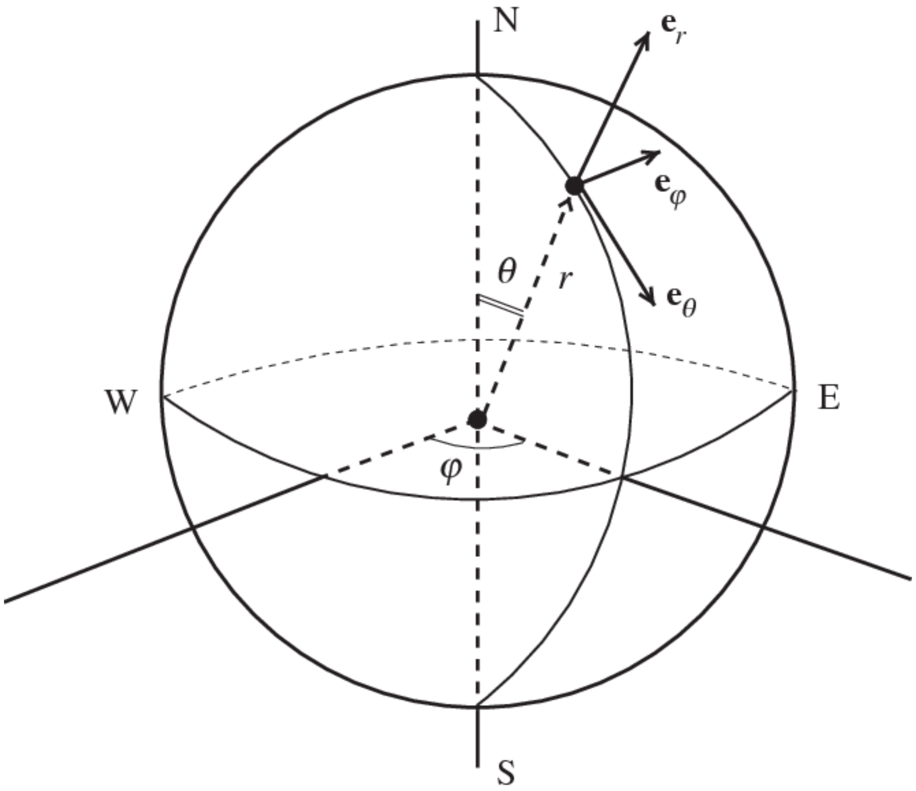
Lecture 14:

Environmental Camera and Virtual Reality

Contents

Environmental Camera

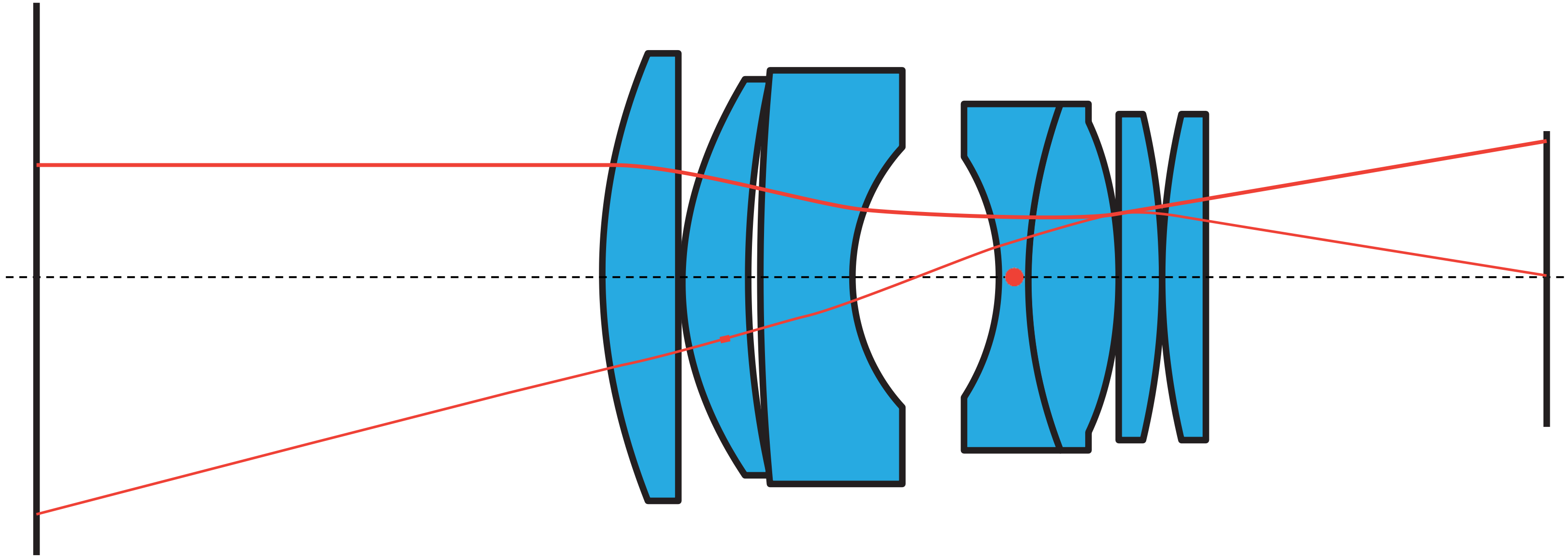
- A camera model that traces rays in all directions around a point in the scene, giving a 2D view of everything that is visible from that point. Such type of images is particularly useful because it represents all of the incident light at a point on the scene



- The current state of scientific and technological progress does not allow to build such a camera

