CSE 190: Virtual Reality Technologies

LECTURE #19: PANORAMA IMAGING

Upcoming Deadlines

Sunday, June 6: Project 4 due

June 7+8: Final exam Monday 11:30am – Tuesday 11:30am

App Presentations

Baily Chen

- Minecraft VR

Juan Ramirez

- Super Hot VR

Final Exam

Exam window: Monday 11:30am – Tuesday 11:30am

Exam duration: 3 hours (continuous block)

Exam type: written exam (Canvas Quiz)

Open book, open internet

No consulting of other people (local or remote)

No posting or discussing exam questions or answers

Panoramic Photos and Video

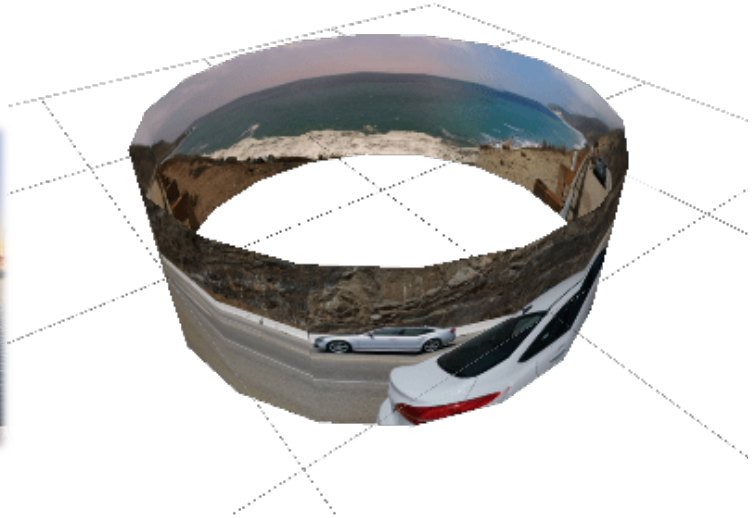
360˚ Photos

A.k.a. panoramic photographs, surround images, image spheres

360˚ photos simulate being in the shoes of a photographer and looking around to the left, right, up and down as desired as well as sometimes zooming.

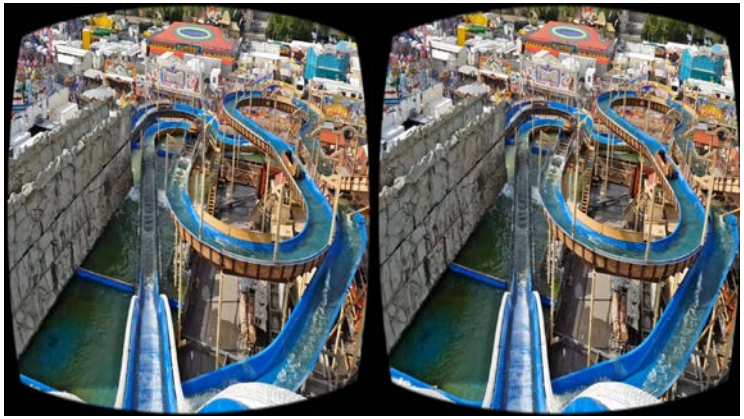
Popular example: Google Streetview

- https://www.google.com/streetview/



VR Video Formats

Fixed view 3D stereo videos are typically stored side-by-side:



360 degree 3D stereo videos are stored in over-under format:

360° Video on Youtube

Youtube VR videos can be viewed with almost any VR device:

- Google Cardboard, Daydream, Gear VR, Oculus, Playstation VR, HTC Vive

Youtube supports 360 degree videos

- uses Mercator projection
- 3D stereo in over-under format with up to 8192 x 8192 pixels resolution

Example: City tour of Rome (monoscopic 360 degree video)

