



PANORAMIC IMAGING – PART 2

STEREO PANORAMAS

Panorama: Virtual Wide Angle



<http://people.csail.mit.edu/fredo/Panos/>

Two lectures:

- Part 1: Monoscopic Panoramas
(previous lecture)
- Part 2: Stereoscopic Panoramas
(today's lecture)

Review

Q: What is a Panorama?

A: Wider-angle image than a normal camera can capture

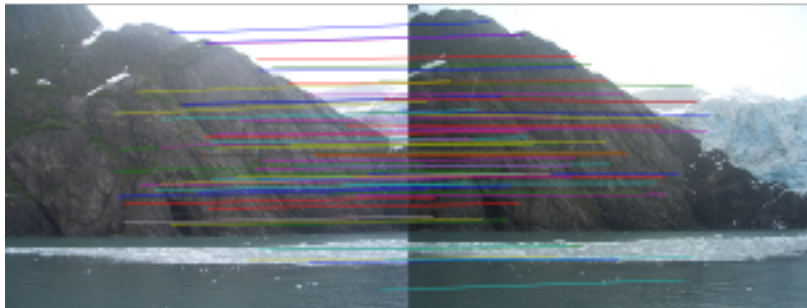
Compensate for shortcomings of traditional cameras by capturing and fusing many images

Technique:

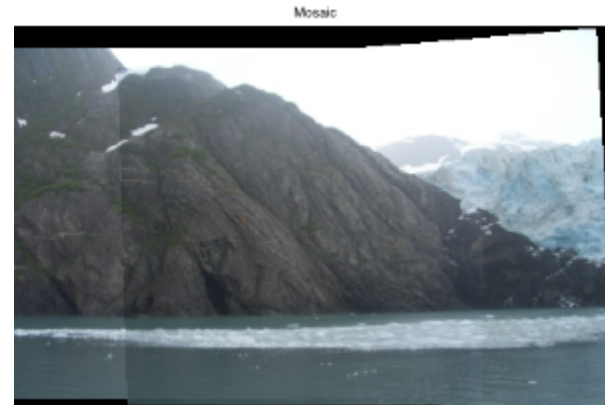
- Take N images at different directions
- Deduce the image that would have been taken by a wide angle lens

Review: Panoramic Imaging Pipeline

Estimating
Correspondences



Warping



Blending

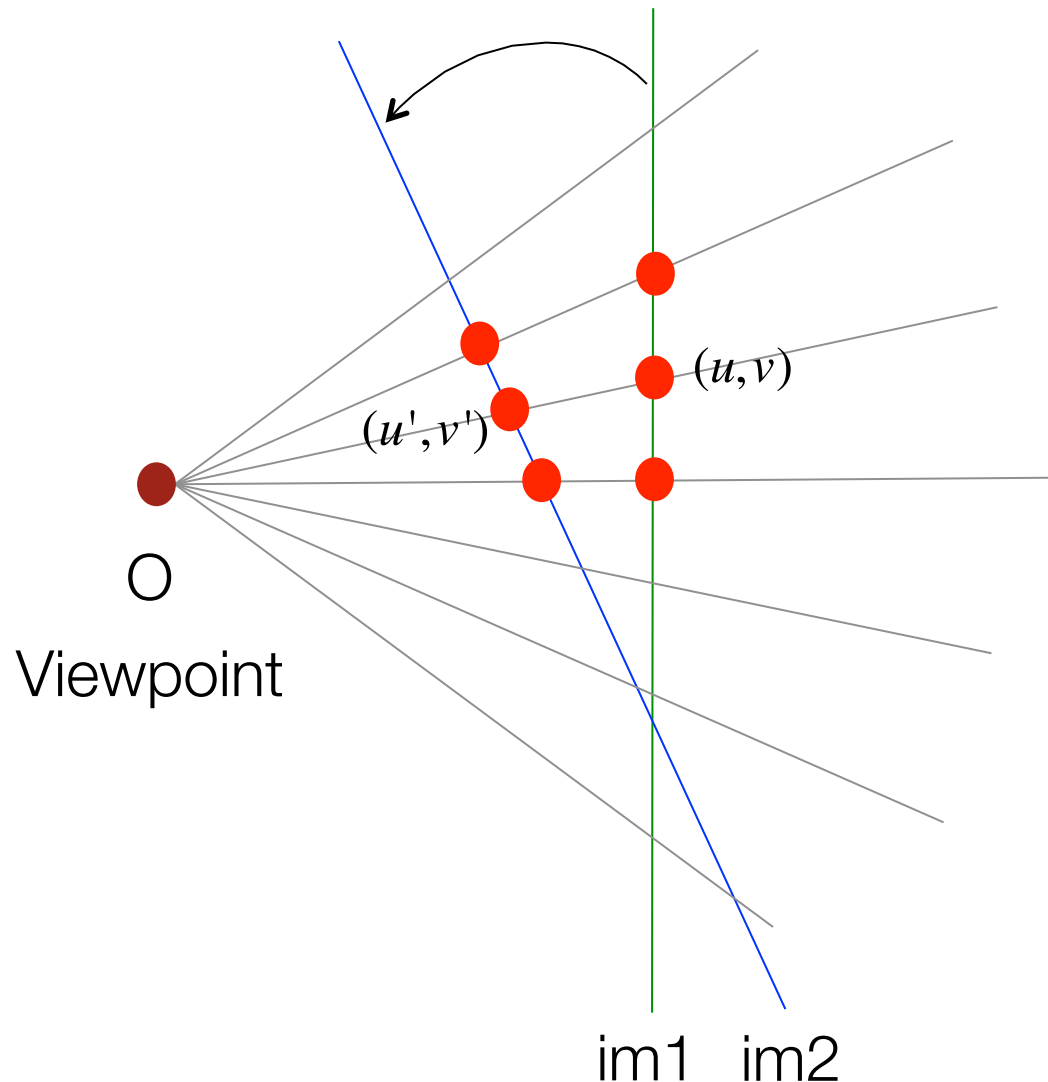


Review: Homogeneous Coordinates

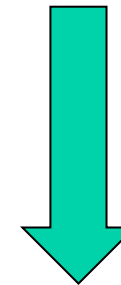
- Notation trick
- Represent 2D points with 3 numbers
- Homogeneous coordinates $(u, v, w) \rightarrow$ image coordinates $(u/w, v/w)$

$$\begin{aligned} u' &= u + t_u \\ v' &= v + t_v \end{aligned} \quad \longrightarrow \quad \begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_u \\ 0 & 1 & t_v \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix}$$

Review: Central Projection and Homography



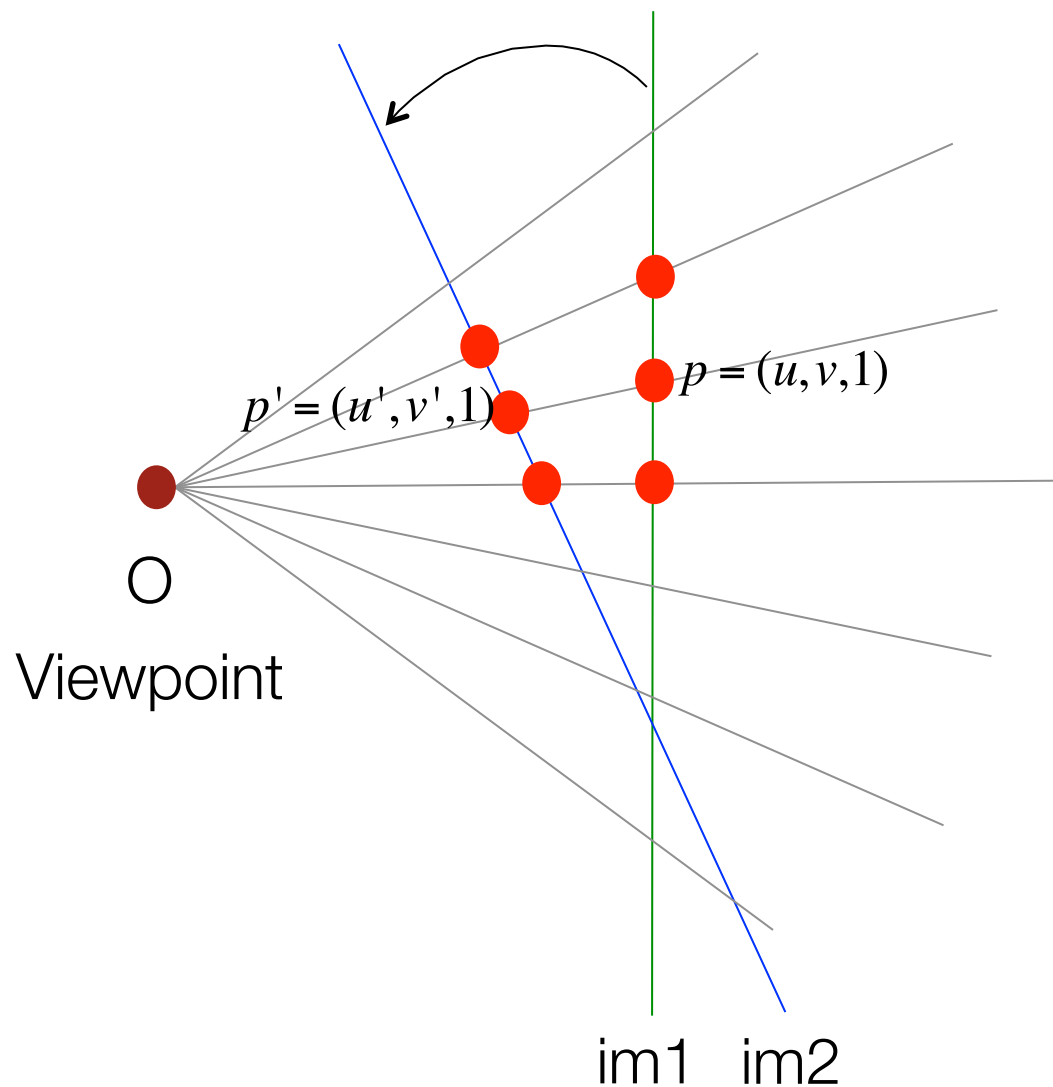
Observation:
Lines in $im1$ map onto lines in $im2$



Any transformation of a plane onto a plane that preserves straight lines must be a homography

Hartley & Zisserman, Theorem 2.10

Review: Central Projection and Homography



H : non-singular 3×3 matrix

$$p' = H.p$$

$$\begin{bmatrix} wu' \\ wv' \\ w \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix}$$

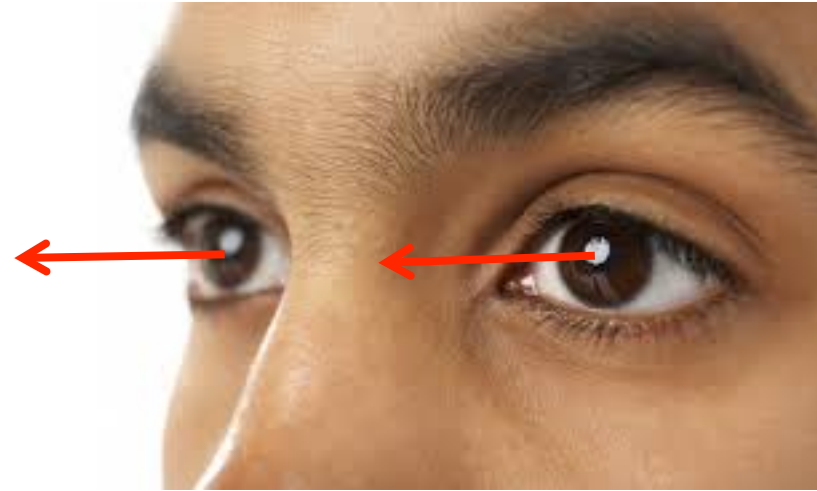
Valid up to scale
So can set $i = 1$

Today's Lecture

Check CS231A for
in-depth 3D Computer Vision

- Introduction to stereo vision
- From simple stereo system to stereo panorama
- Example Application: Cinematic Virtual Reality