Wide-angle optics

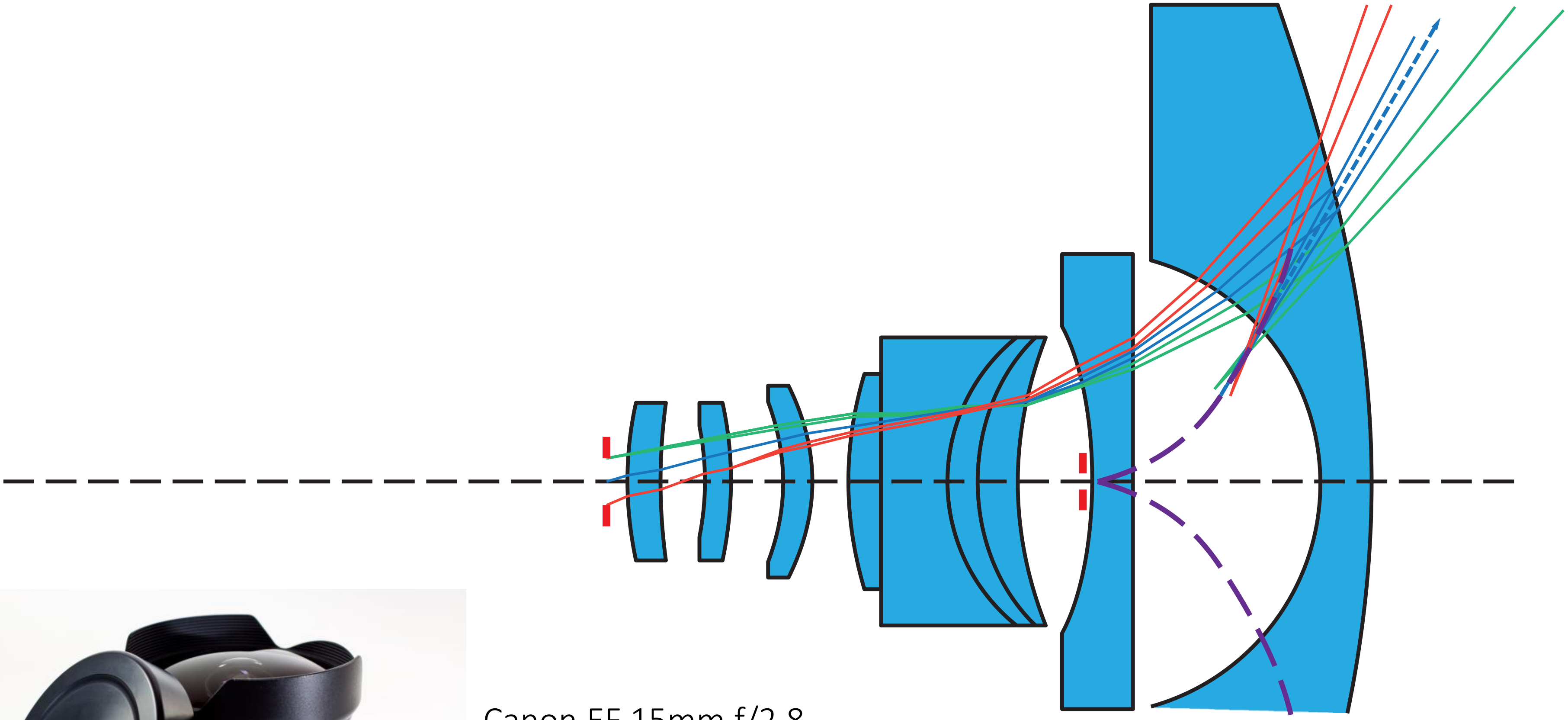
- Modern ultra-wide angle lenses can give up to 126° FOV (diagonal)



Canon EF 11-24 f/4L
USM Lens

Wide-angle optics

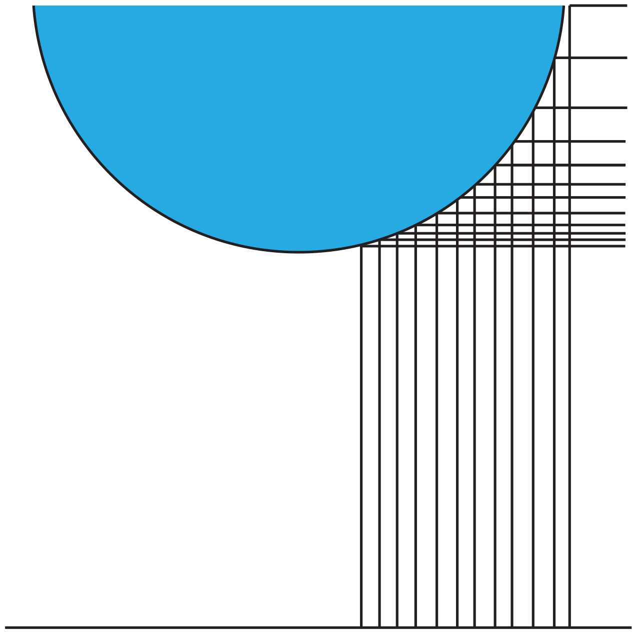
- Modern fisheye lenses can give up to 185° FOV (diagonal)

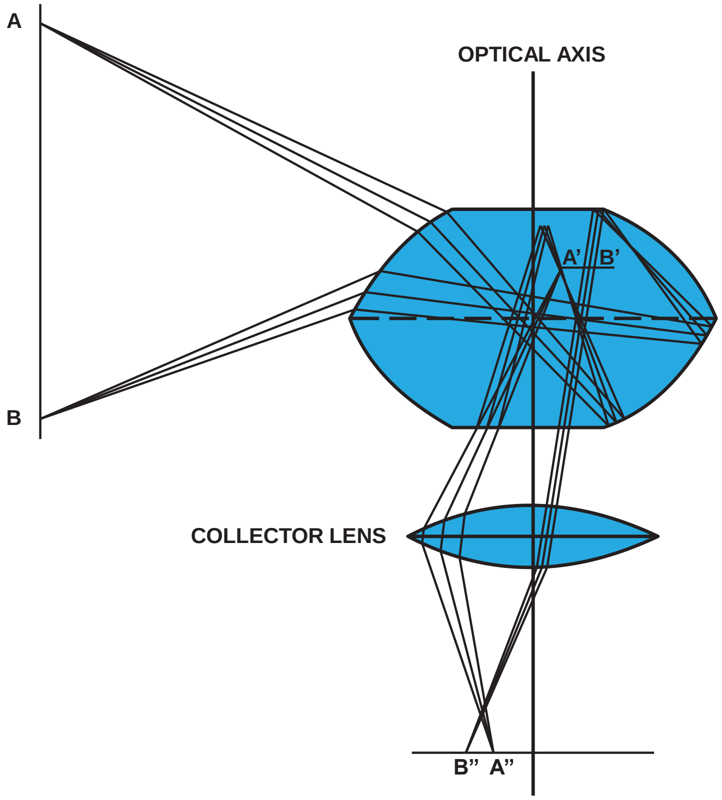


Canon EF 15mm f/2.8 Fisheye Lens with 180° FOV (diagonal)