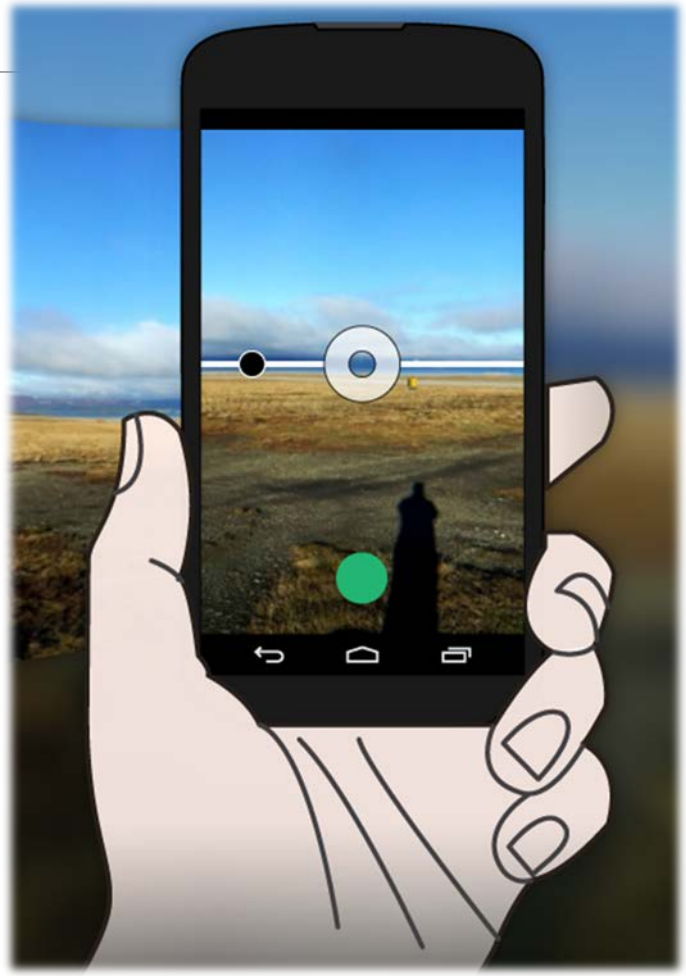
https://www.youtube.com/watch?time_continue=93&v=1ziMH_lAUW0&feature=emb_logo

Panorama Capture Devices

Smartphone

Most smartphones have panorama photo capture modes/apps

Photos are 360 degrees but monoscopic



Samsung Gear 360

Two versions: released in 2016 ($350) and 2017 ($230)

360˚ Photos:

- Dual Lens: 25.9 MP (7200 x 3600) (2016) or 15MP (5472 x 2736) (2017)

360˚ Video:

- Dual Lens: up to 4096 x 2048 (24fps)

2017 version has better picture quality

Sensors:

- Gyroscope, Accelerometer

Storage: microSD

IP53 Dust and Splash-proof

V1 (2016)

V2 (2017)

Vuze XR

Photos: 6000 x 3000 pixels

Video: 5.7K@30 fps

Storage: microSD

Lenses: 2x F/2.4 210° fisheye lenses

Sensors: 2 x Sony 12MP

Price: $400

Google VR180

Limited to 180 degree FOV

Advantage: much easier to shoot

- Camera people don’t need to hide
- Camera and audio equipment can be used almost like in traditional video production

Lenovo Mirage Camera

YI Horizon VR180 Camera

Vuze+

Spherical Resolution: 4K (per eye)

Frame rate: 30fps for 3D or 60fps for 2D

Sensors: 8 Sony FHD image sensors

Lenses: 8x F/2.4 fisheye lenses

Media FOV: 360°x180° (Full Spherical)

Price: $700

Nokia Ozo

Released 2015

Discontinued 2017

Price: $45,000

8 lenses

3D 360 degree stitching

Samsung 360 Round

Price: $10,500

17 cameras with 2MP image sensor and F1.8 Lens

- 16 horizontal, 1 up camera

3D Video 3D: 4096 x 2048 at 30fps per eye

6 microphones for spatial audio

IP65 Splash and Dust Resistant

Weight: 4.3 lbs

3D Video: Google Jump Yi Halo

Price: $20,000

16 horizontal cameras + 1 up camera

Sensors: Sony IMX377, 1/2.3", 12 megapixels CMOS

Lenses: F2.8 aperture / 155° wide-angle

Omni-directional microphone

Battery: ATL 93Wh high density lithium polymer battery, battery life 100 minutes in video recording

Video and photo resolution:

- 8192x8192 @30fps

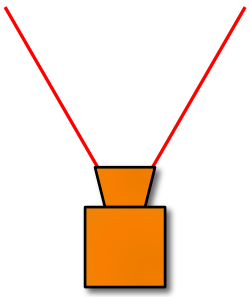
CAVECam
For full 360° by 180° Panoramas
By UCSD’s Drs. Tom DeFanti and Dan Sandin