Stereo Vision



L and R eyes
see the world from
slightly different viewpoints

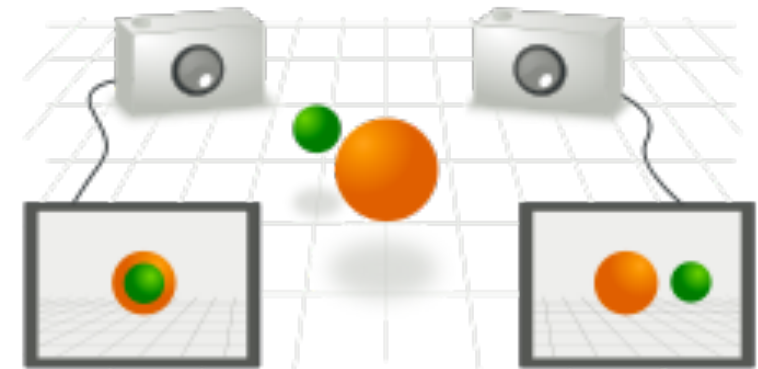
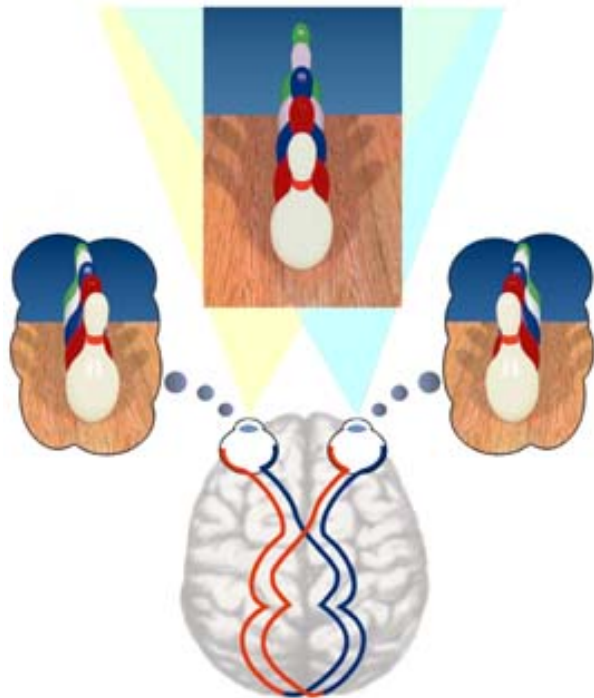
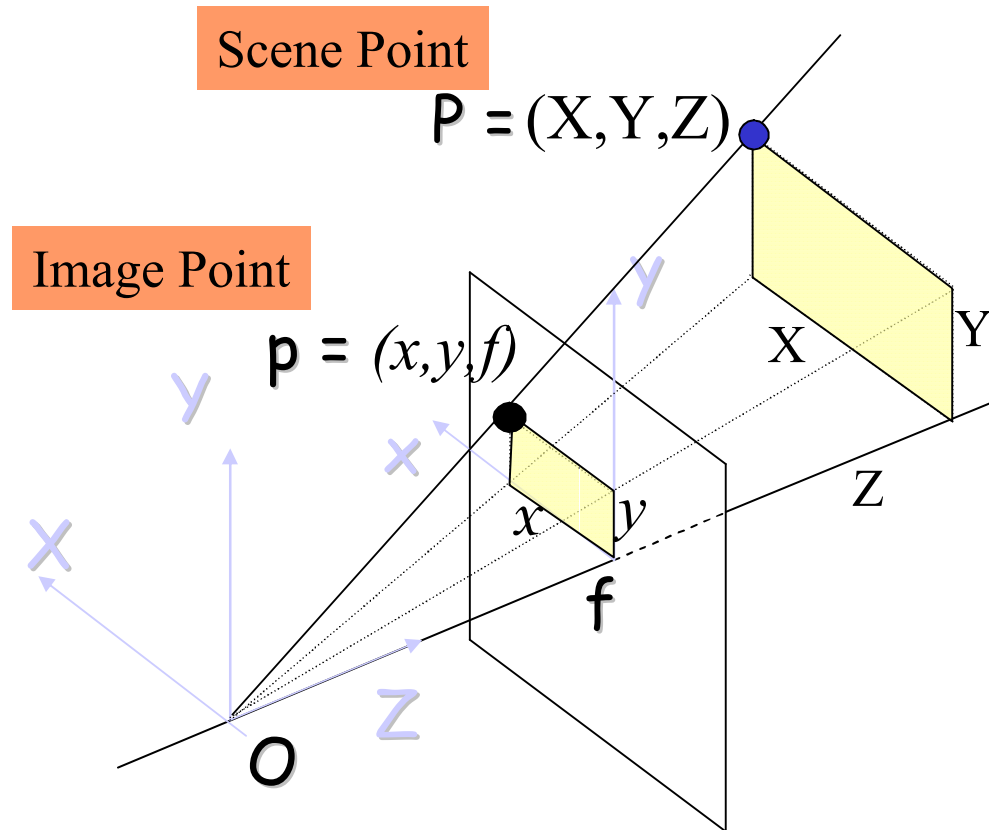


Image: wikipedia

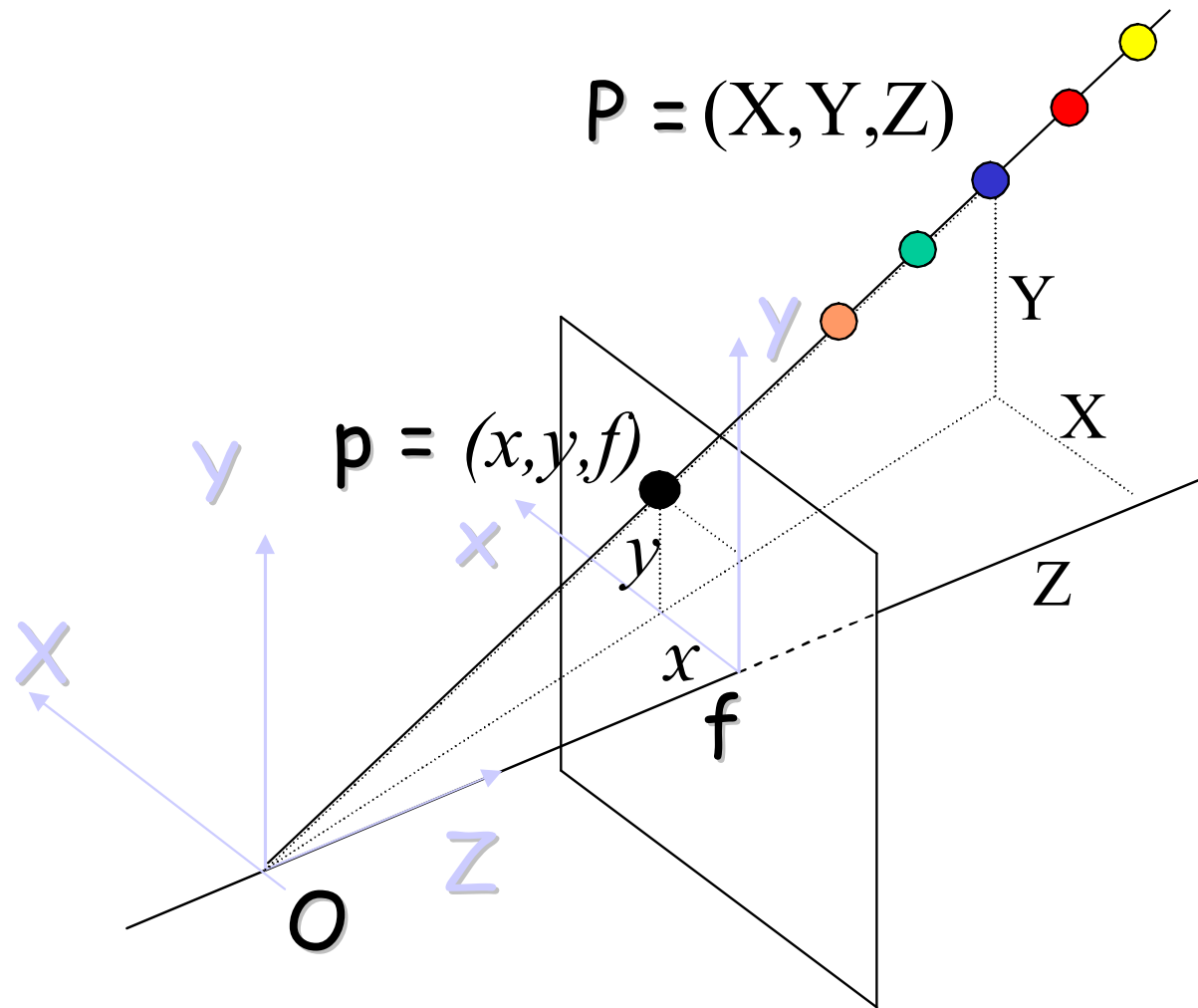
Basic Perspective Projection



Perspective Projection Eqns

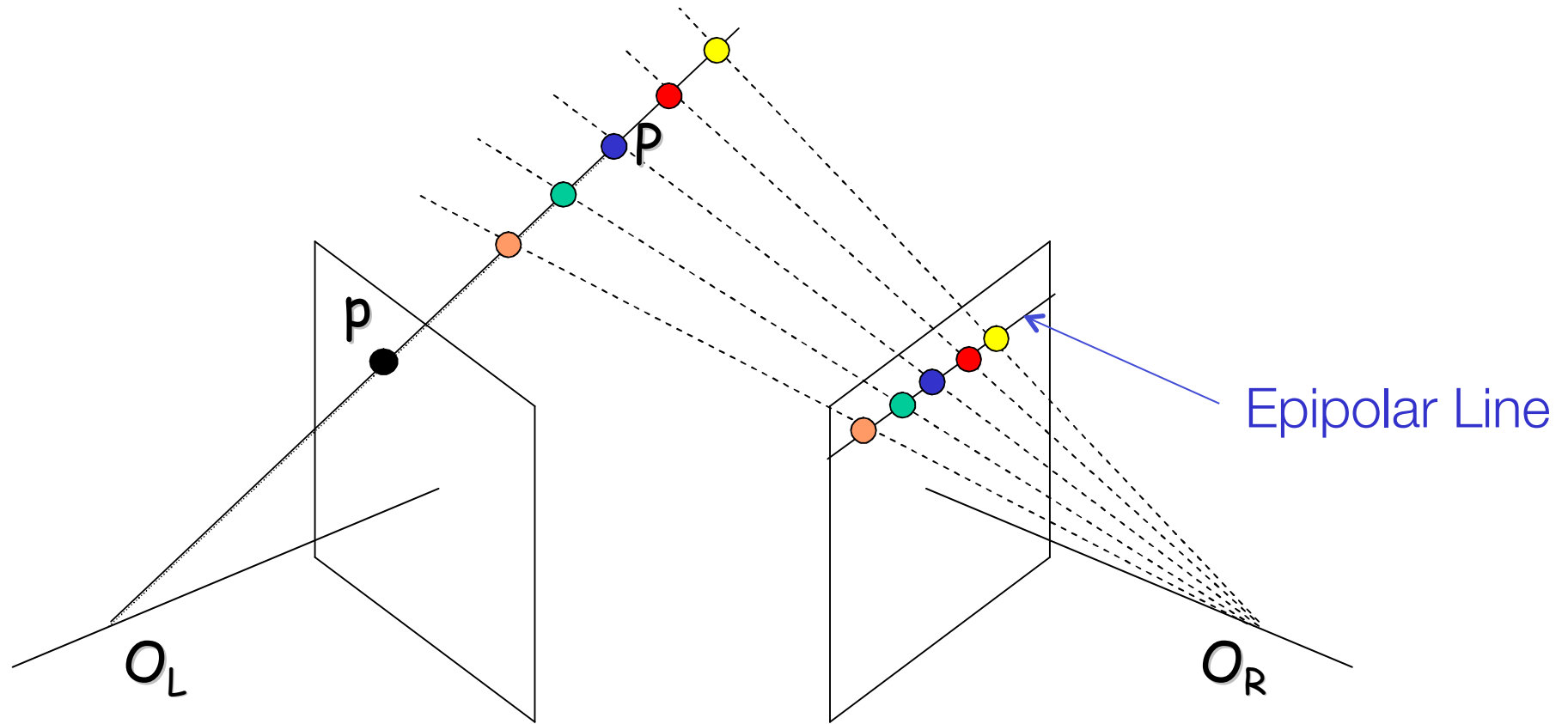
$$x = f \frac{X}{Z}$$
$$y = f \frac{Y}{Z}$$