Catadioptric optics

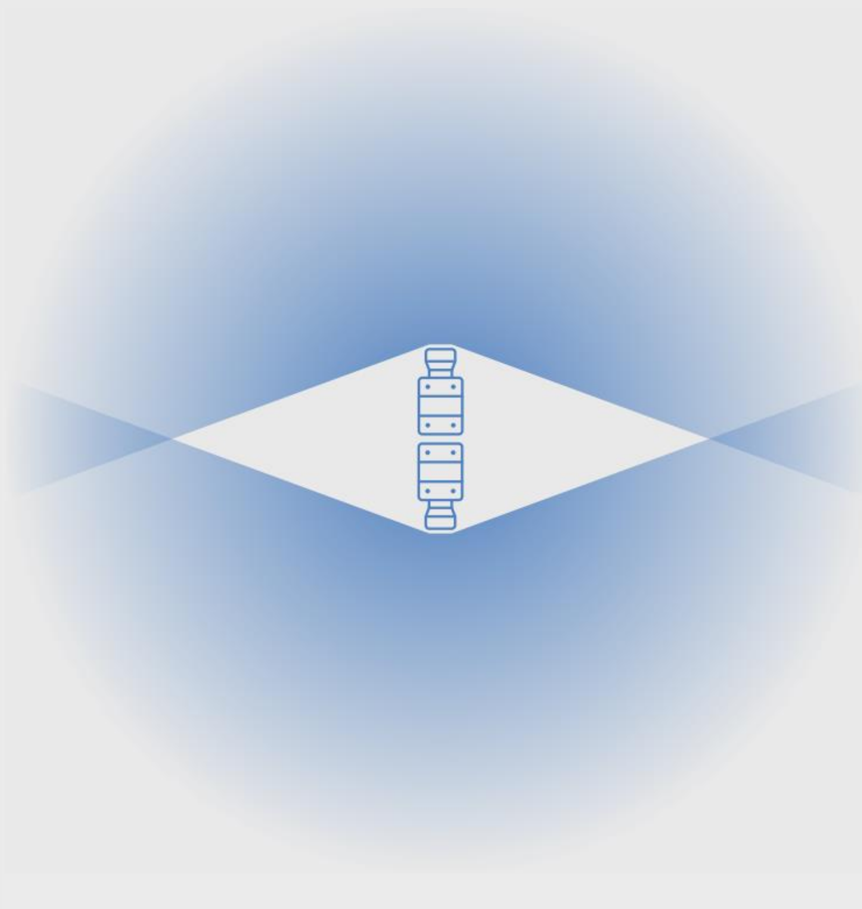
- These are really cylindrical capture but no stitch lines!





Monoscopic 360° capture

- Two cameras with fisheye lenses and field of view (FOV) of 185° are enough to build a reasonable physical approximation to the concept of environmental camera

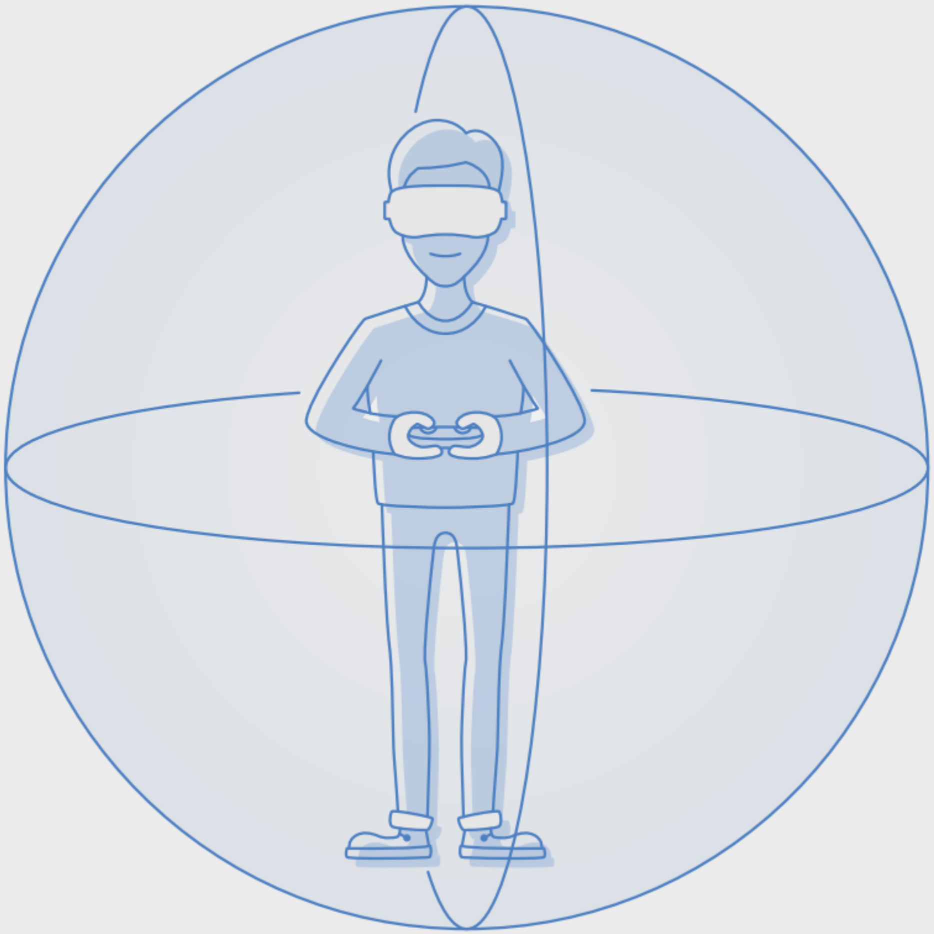


GoPro MAX 360° Camera

Insta360 One X2 Camera

Monoscopic 360° viewing

- Best way to view in a virtual reality (VR) glasses
- Monoscopic 360° panoramas do not provide feeling of depth