Panorama Capturing

Panorama v Stereo Movie v Stereo Panorama

Panorama

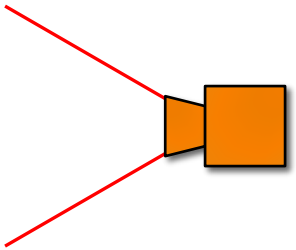
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

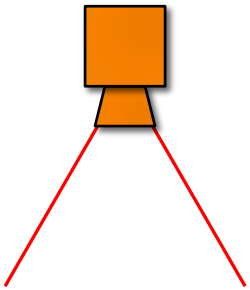
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

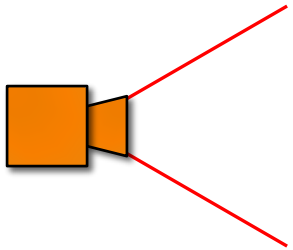
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

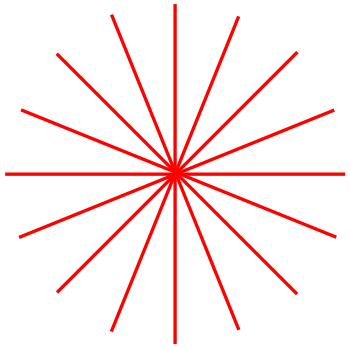
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation

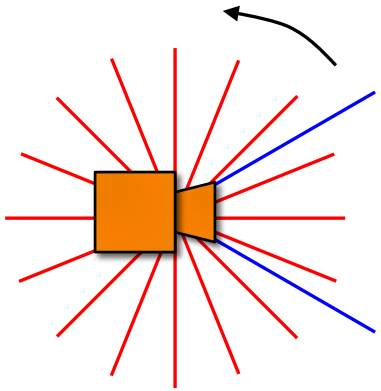


1 center of projection!

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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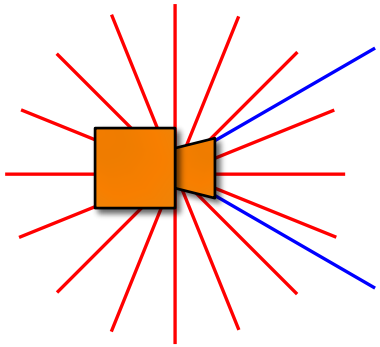
Panorama v Stereo Movie v Stereo Panorama