How Stereo Helps



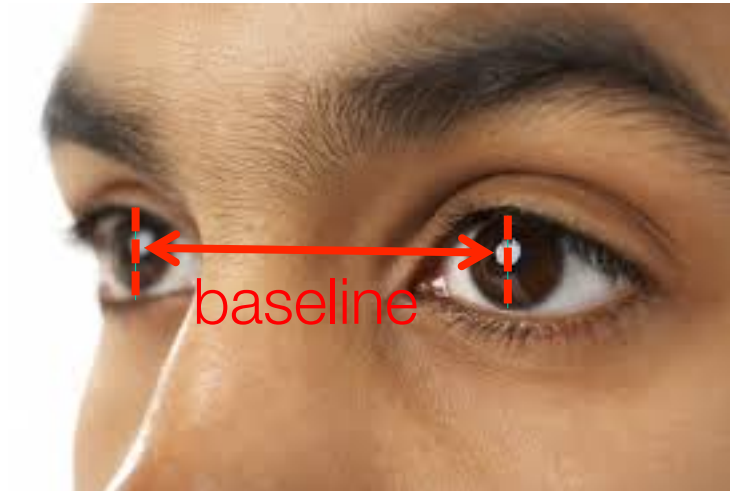
All points on the ray OP map to p

How Stereo Helps



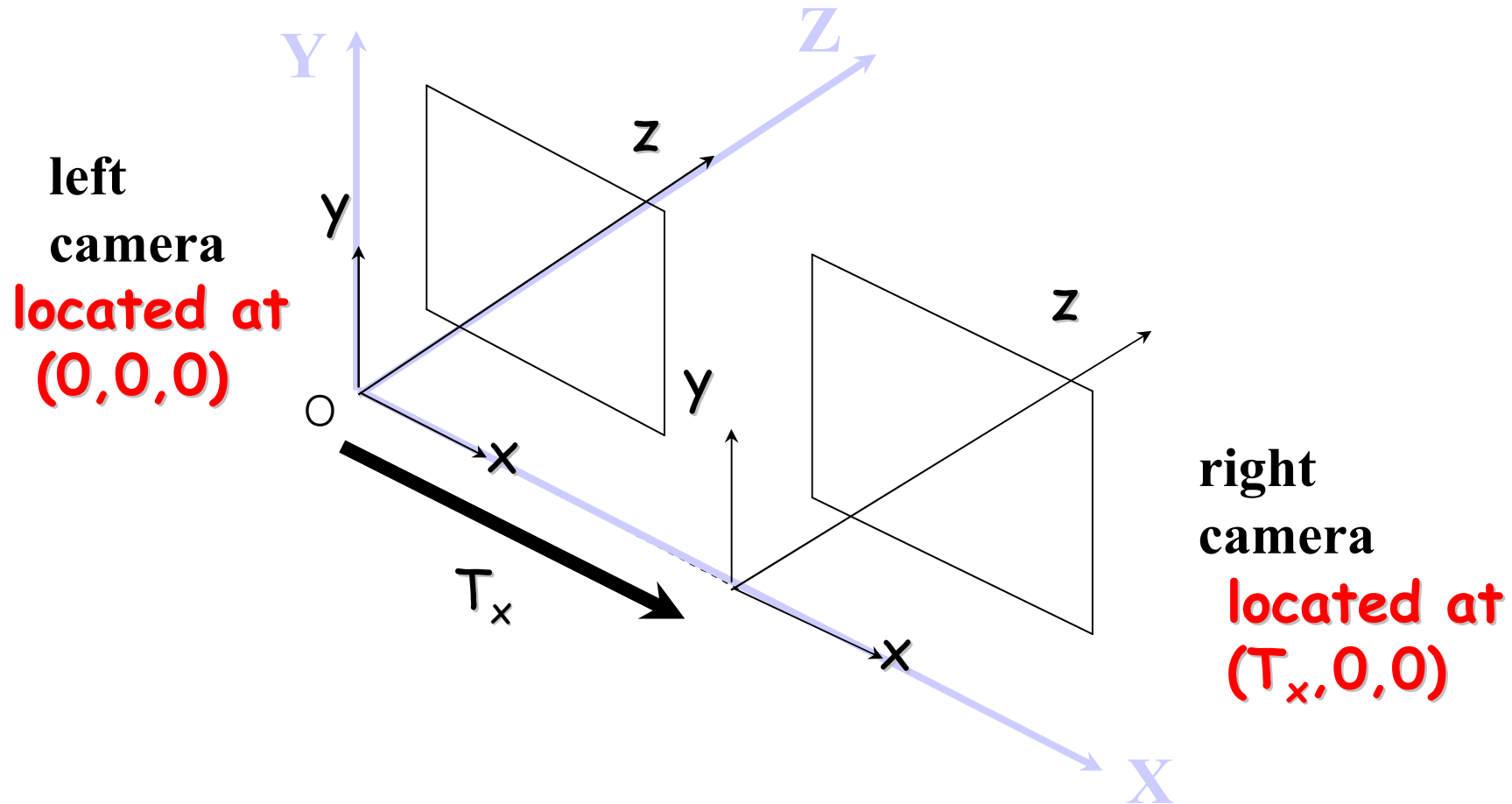
A second camera can resolve the ambiguity

How Stereo Helps

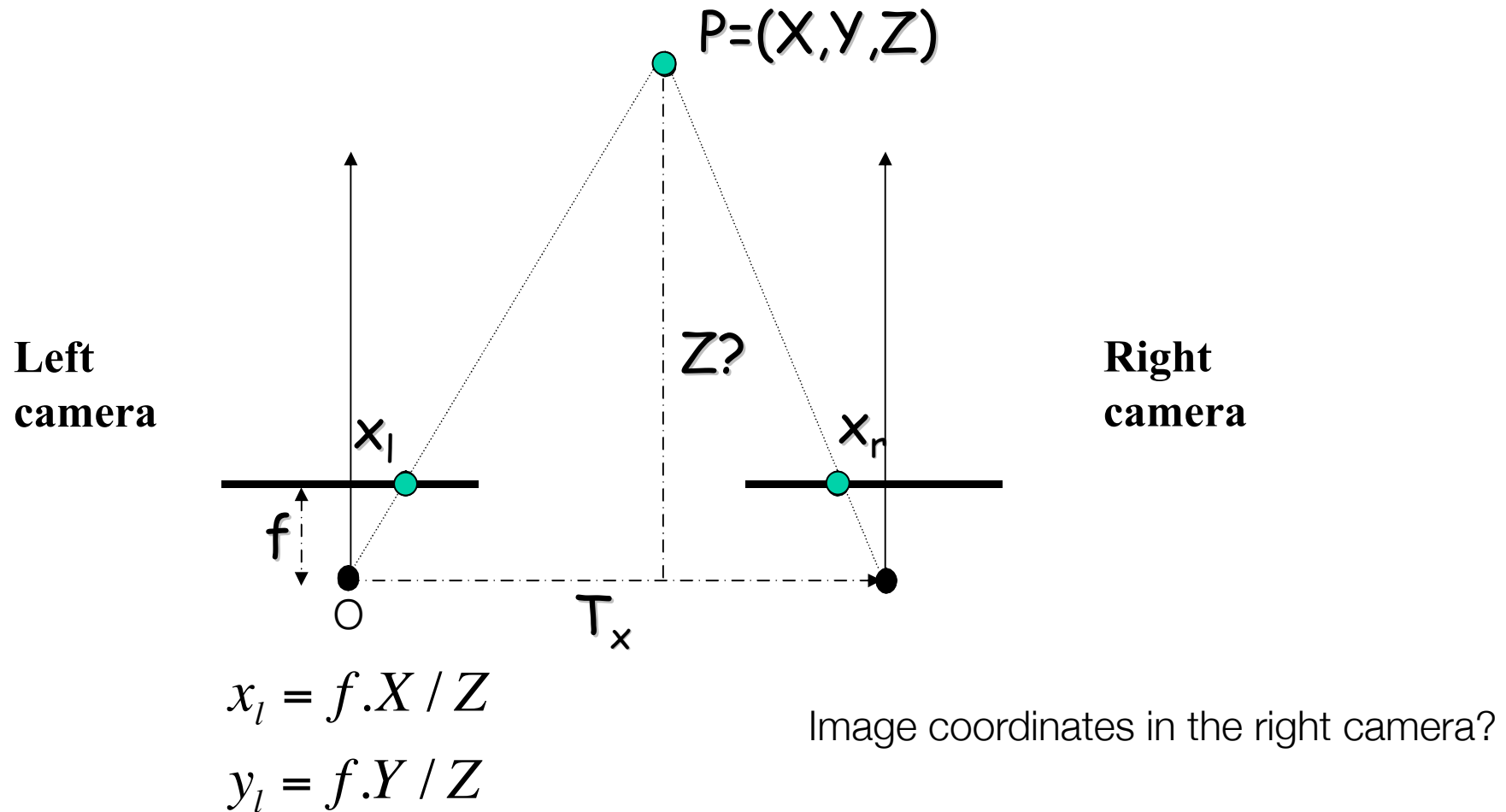


Two eyes form the stereo system
Inter Pupillary Distance (IPD) or baseline ~6.5 cm

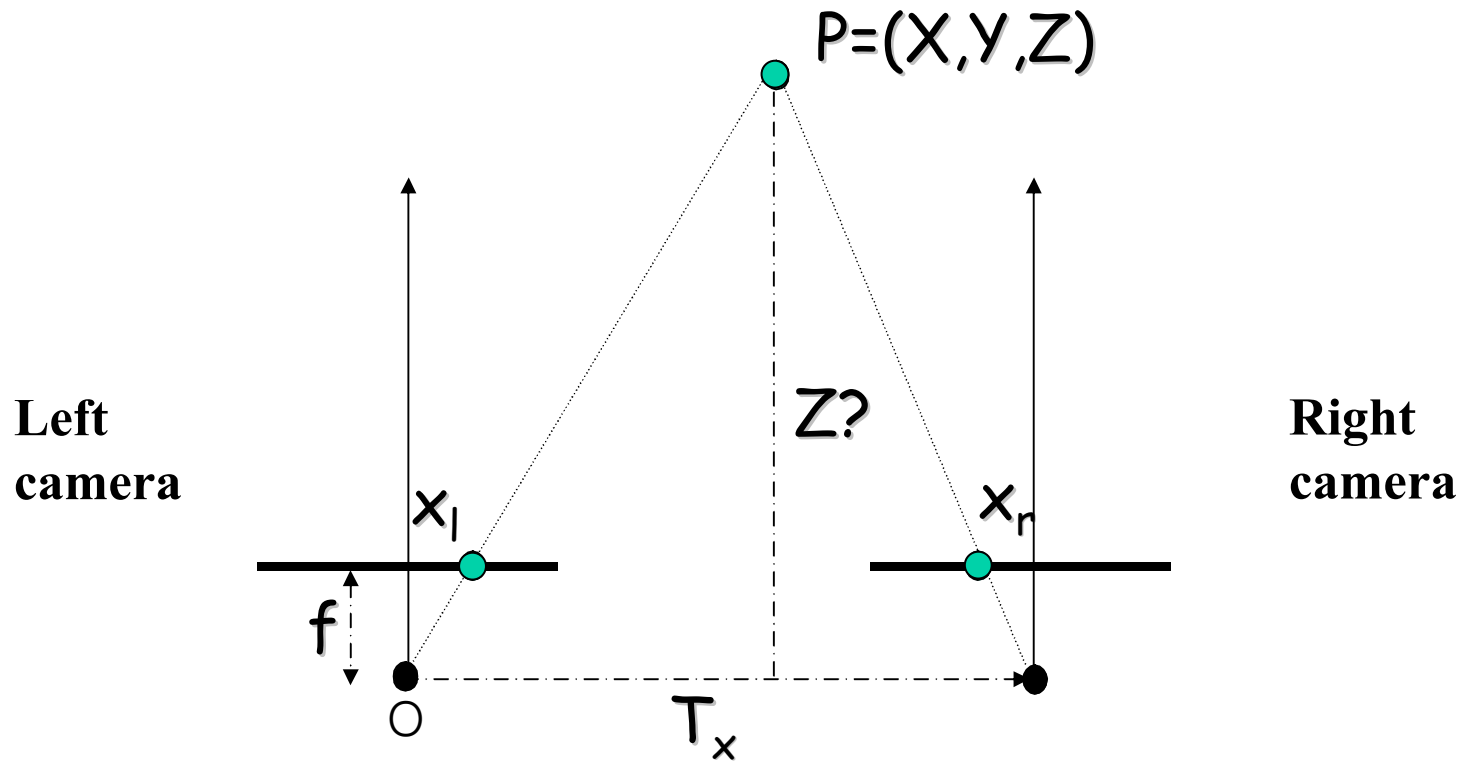
A Simple Stereo System



Top-down View



A Simple Stereo System

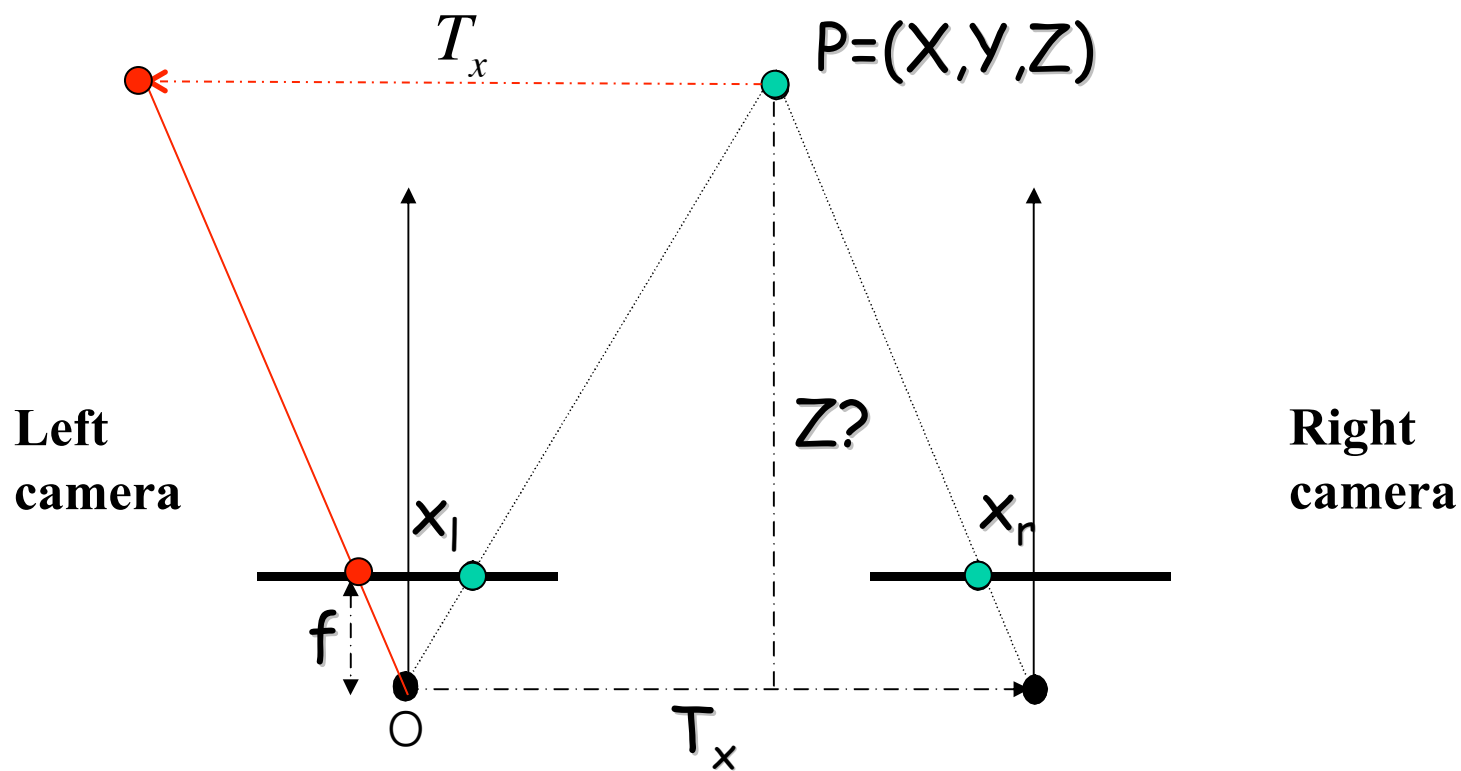


$$x_l = f \cdot X / Z$$

$$y_l = f \cdot Y / Z$$

Translating the camera is equivalent to keeping the camera fixed and translating the world in opposite direction