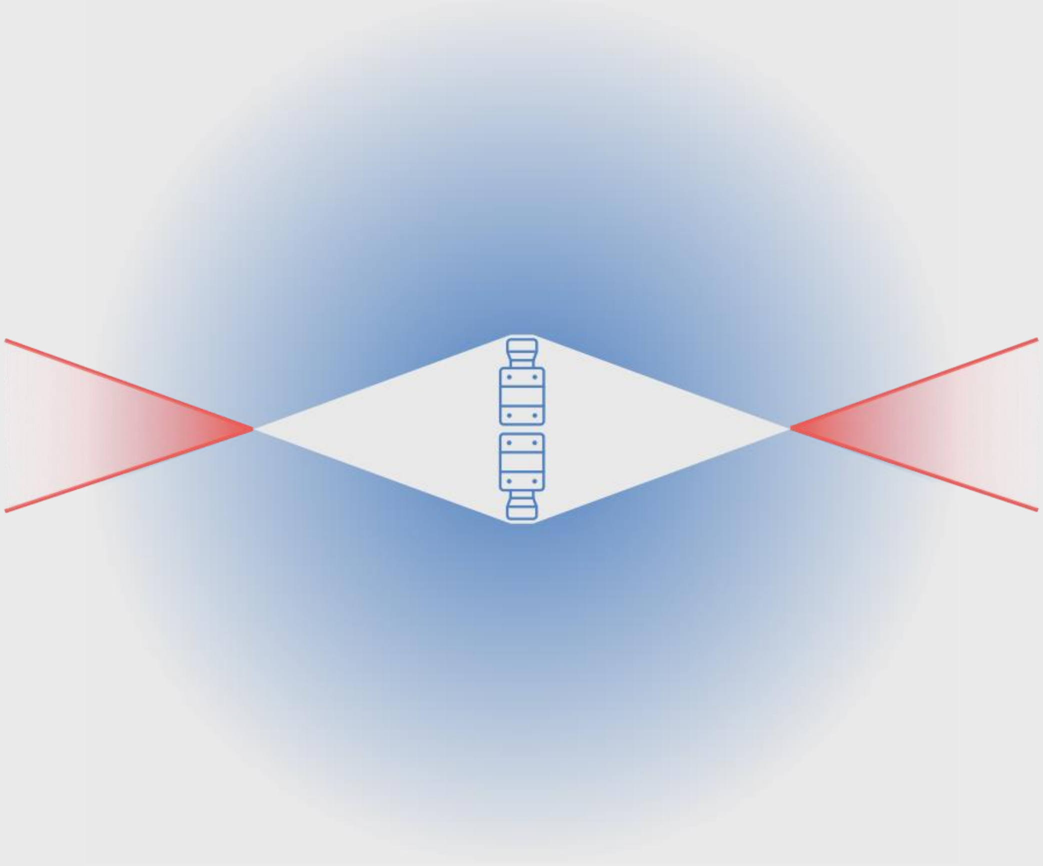


Oculus Go VR Glasses

Google Cardboard VR Glasses

Stereoscopic 360° capture

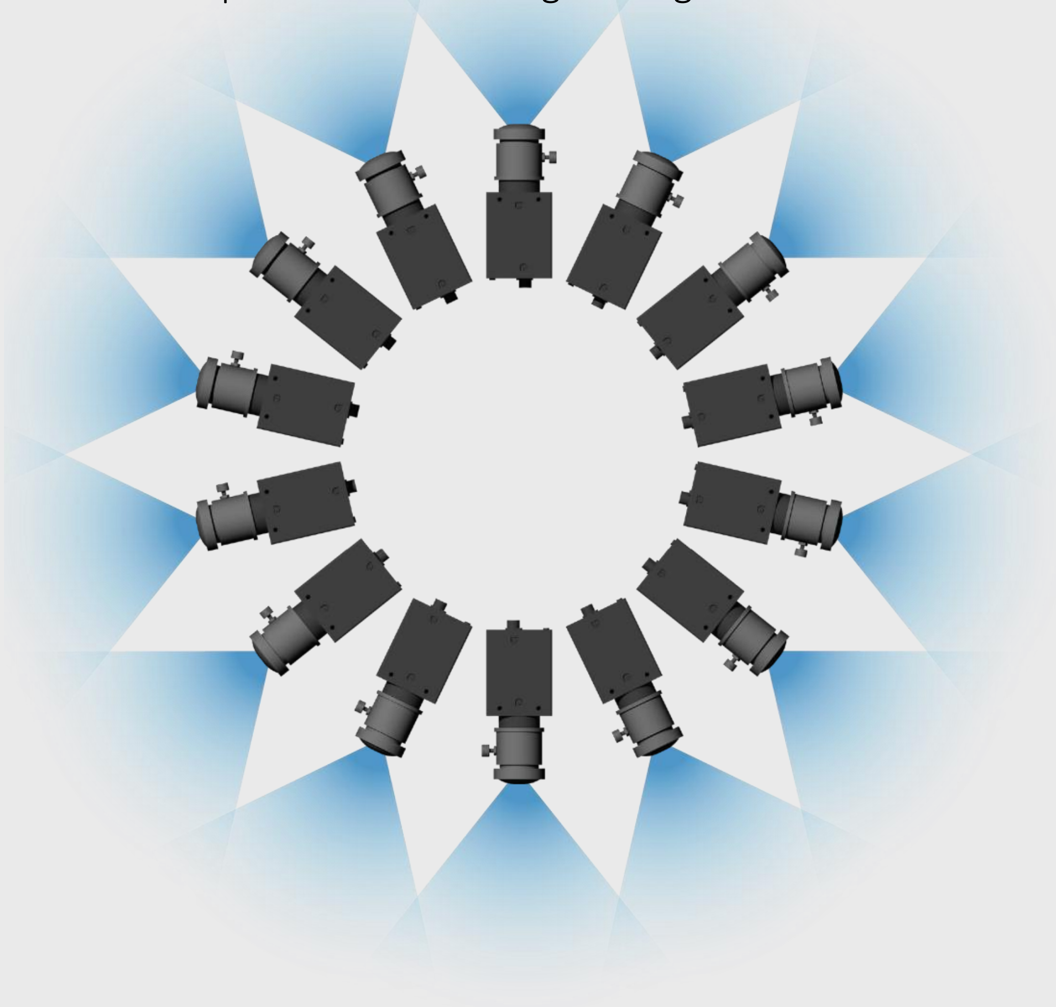
- Stereoscopic 360° panoramas provide feeling of depth
- To capture depth information every point of the world must me captures from at least 2 different positions



