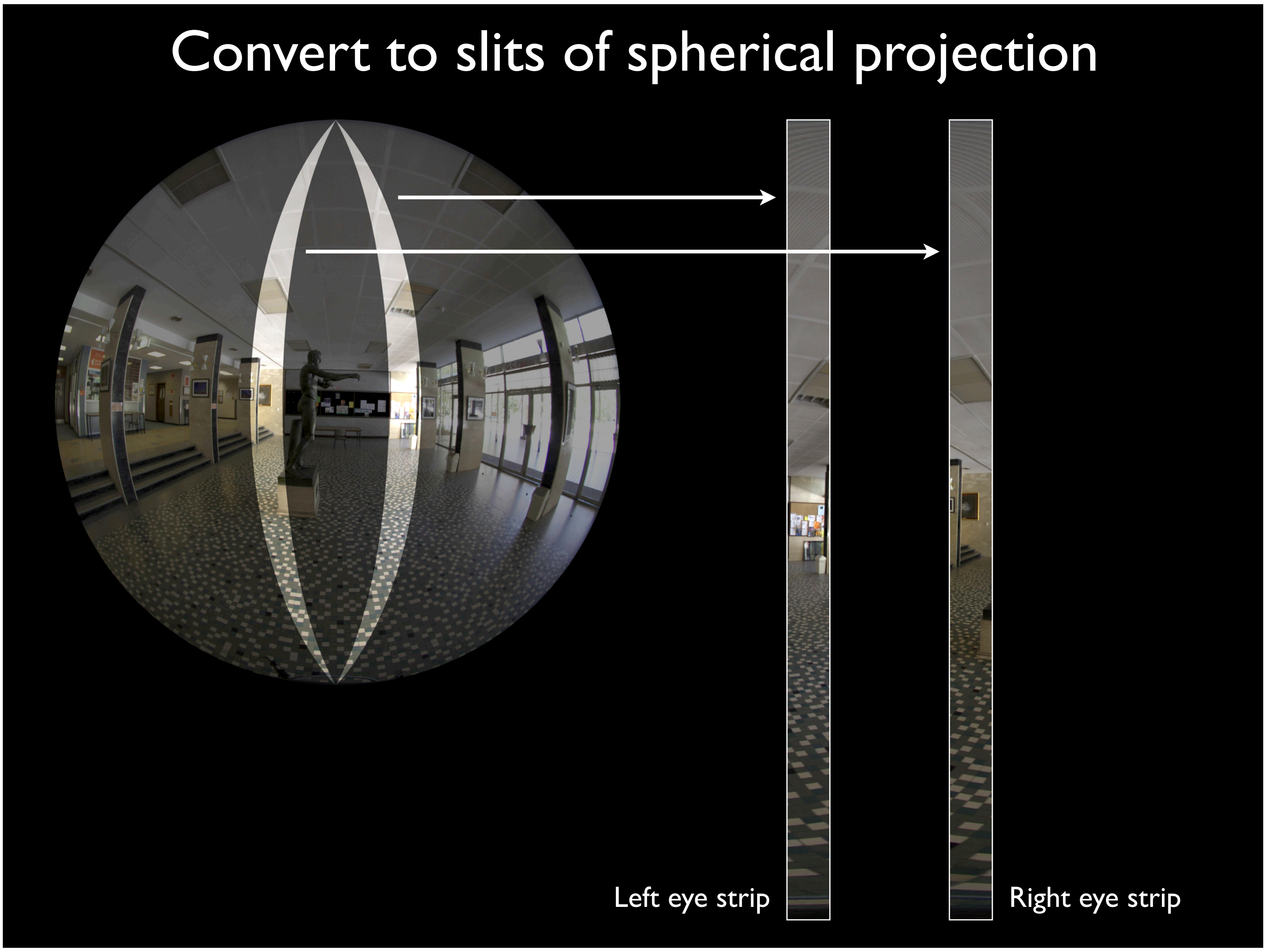
Camera rig



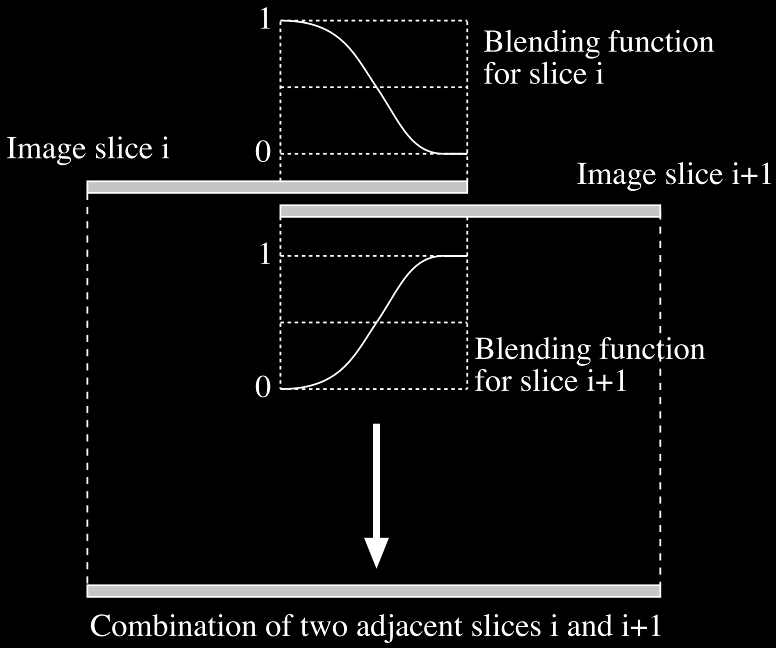
Capture fisheye images

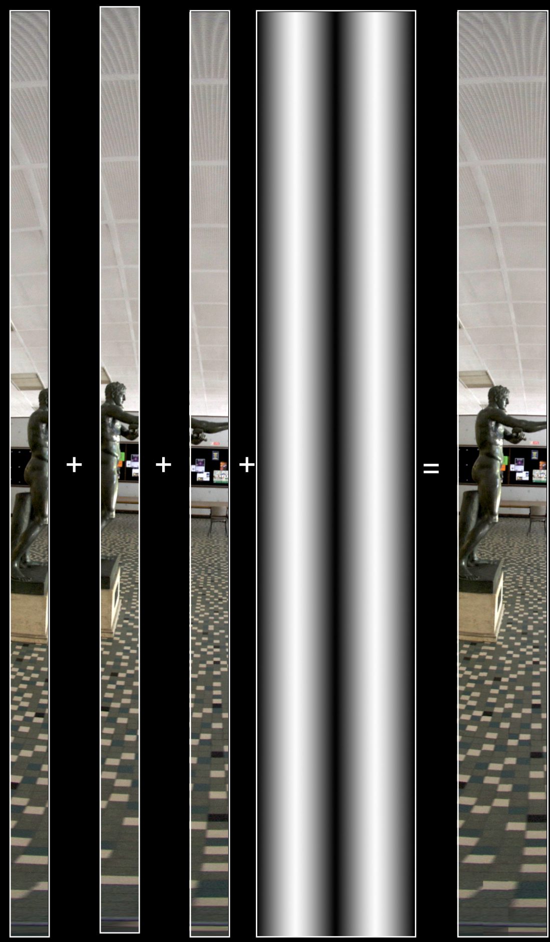



Extract lune slits
Right eye lune
Left eye lune


Convert to slits of spherical projection
Left eye strip
Right eye strip

Stitch/blend slices together





Form spherical panorama or fisheye

Left eye

Right eye

Spherical projections

Fisheye projections

Examples

- On a flat screen one is free to pan around with a perfectly adequate stereo experience.
- On a dome or cylinder one can both pan around or look in any direction.
  This is equivalent to saying multiple observers can share the same environment.
- The parallax is correct up to the poles of the fisheye, the image quality in that region is dictated by the quality of the camera rotation.

Single screen stereo display

iDome

Questions?

In a previous paper an algorithm was presented that created omni-direction stereoscopic fisheye pairs using a raytracer. An example is given there that creates the equivalent for a photographic image. That is, a stereoscopic image pair which when projected correctly in a hemispherical dome allows an audience to appreciate stereoscopic depth perception regardless of where they look.