A Simple Stereo System



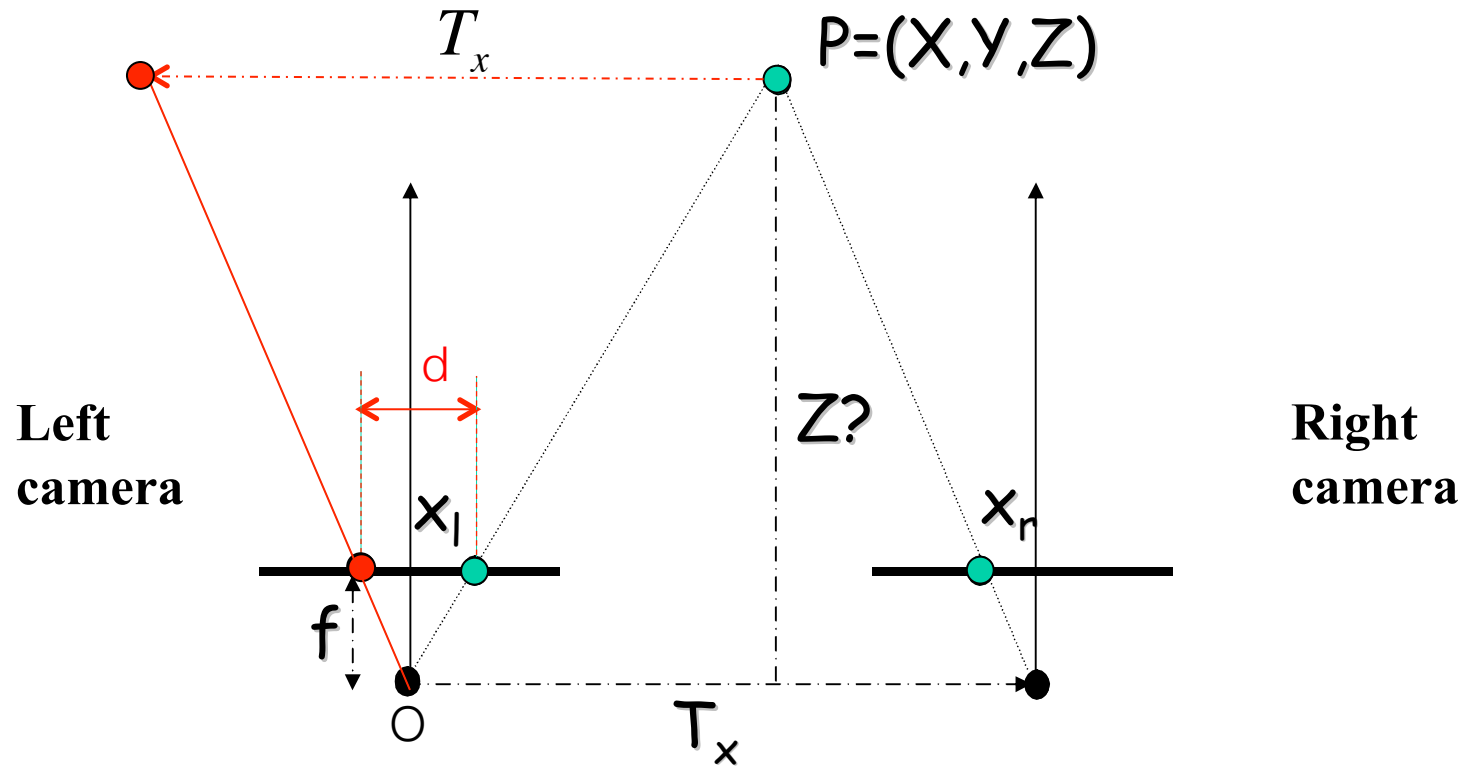
$$x_l = f \cdot X / Z$$

$$x_r = f \cdot (X - T_x) / Z$$

$$y_l = f \cdot Y / Z$$

$$y_r = f \cdot Y / Z$$

A Simple Stereo System



$$x_l = f.X / Z$$

$$y_l = f.Y / Z$$

$$x_r = f.(X - T_x) / Z$$

$$y_r = f.Y / Z$$

Disparity

$$d = fT_x / Z$$

Stereo Disparity

$$d = f \cdot T_x / Z$$

Disparity Baseline Depth

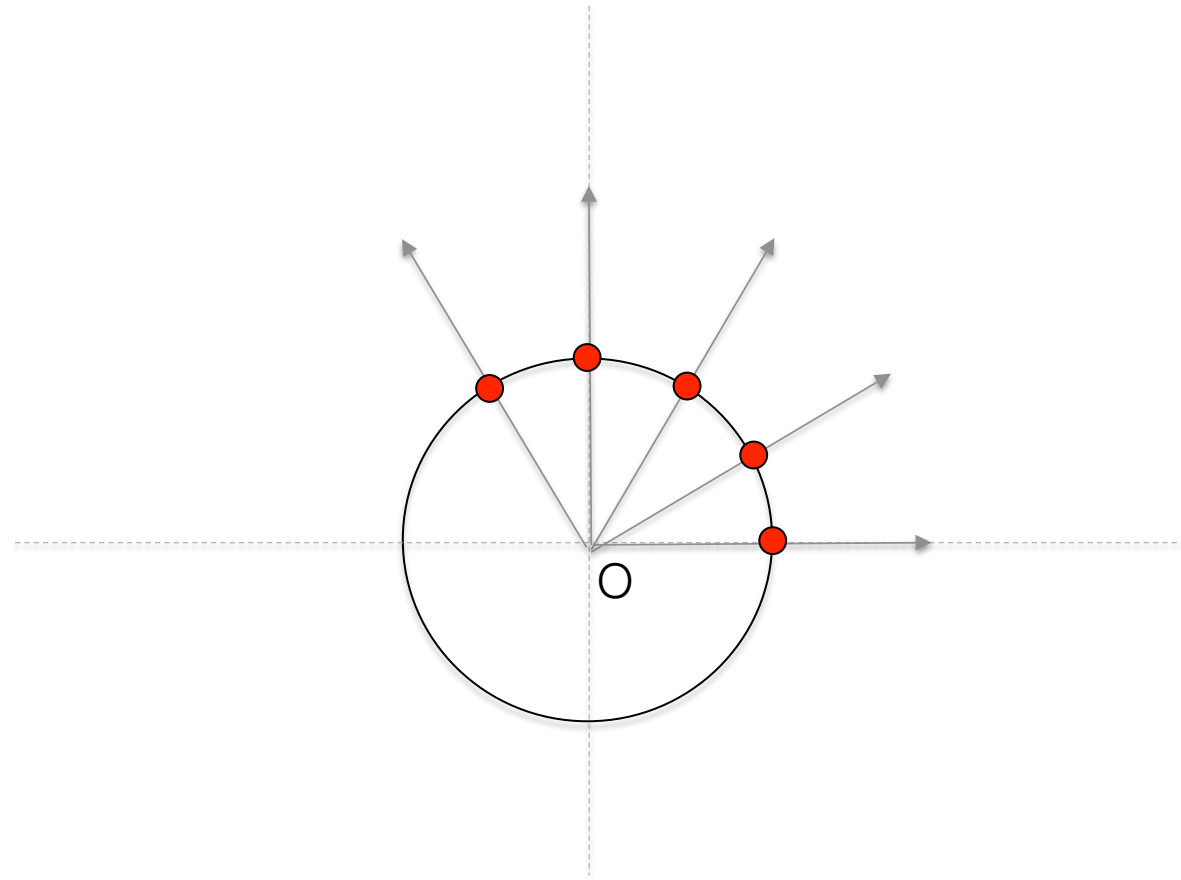
Disparity is
inversely proportional
to depth

Units:
 $1/(\text{depth in meter}) = \text{diopter}$

Today's Lecture

- Introduction to stereo vision
- From simple stereo system to stereo panorama
- Example Application: Cinematic Virtual Reality