Regions of overlap have parallax near and within hyperfocal distance

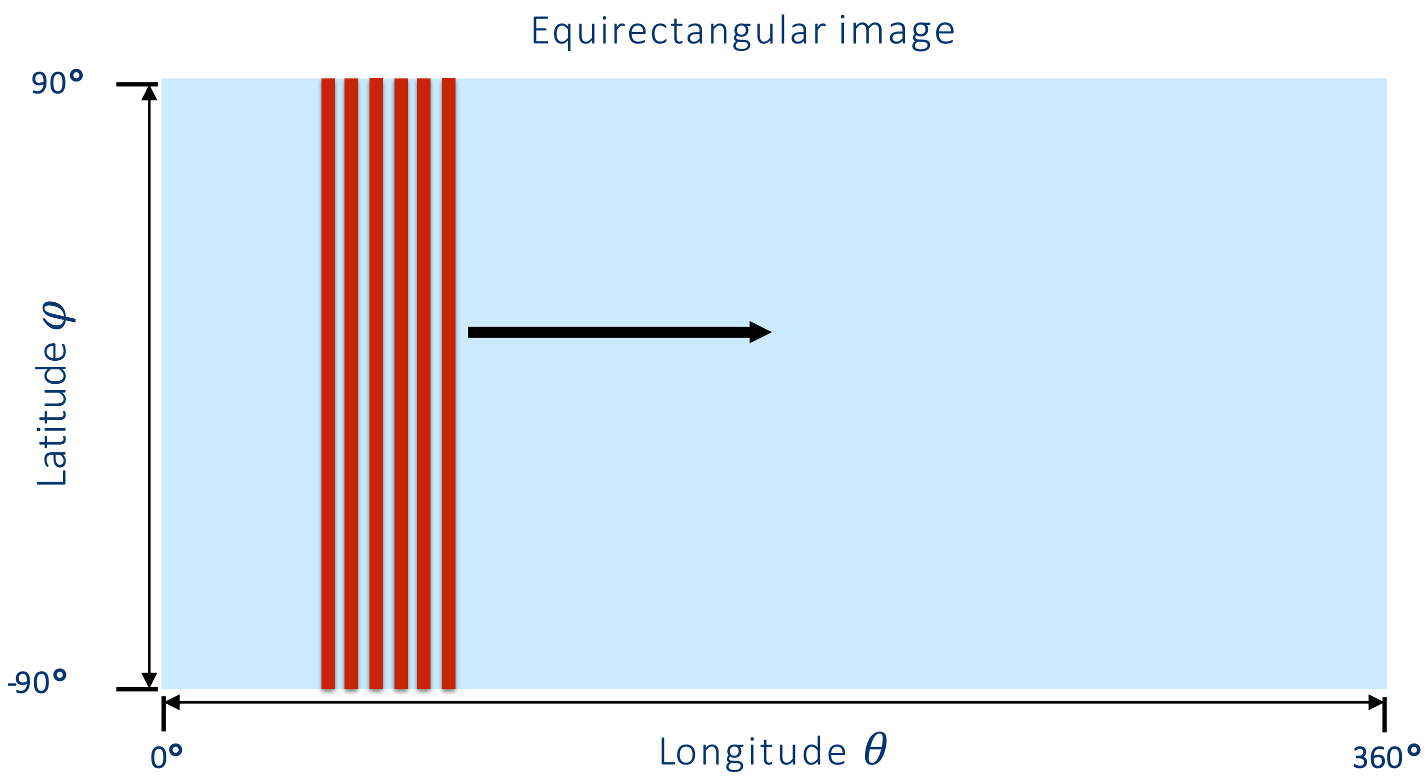
Stereoscopic 360° capture

- 14 Cameras with wide-angle lenses allow for Stereoscopic 360° capture
- Every camera has 66% overlap in FOV with a neighboring camera



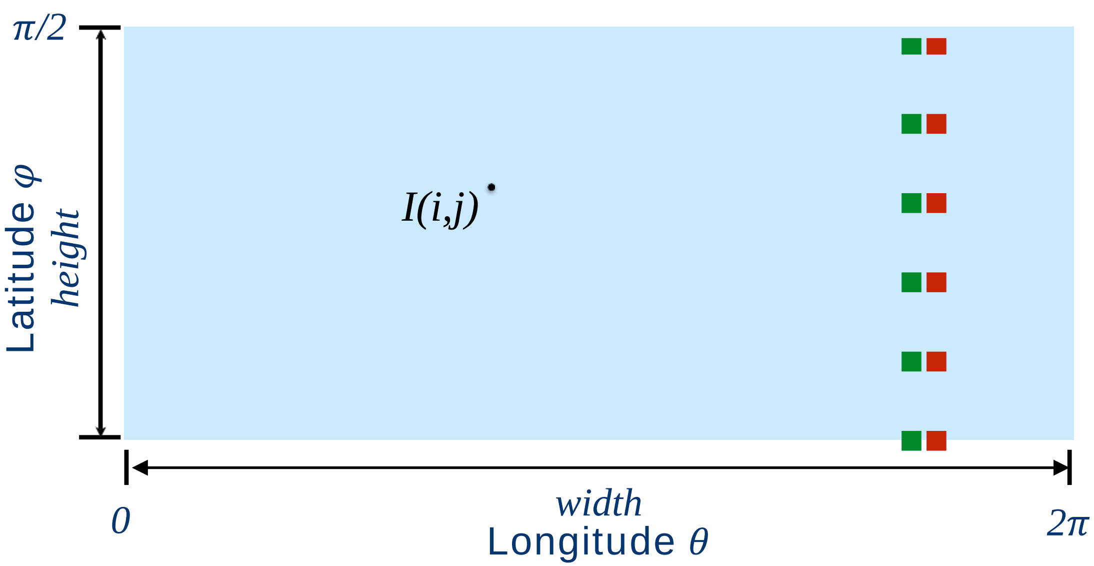
The slit-scan camera model

- Another way to create a 360° image

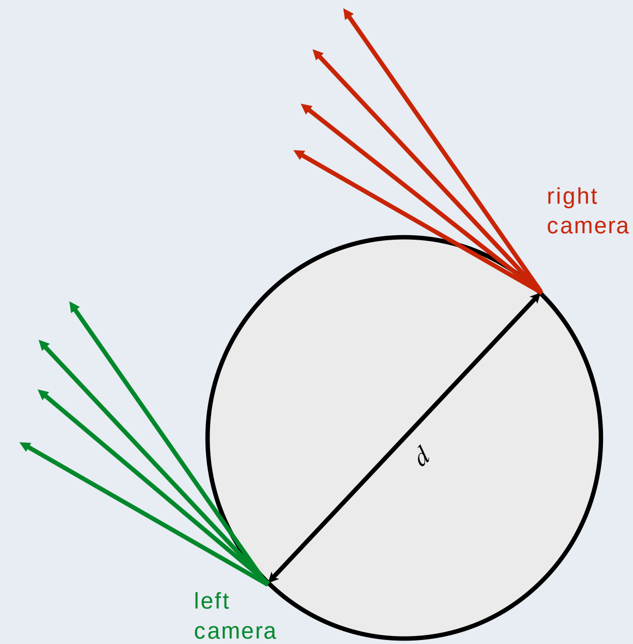


Omni-Directional Stereo (ODS)