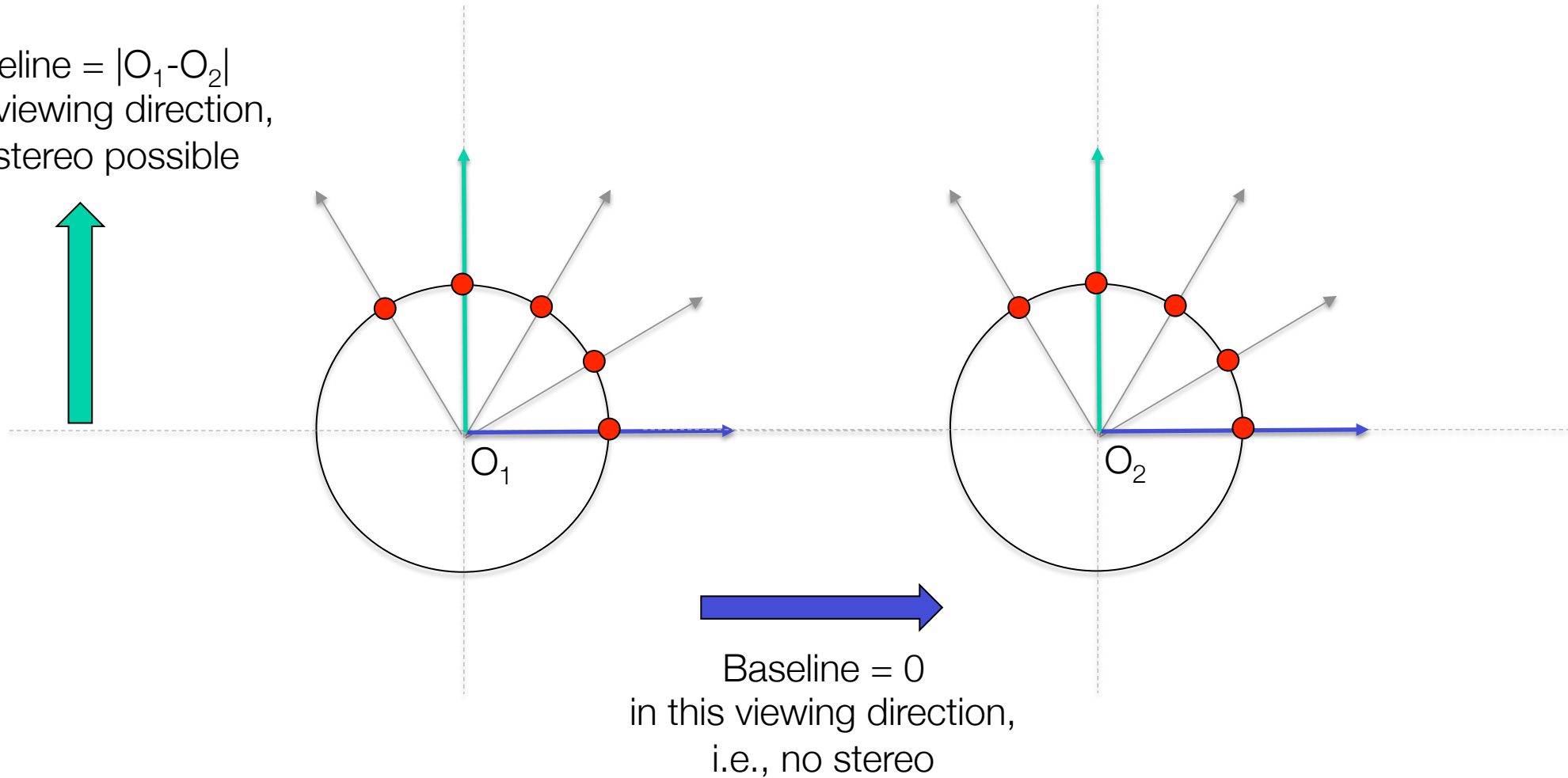
Mono Panorama



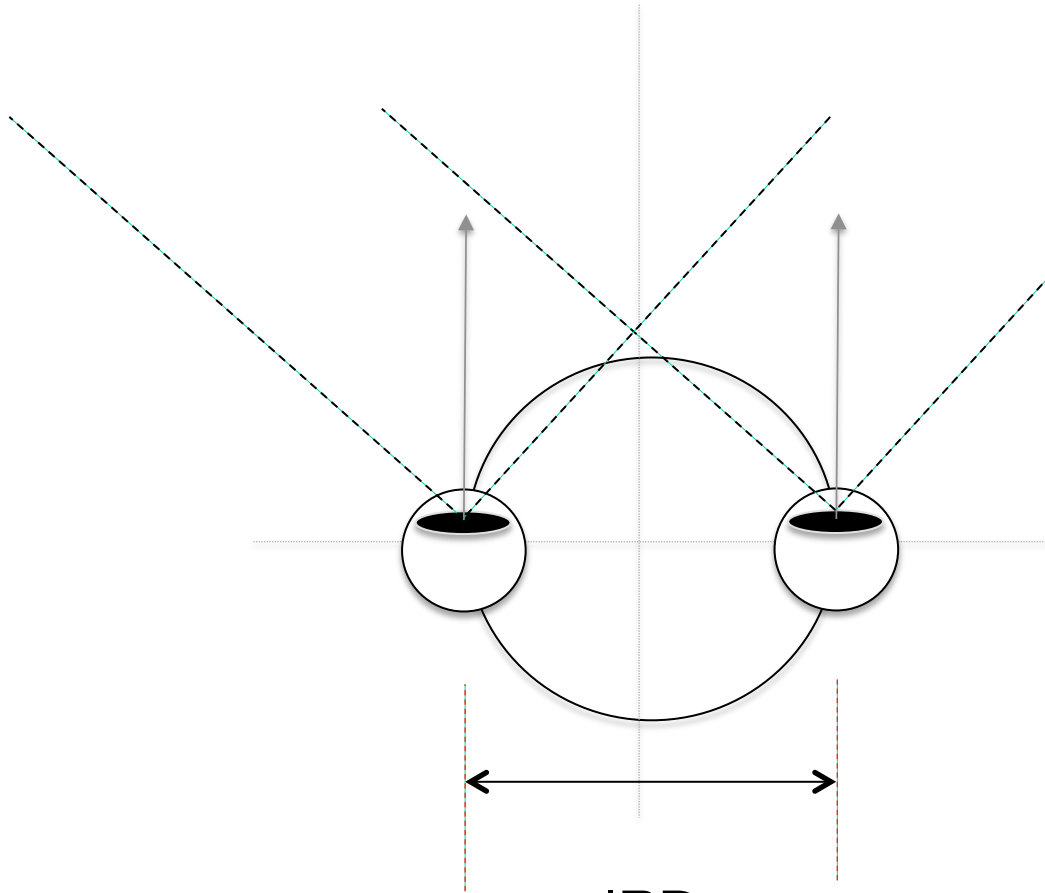
Single Center of Projection

A Pair of Mono Panoramas

Baseline = $|O_1 - O_2|$
in this viewing direction,
i.e., stereo possible



Head Rotation



IPD
Inter Pupillary Distance

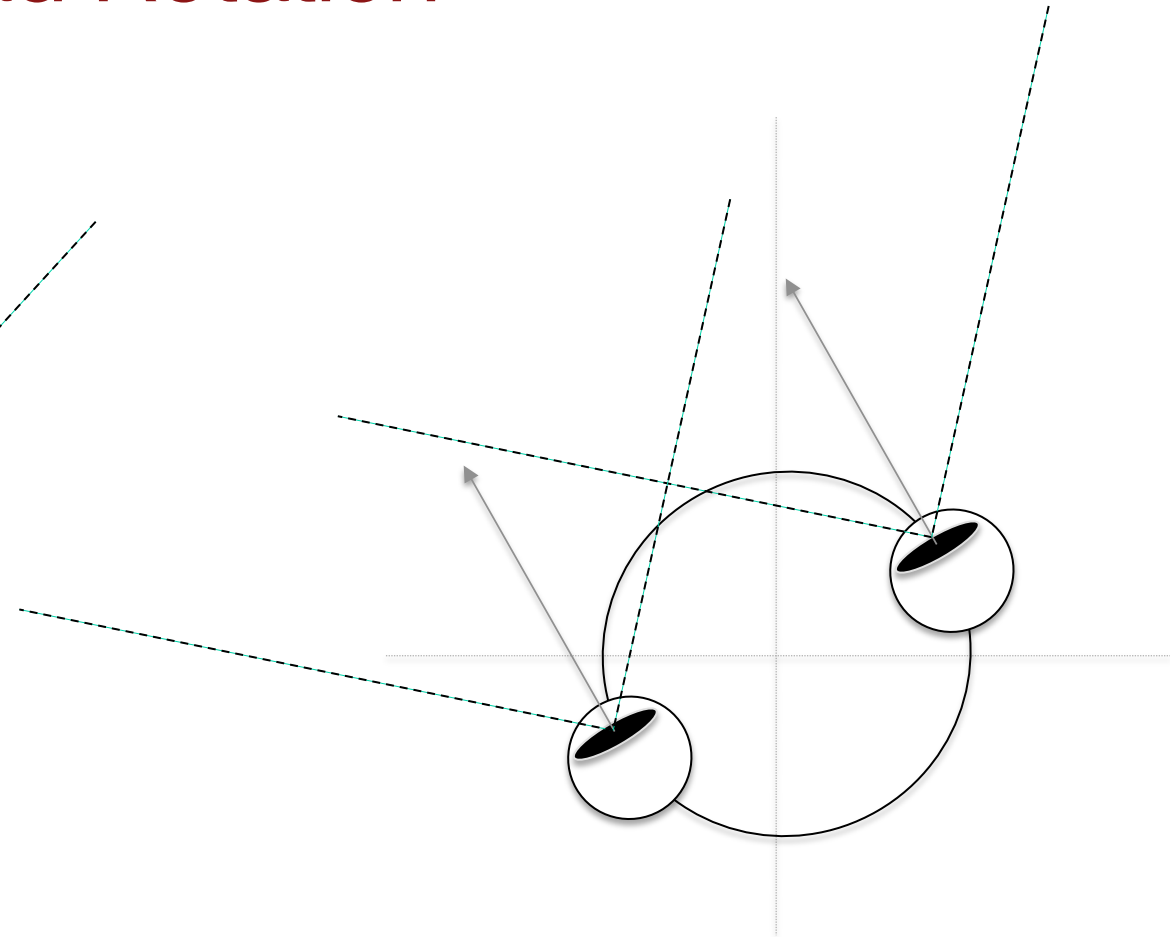
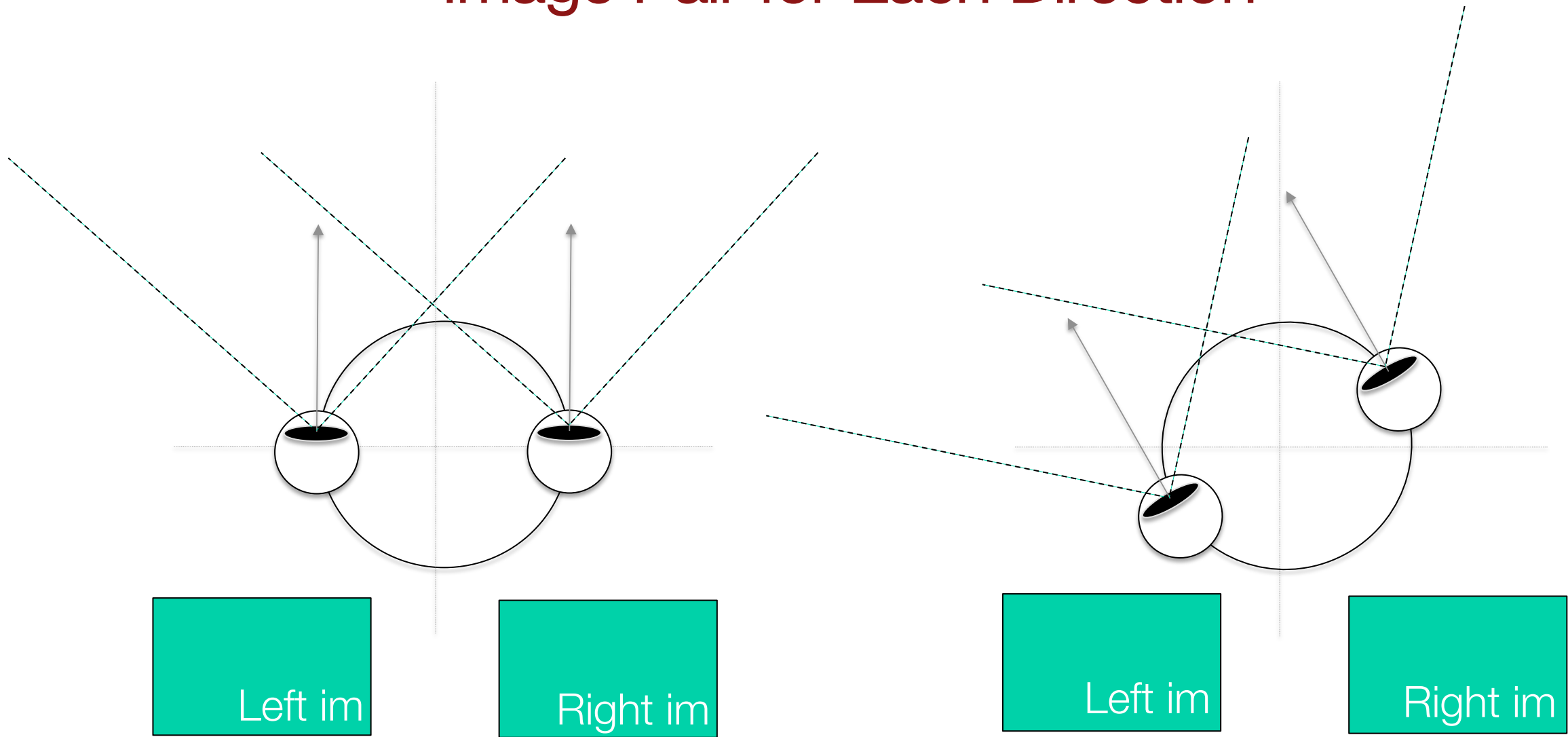


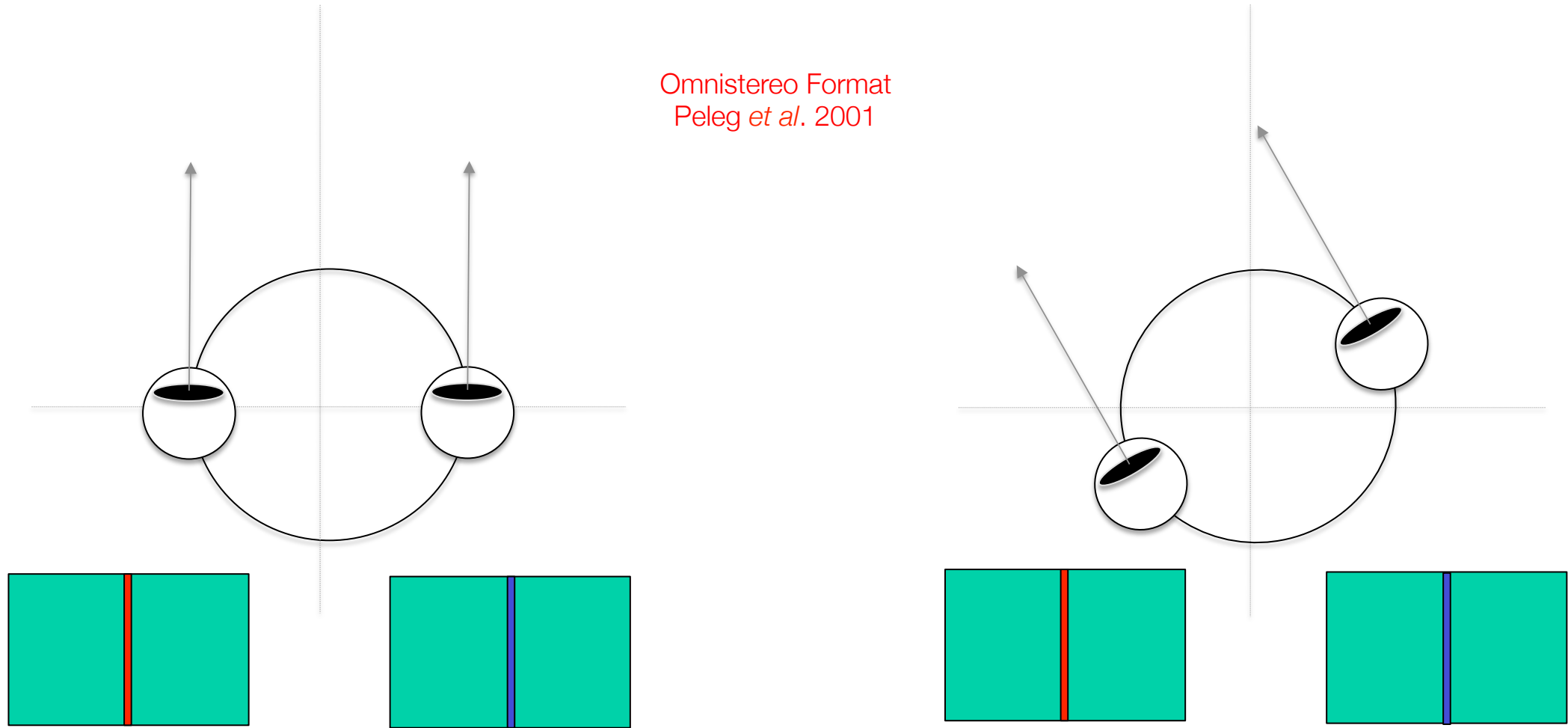
Image Pair for Each Direction



Store image pair for each direction → Problem: Too much data

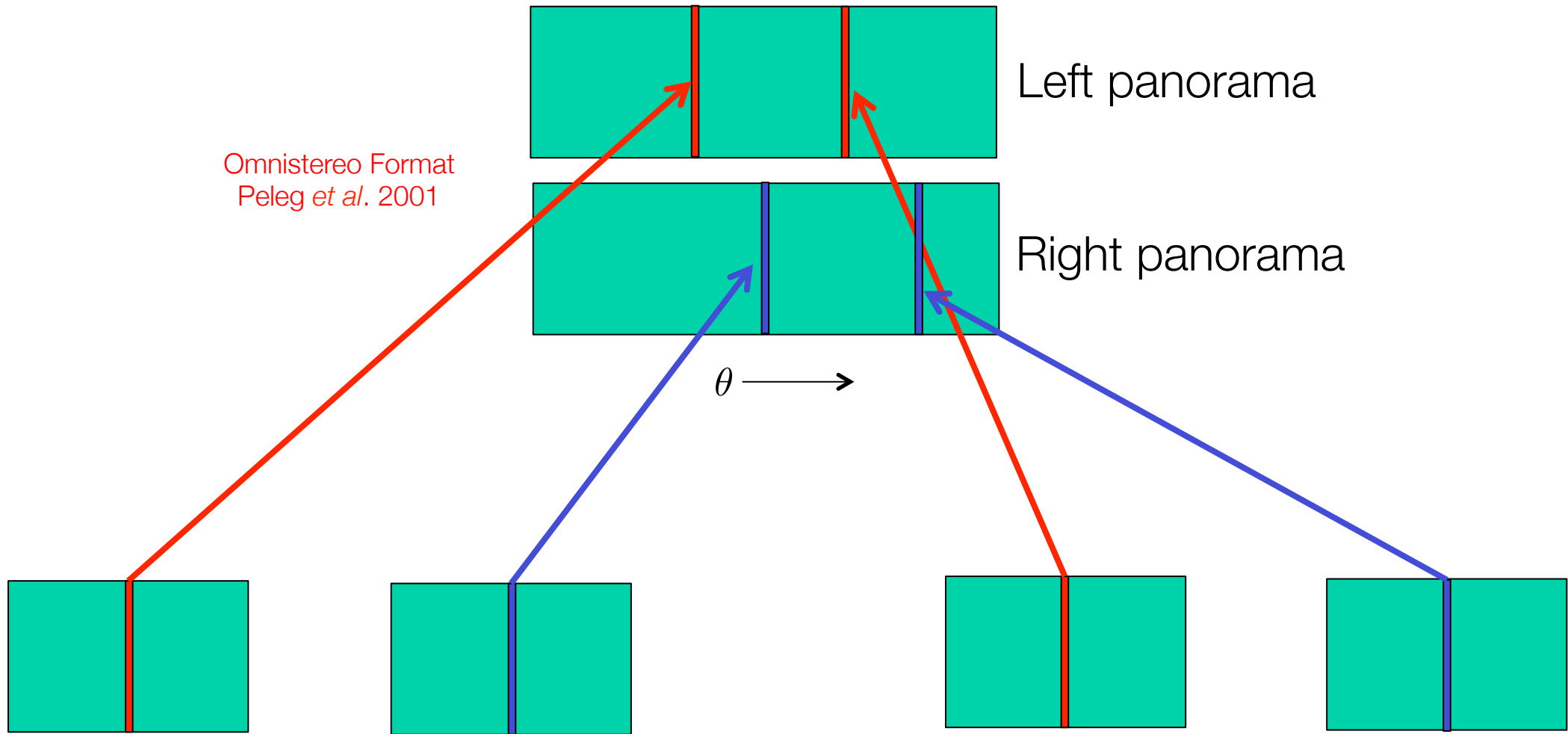
Approximation: Store only Middle Ray

Omnistereo Format
Peleg *et al.* 2001



Approximation: store only middle ray for L and R eyes for each direction

Omnistereos Panoramas



Omnistereero: Geometry Details

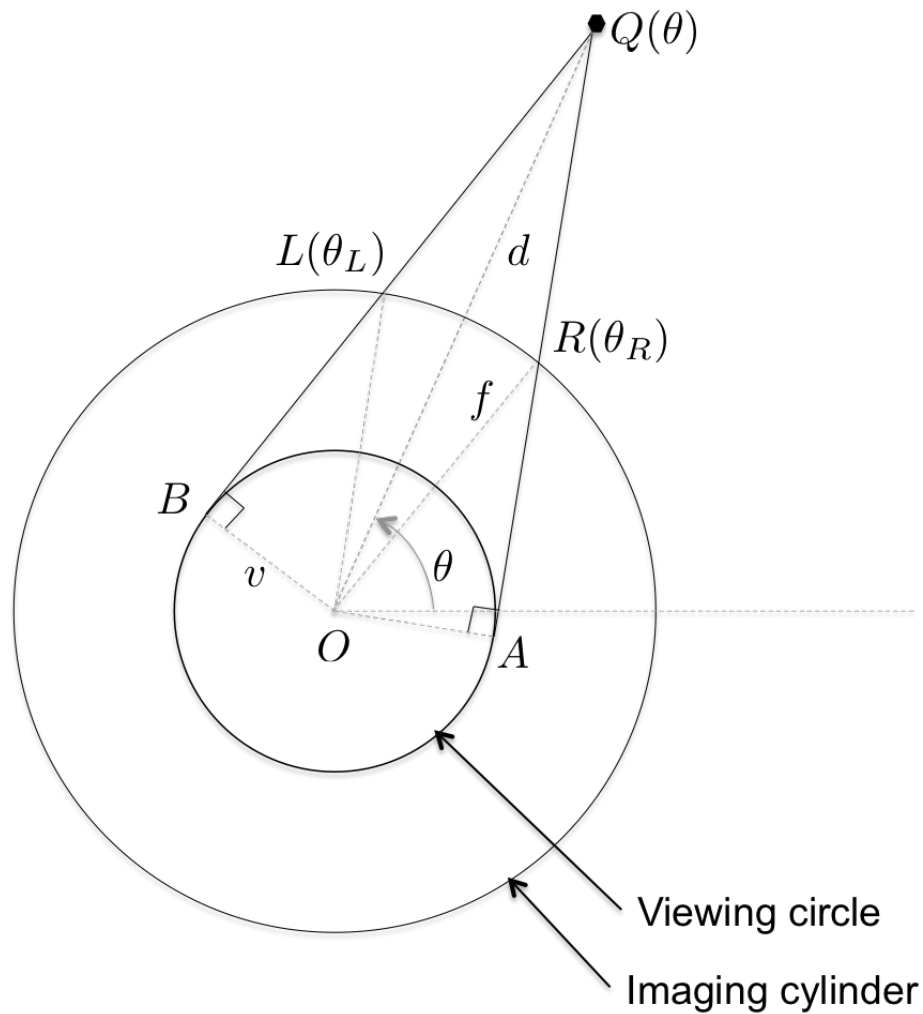


Diagram for a point on equatorial plane

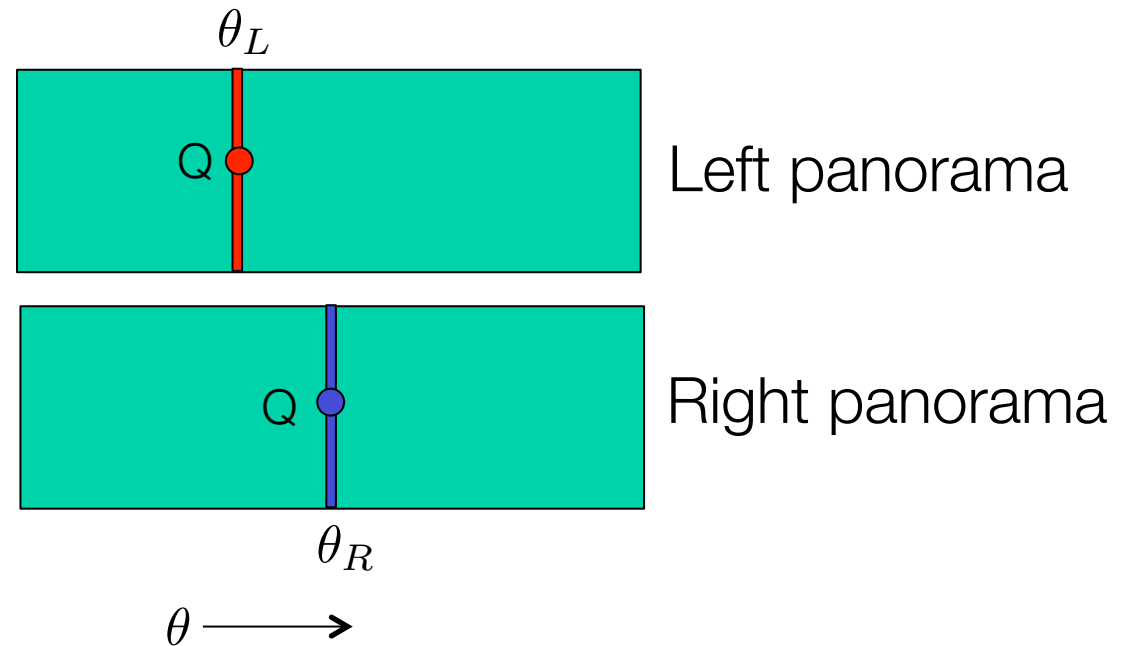
Q: scene point

d: distance to Q from origin

v: viewing circle radius

f: imaging cylinder radius

L, R: coordinates of Q in panoramas



What about elevation?

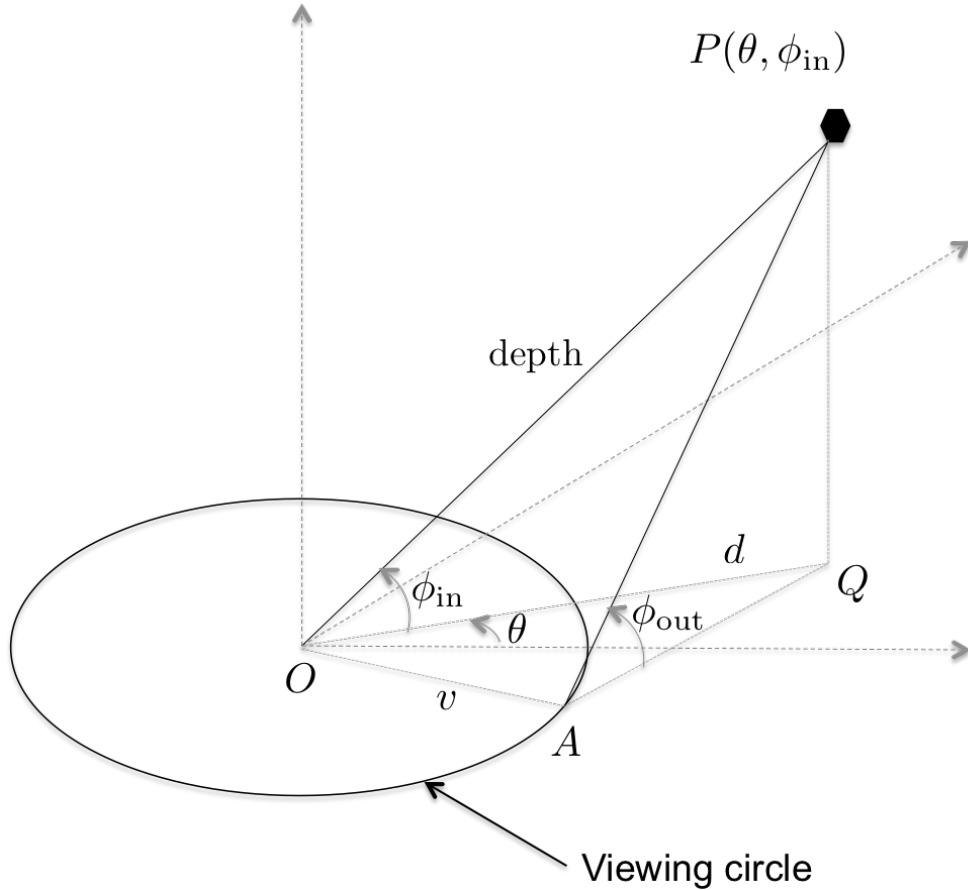
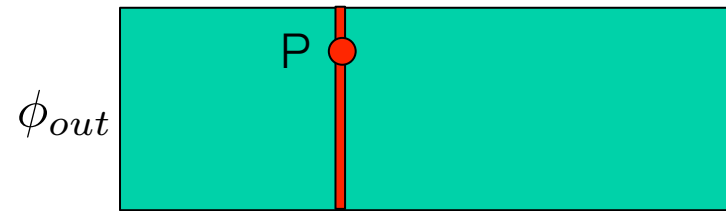