- Slit photography for each eye



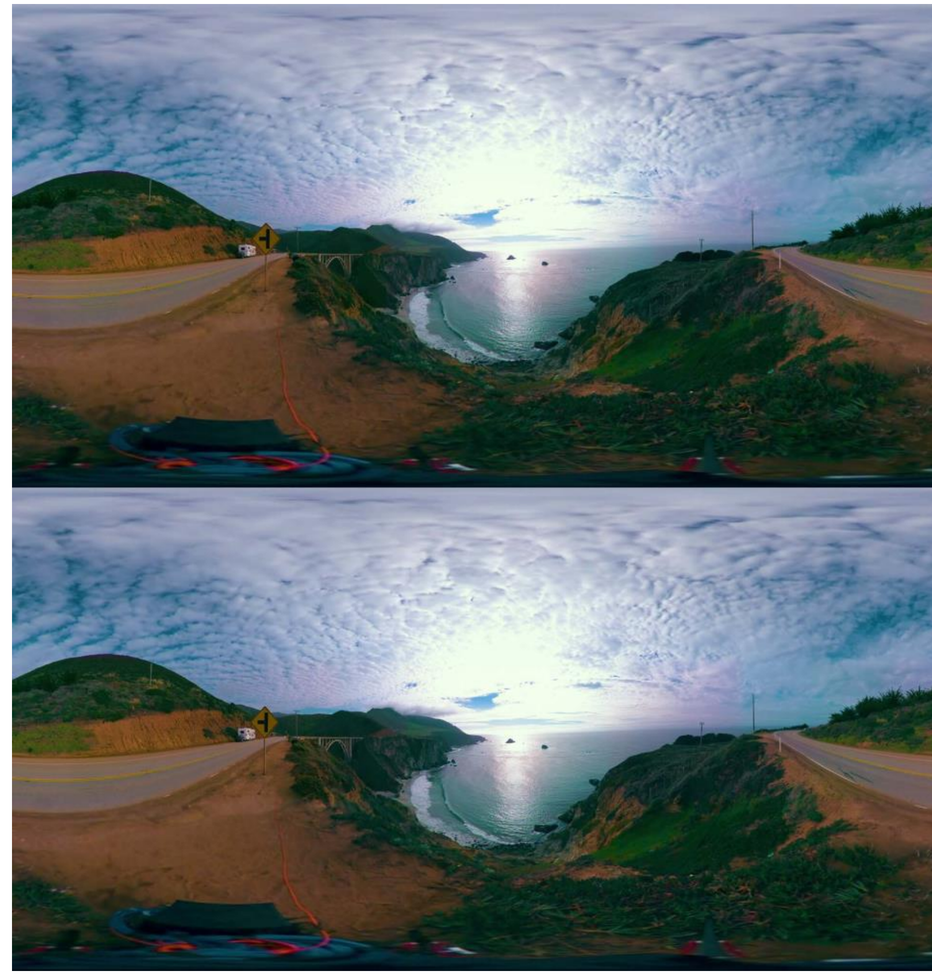
$$\varphi = \pi\ i\ /\ height - \pi/2$$
$$\theta = 2\pi\ j\ /\ width$$



where d is the inter ocular distance, $r = d/2$

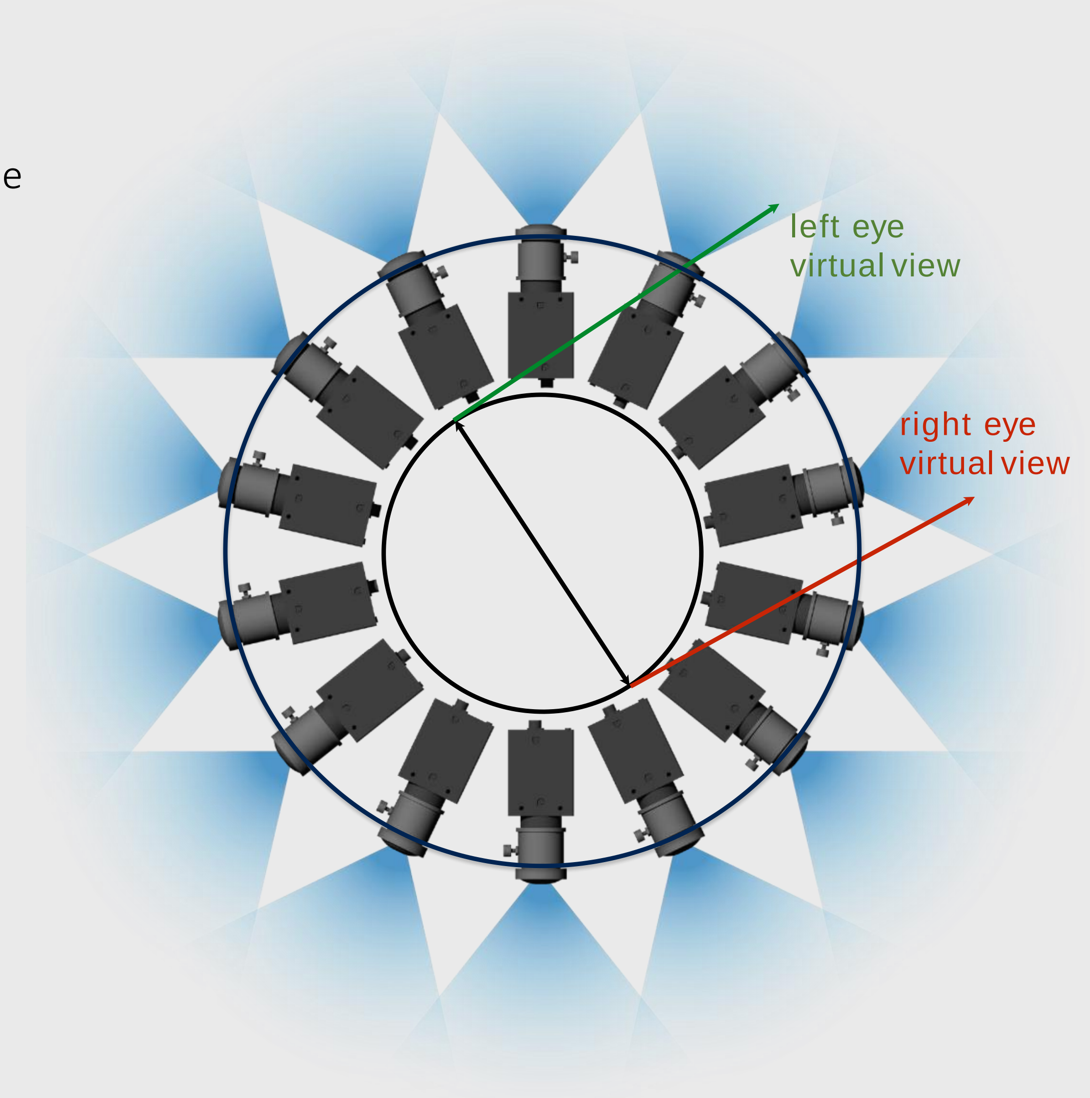
Left Eye Rays	Right Eye Rays
l.x = sin(φ) * cos(θ) - r*sin(θ)	r.x = sin(φ) * cos(θ) + r*sin(θ)
l.y = sin(φ) * sin(θ) - r*cos(θ)	r.y = sin(φ) * sin(θ) + r*cos(θ)
l.z = cos(φ)	r.z = cos(φ)