Diagram for a point off-equatorial plane

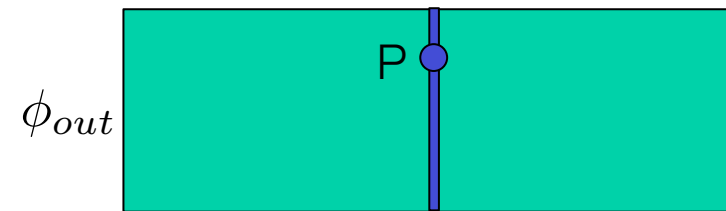
P : scene point

ϕ_{in} : elevation of P from origin

ϕ_{out} : elevation of P from A

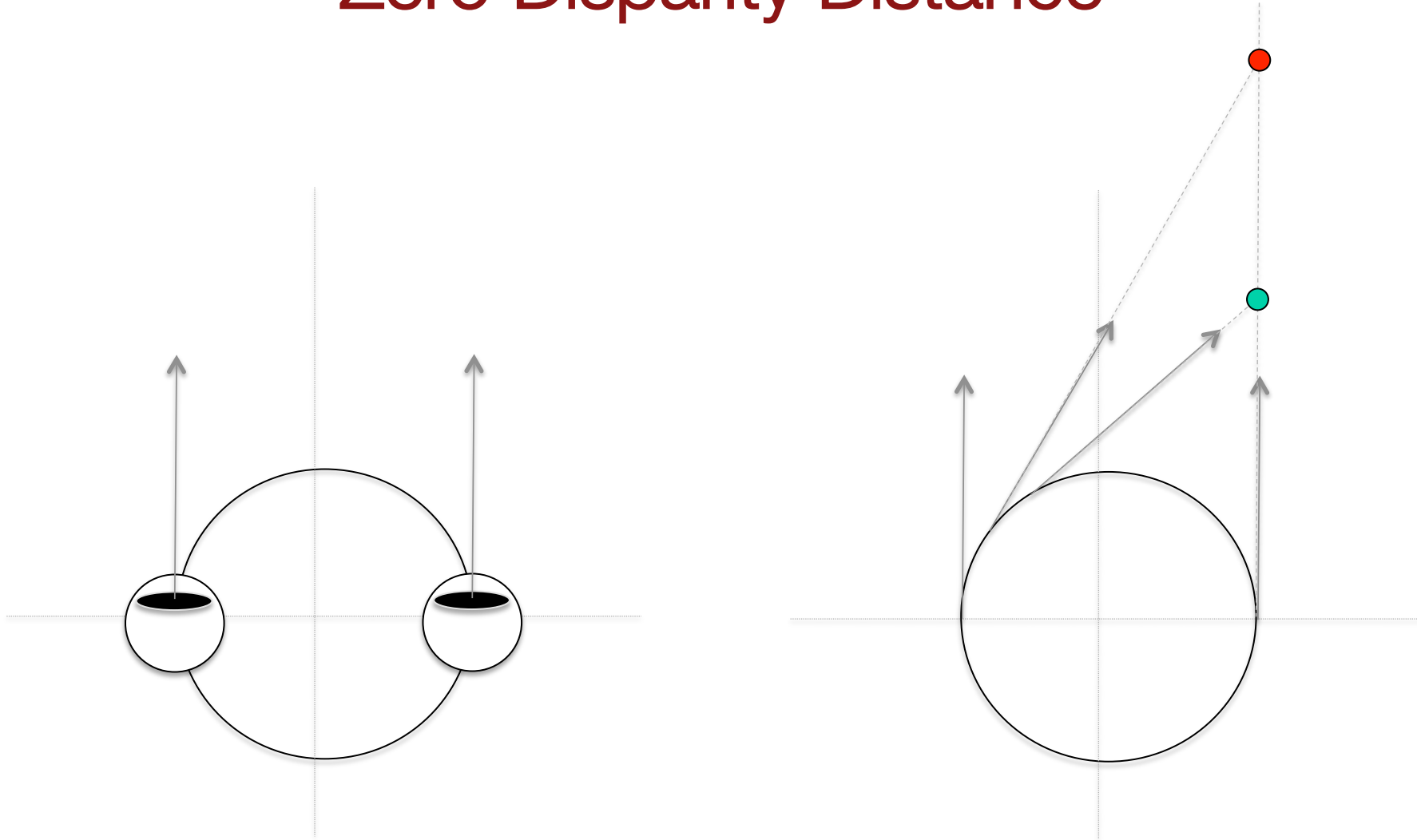


Left panorama



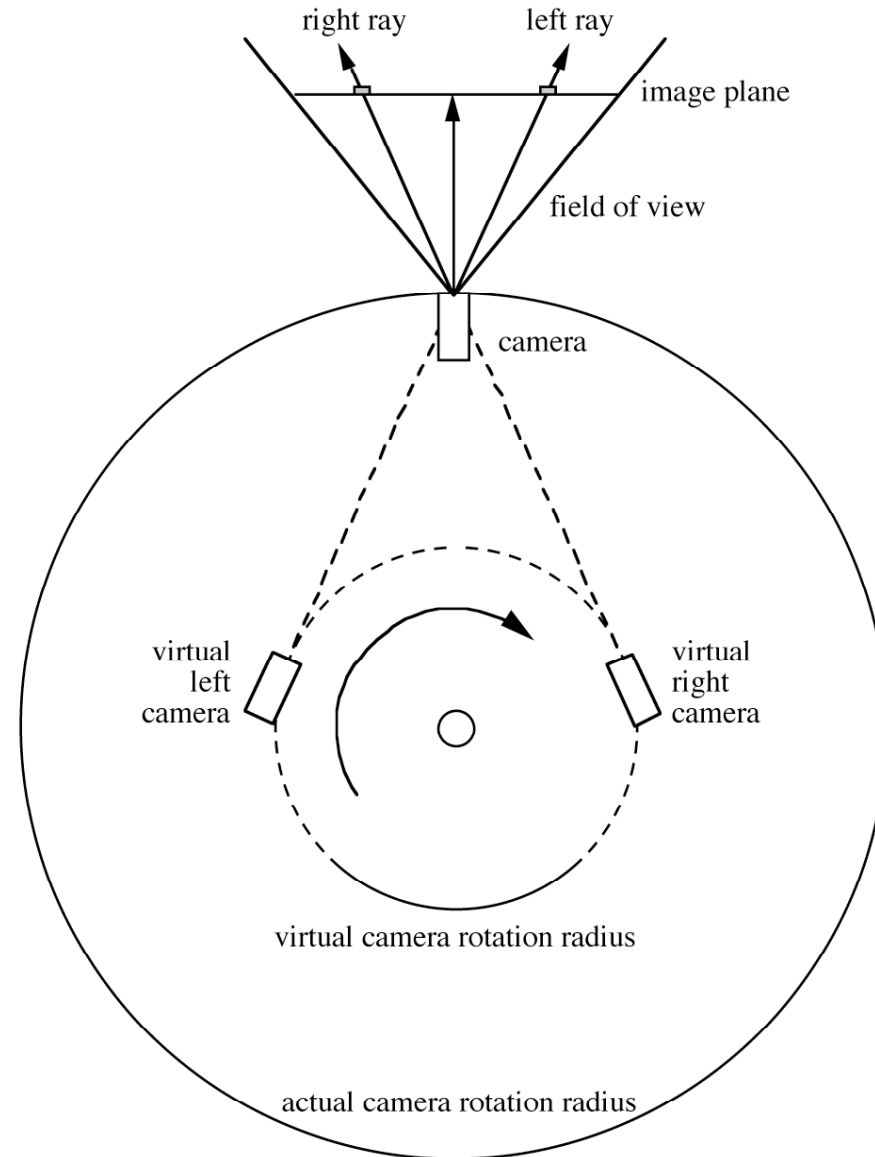
Right panorama

Zero Disparity Distance



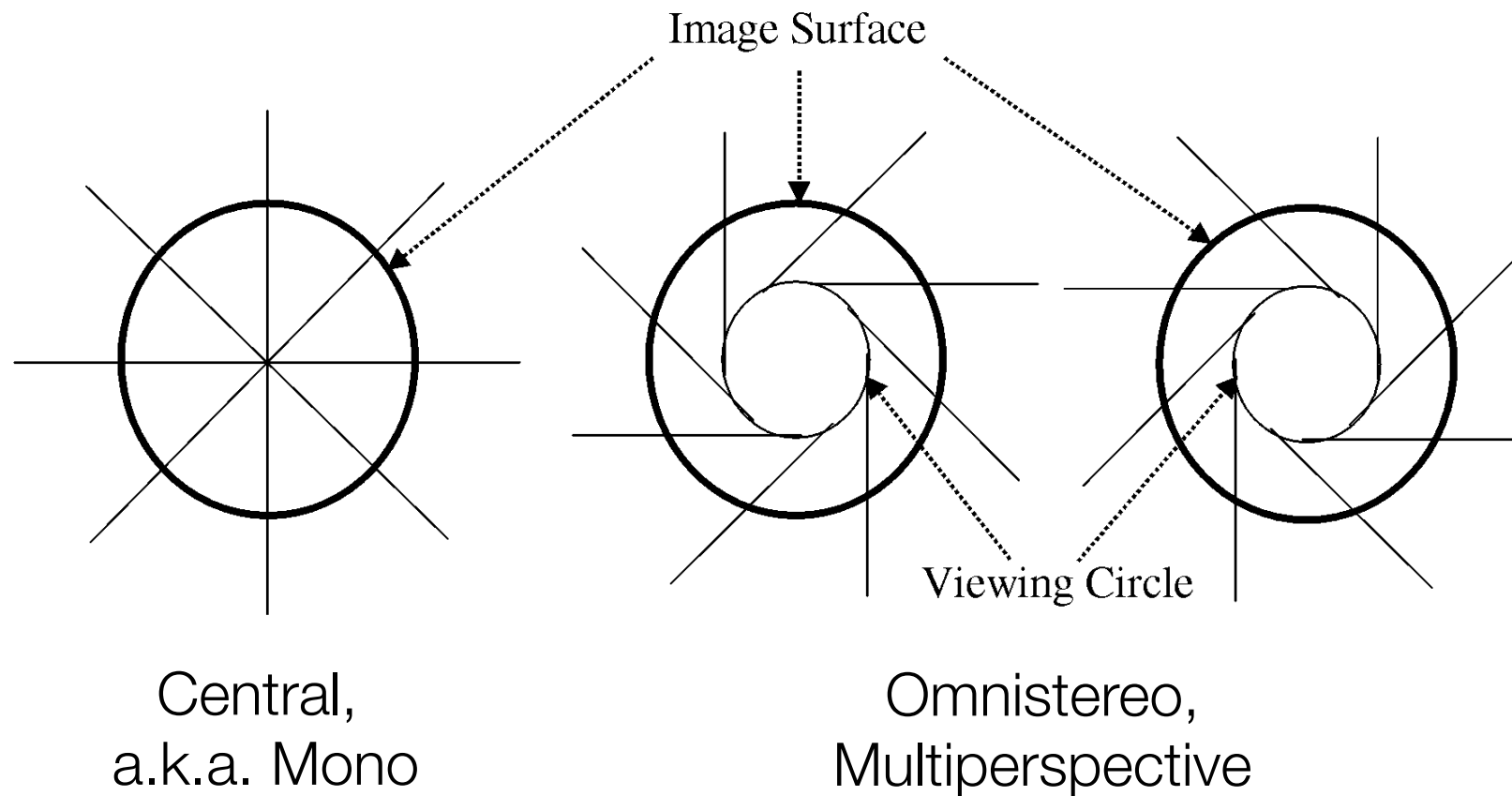
To control zero disparity distance: circularly shift left pano relative to right pano