Left - right, top - bottom ODS stereo pair

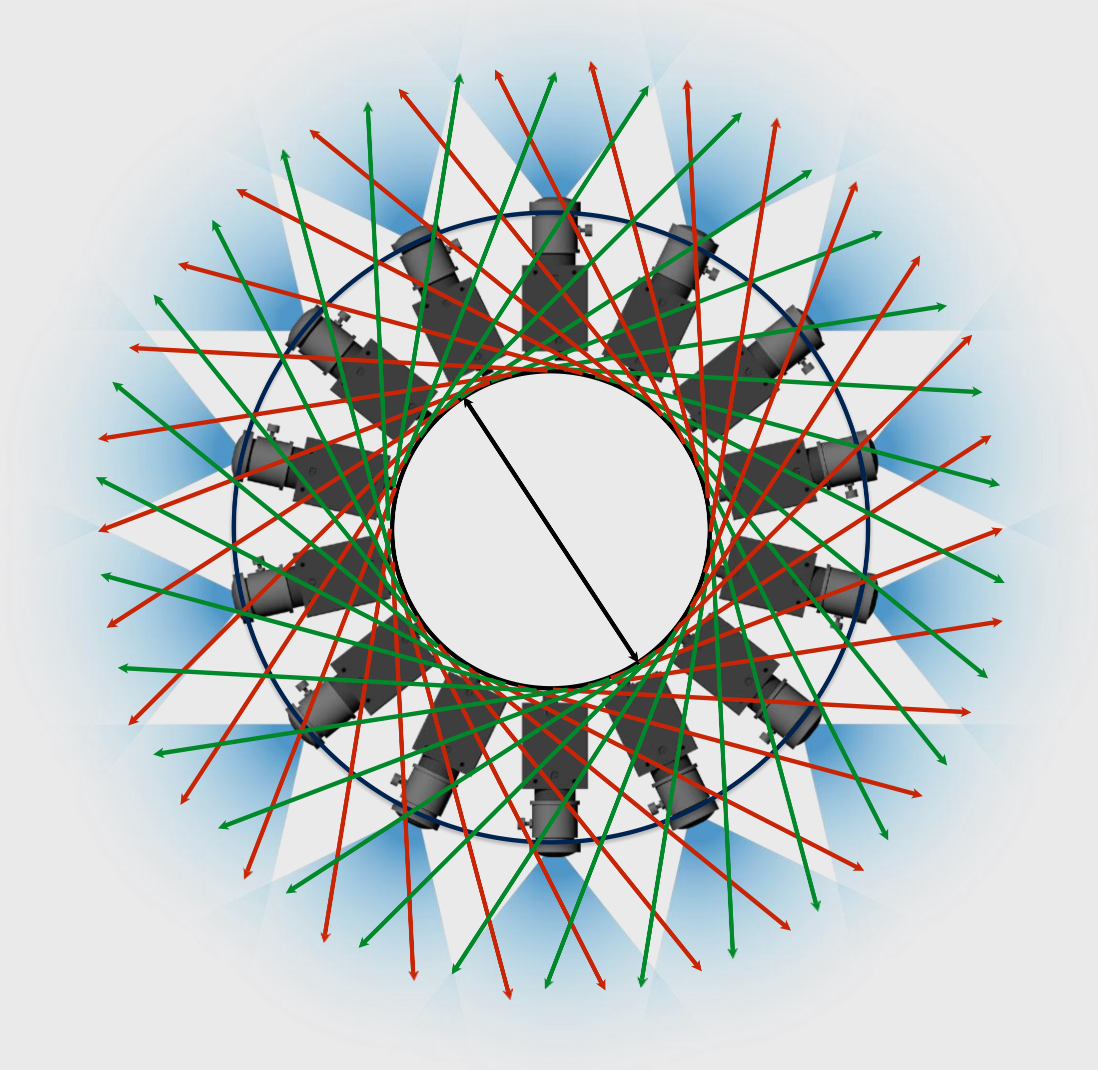


Creating ODS with a fixed array of cameras

- Warp / interpolate nearest 2 images
- Only need to do it for each specific slit
- The virtual camera is modeled as pinhole
- There are $2 * width$ slits
- Blend between cameras
- Handle ghosting via disparity clustering



Creating ODS with a fixed array of cameras



Optical Flow between two images

- Via the first approximation of the Teylor series:

$$I(x, y, t) = I(x + \Delta x, y + \Delta y, t + \Delta t)$$

$$I(x + \Delta x, y + \Delta y, t + \Delta t) = I(x, y, t) + \frac{\partial I}{\partial x}\Delta x + \frac{\partial I}{\partial y}\Delta y + \frac{\partial I}{\partial t}\Delta t + \ldots$$

$$\frac{\partial I}{\partial x}\Delta x + \frac{\partial I}{\partial y}\Delta y + \frac{\partial I}{\partial t}\Delta t = 0$$

$$\frac{\partial I}{\partial x}\frac{\Delta x}{\Delta t} + \frac{\partial I}{\partial y}\frac{\Delta y}{\Delta t} + \frac{\partial I}{\partial t}\frac{\Delta t}{\Delta t} = 0$$

$$I_x V_x + I_y V_y = -I_t$$

Energy Functional:

$$E = \int\int [(I_x V_x + I_y V_y + I_t)^2 + \alpha^2(||\nabla V_x||^2 + ||\nabla V_y||^2)]dxdy$$

Solving the 3-D Euler-Lagrange equations

$$I_x(I_x^{-k} V_x + I_y^{-k} V_y + I_t) - \alpha^2 \Delta V_x = 0$$
$$I_y(I_x^{-k} V_x + I_y^{-k} V_y + I_t) - \alpha^2 \Delta V_y = 0$$

Using finite difference approximations and rearranging

$$(I_x^2 + 4\alpha^2)V_x + I_x I_y V_y = 4\alpha^2 \overline{V_x} - I_x I_t$$
$$(I_y^2 + 4\alpha^2)V_y + I_x I_y V_x = 4\alpha^2 \overline{V_y} - I_y I_y$$

Solving for the next flow time step

$$V_x^{k+1} = V_x^{-k} - \frac{I_x(I_x^{-k} V_x + I_y^{-k} V_y + I_t)}{4\alpha^4 + I_x^2 + I_y^2}$$
$$V_y^{k+1} = V_y^{-k} - \frac{I_y(I_x^{-k} V_x + I_y^{-k} V_y + I_t)}{4\alpha^4 + I_x^2 + I_y^2}$$