Capture using Single Camera



Peleg et al. 2001

Comparison: Mono and Stereo Panoramas



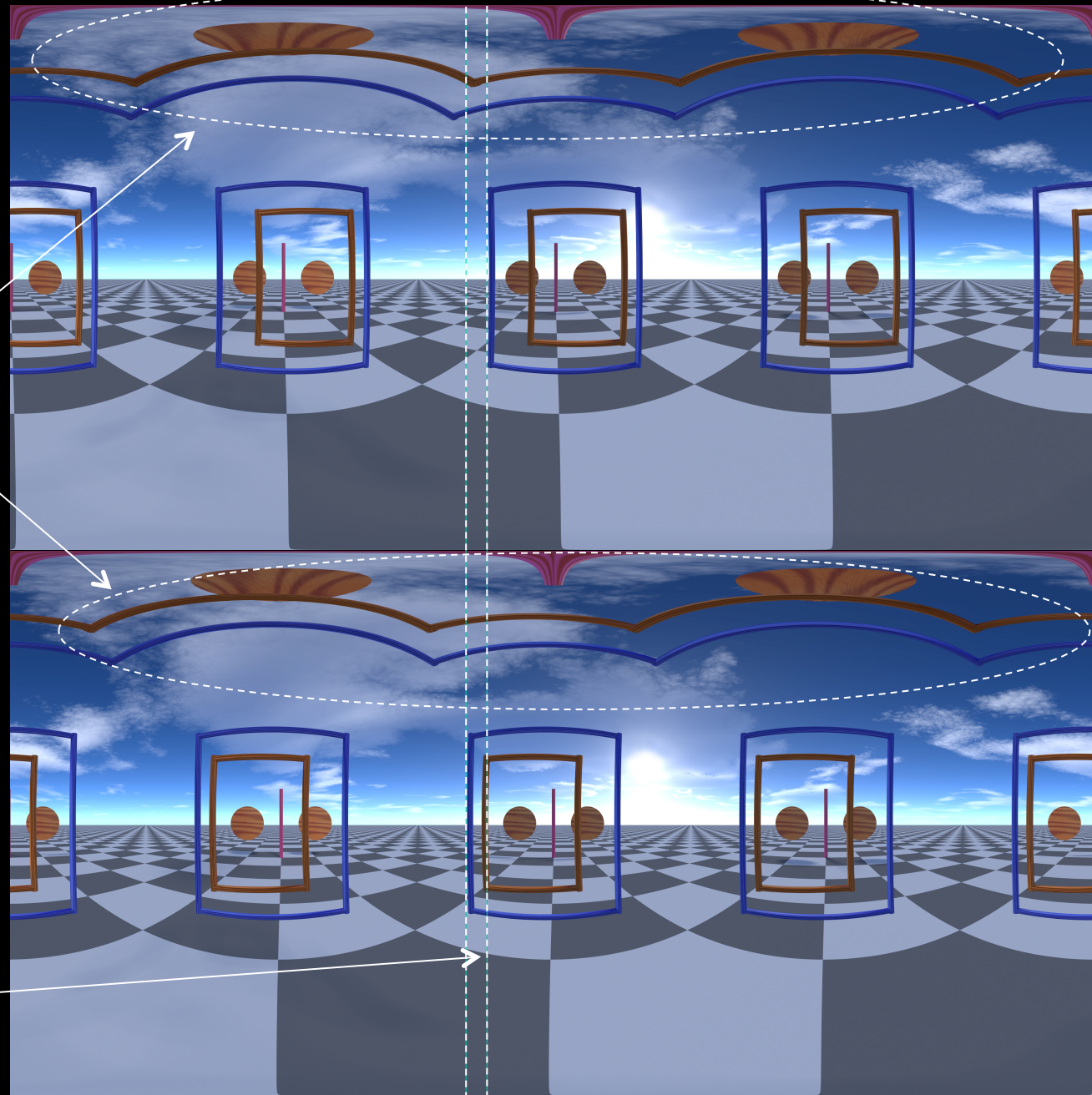
Omnistereo example

Sphere-to-plane distortions

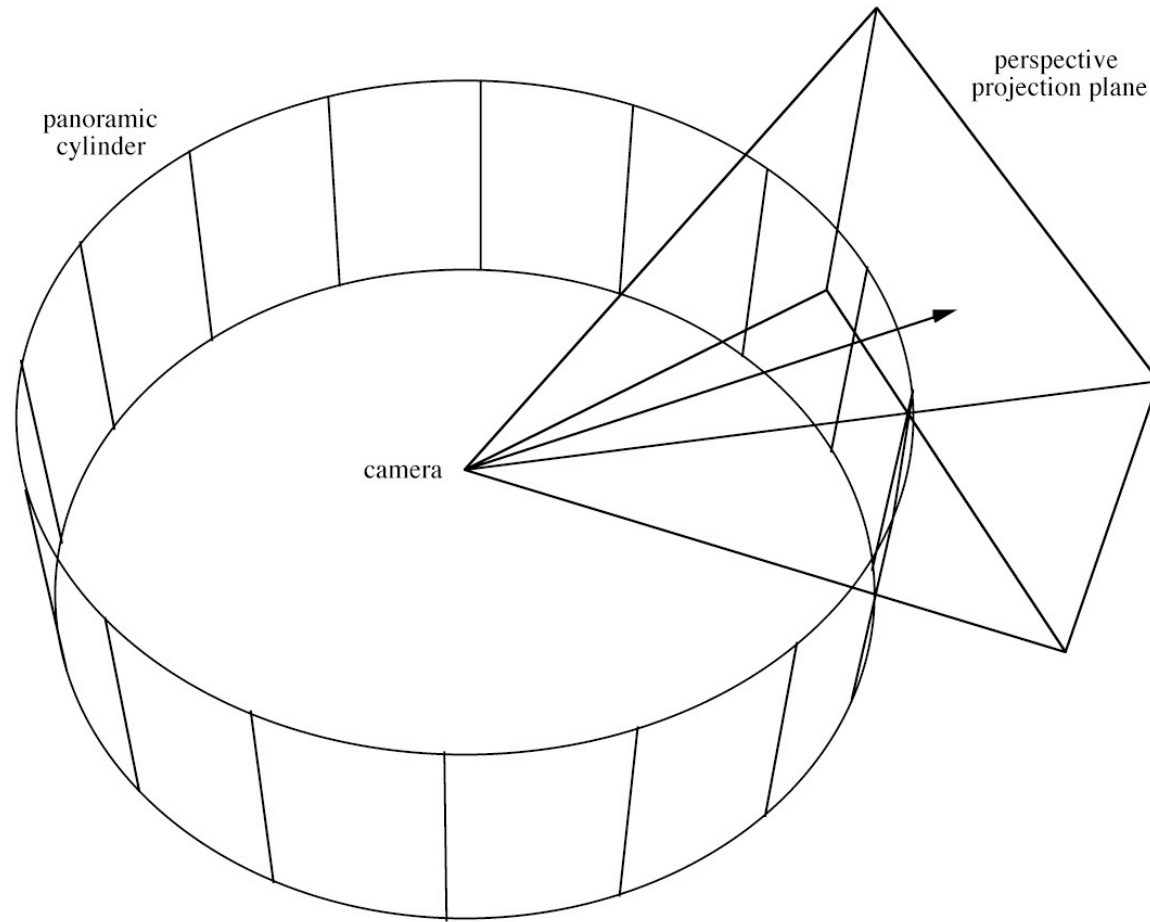
Left panorama

Right panorama

Disparity



Generating Viewports from Panoramas

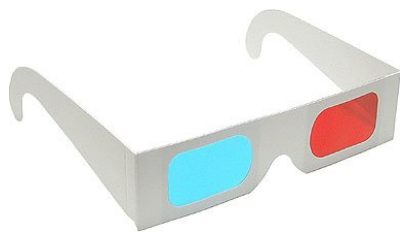


Viewport:
Projection from cylinder/sphere to plane

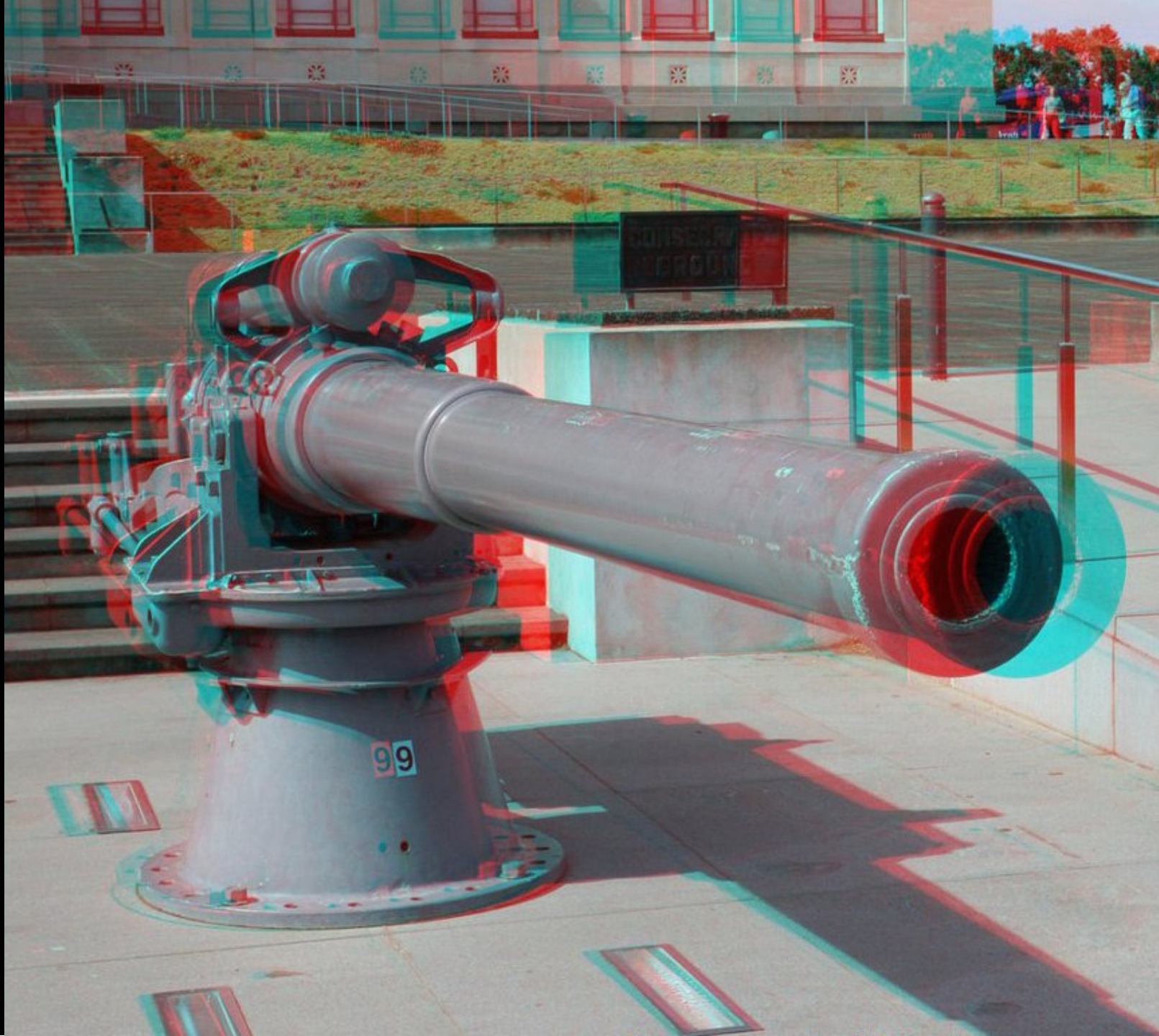
Image: Bourke

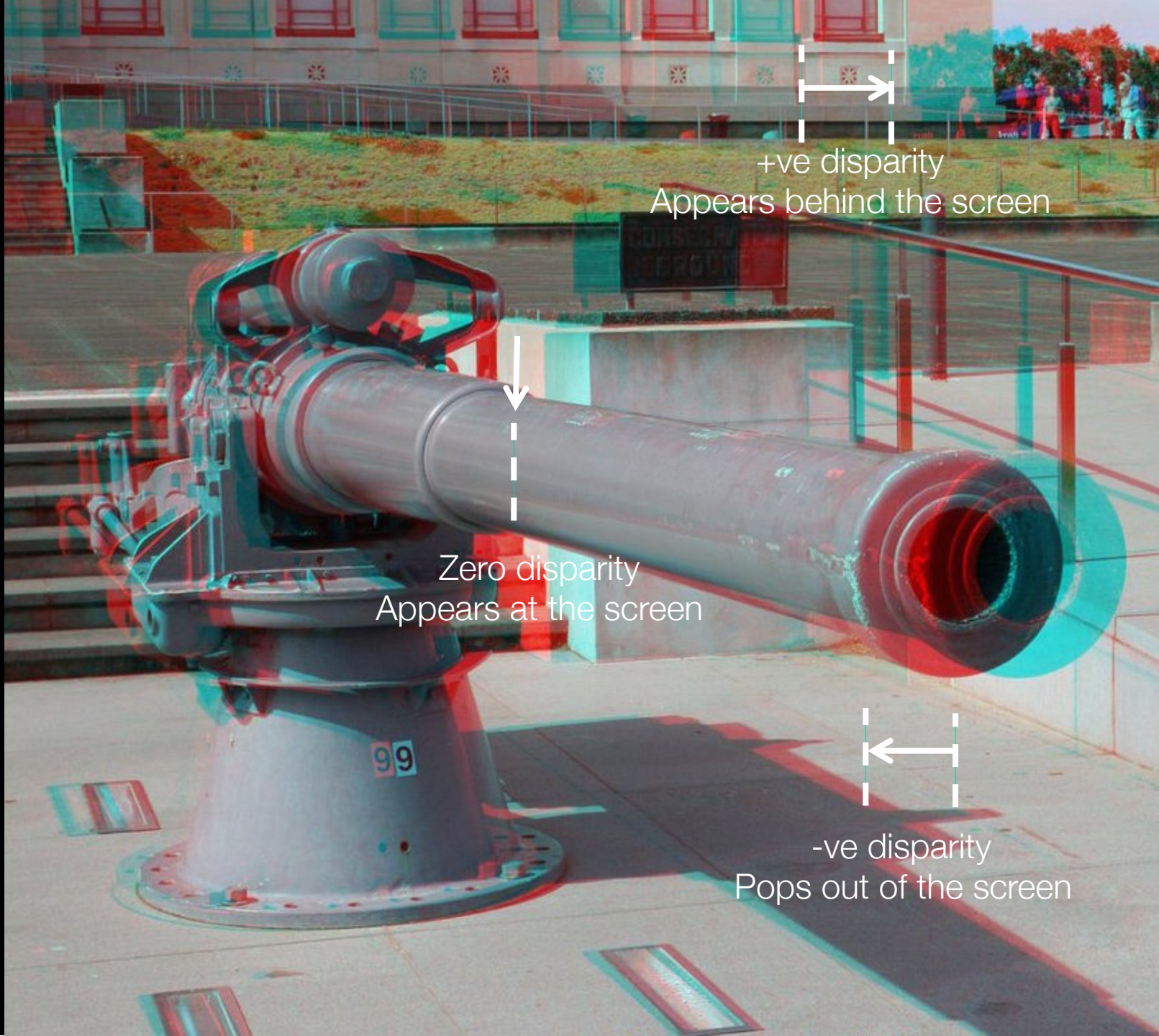
Generating Viewports from Panoramas

- Create viewports to view on HMD, computer monitor, TV
- Get left and right viewports from left and right panoramas, i.e., stereo pairs from stereo panoramas
- Can create anaglyph image from stereo pair for quick visualization (`stereoAnaglyph` function in Matlab)



Put red filter over left eye





+ve disparity
Appears behind the screen

Zero disparity
Appears at the screen

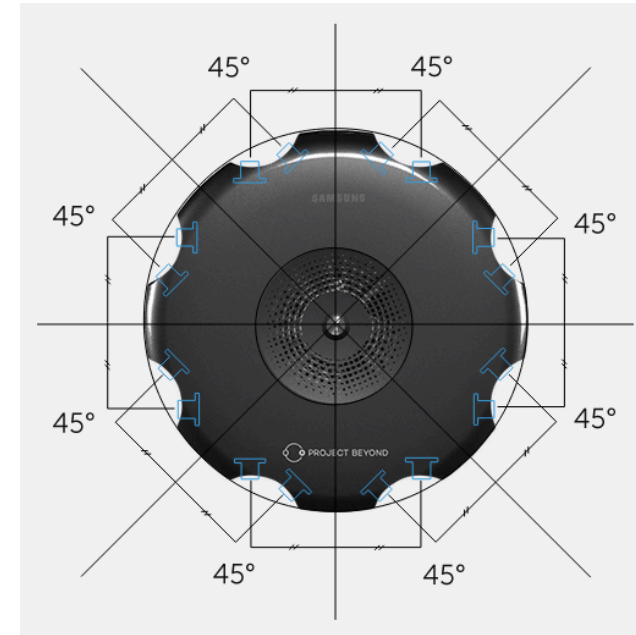
-ve disparity
Pops out of the screen

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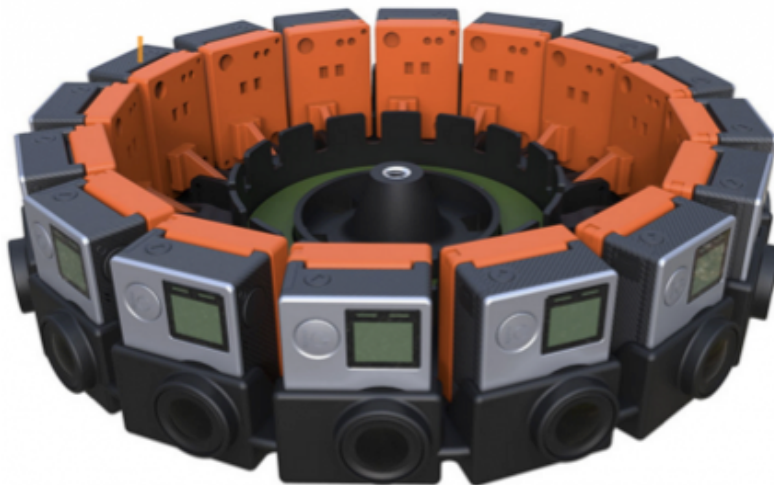
Real World Capture Setups

Jaunt NEO



Samsung Beyond

Google Jump



Nokia OZO

Video Stitching



<https://www.google.com/get/cardboard/jump/>



R&D Areas

Capture



- Camera calibration
- Color adjustment
- Scene reconstruction

Process



- Postproduction
- Coding
- Streaming

Display



- User interaction
- Motion parallax
- Focus cues