Merging and Blending

Merging and Blending

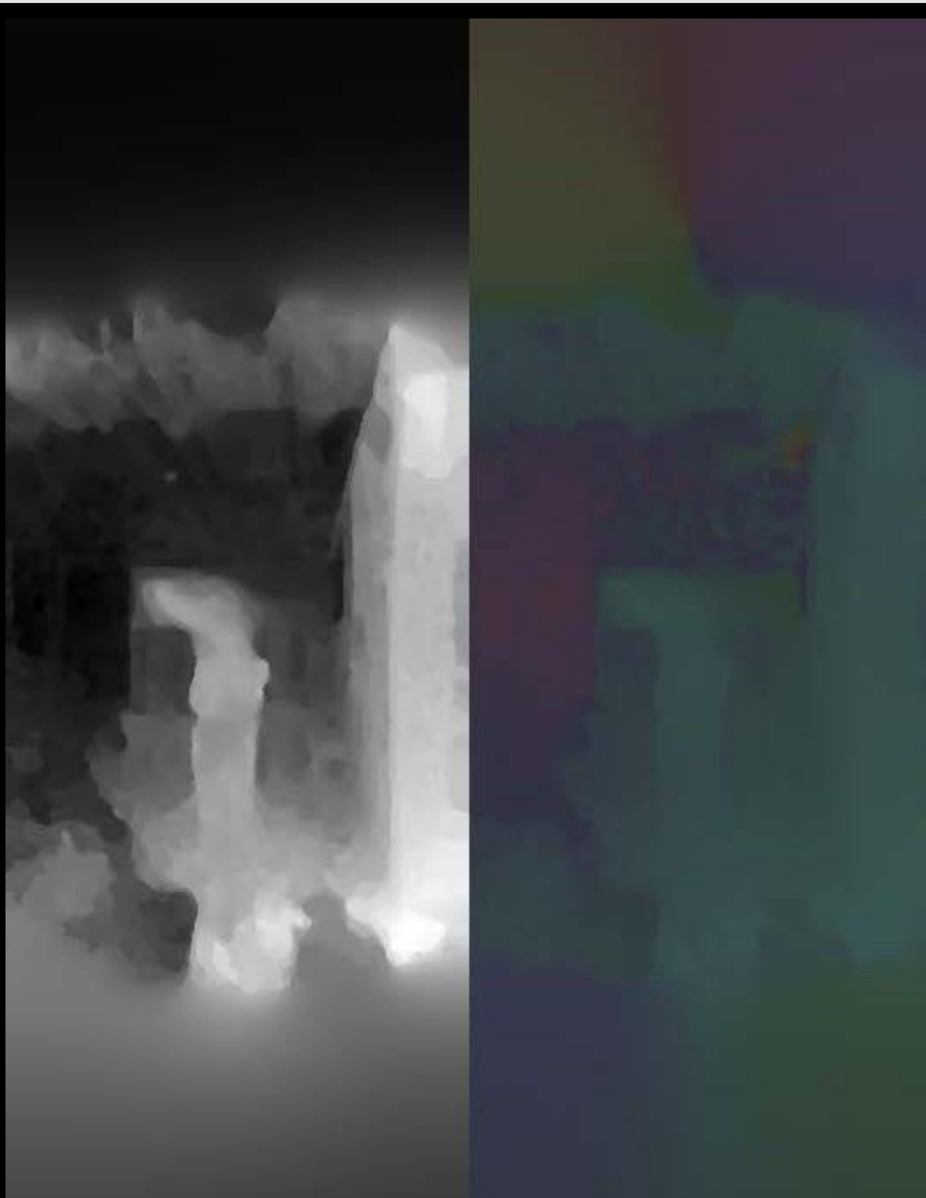

Riya
JOHN
HENDRIK!

Merging and Blending

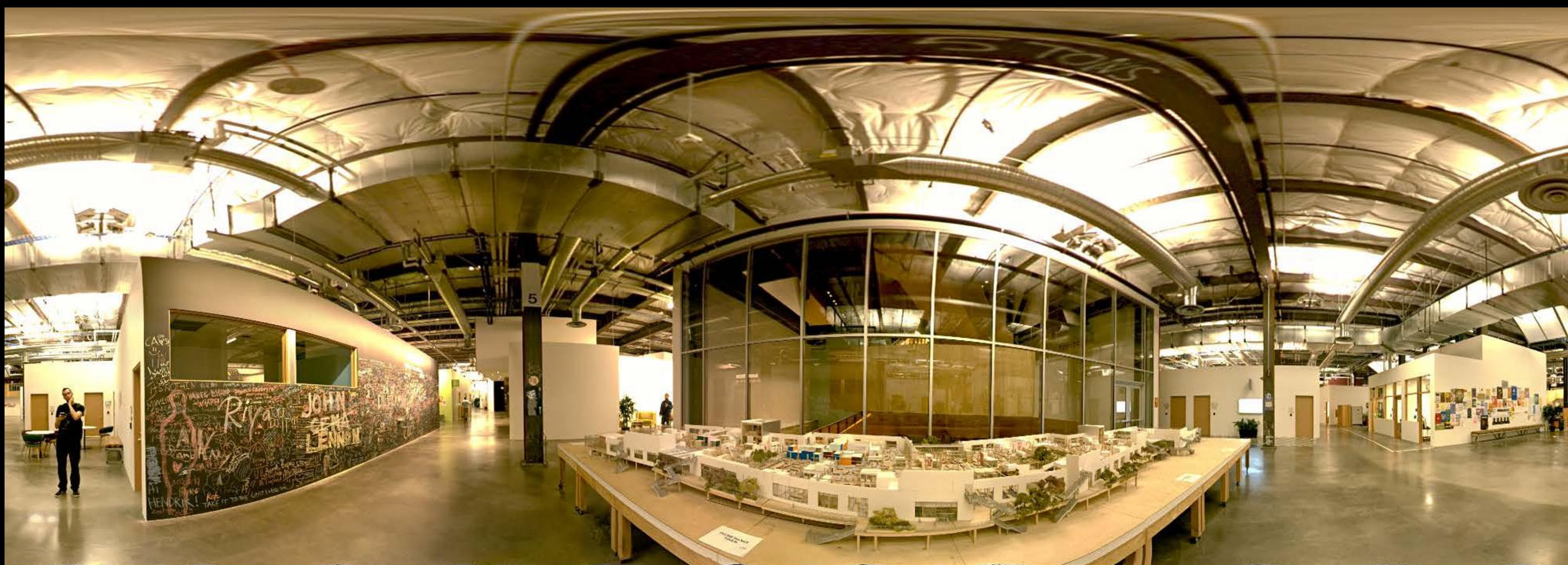
Spherical projections align s.t. parallax = 0 at infinity

Merging and Blending

Merging and Blending



Sharpen and Post-Processing



Merging and Blending