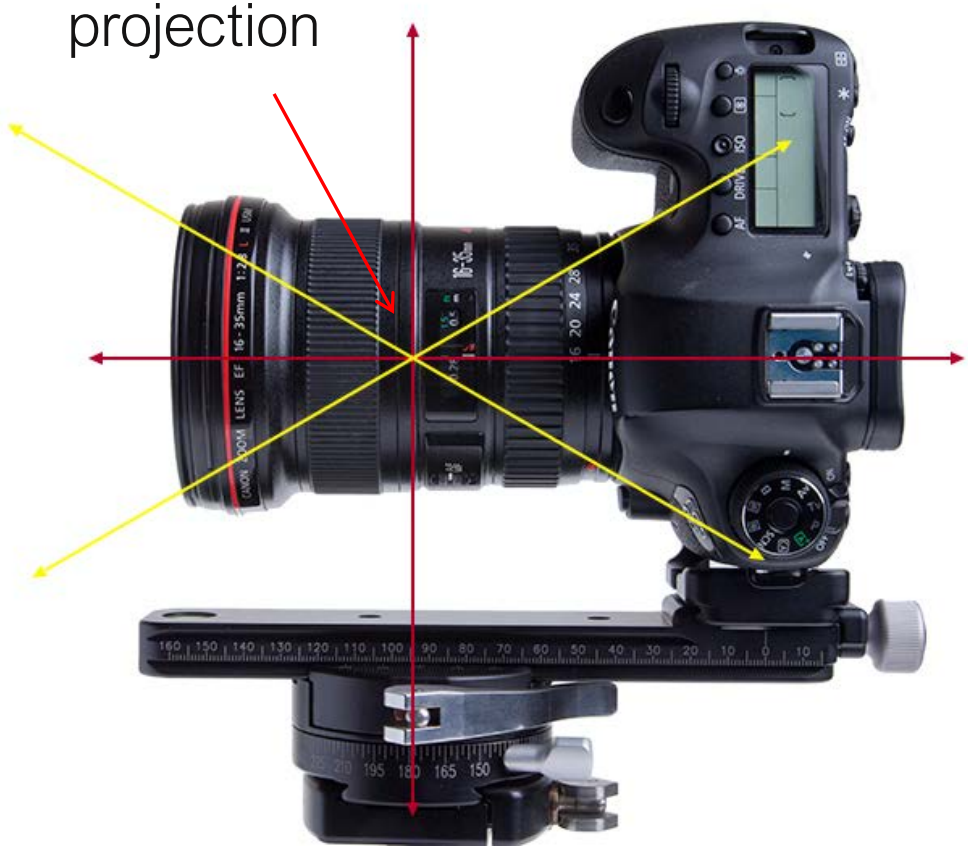
Panorama

mono & head rotation



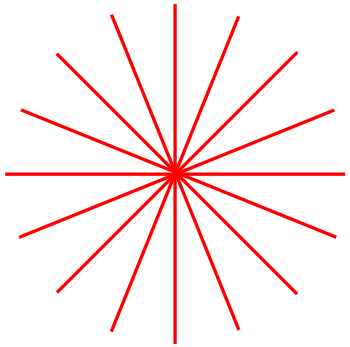
1 center of projection!

center of projection



Panorama v Stereo Movie v Stereo Panorama

Panorama	Stereo	Stereo Panorama
mono & head rotation	stereo & no head rotation	stereo & head rotation



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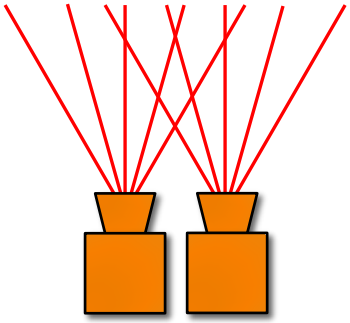
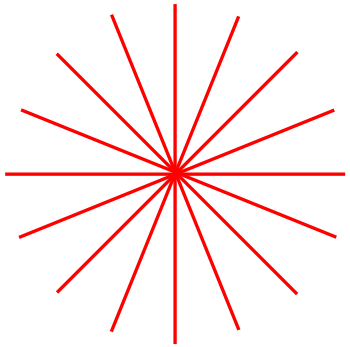


Panorama v Stereo Movie v Stereo Panorama

Panorama	Stereo	Stereo Panorama
mono & head rotation	stereo & no head rotation	stereo & head rotation



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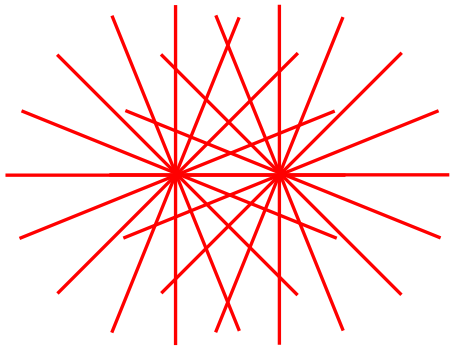
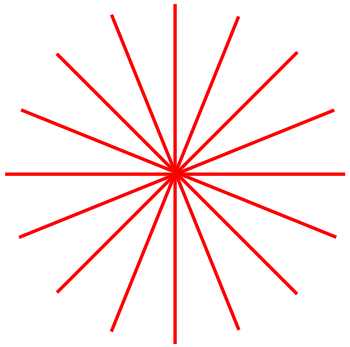


2 centers of projection!

Panorama v Stereo Movie v Stereo Panorama

Panorama

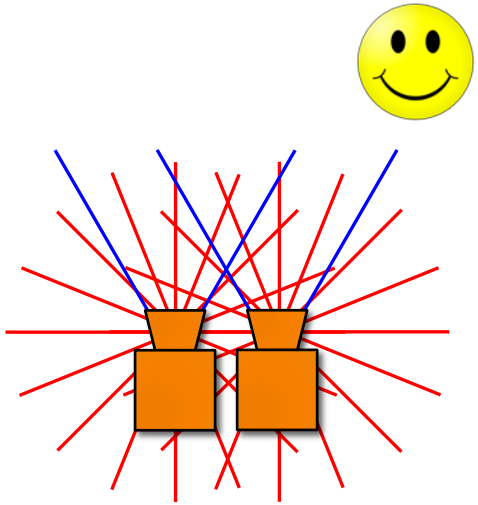
mono & head rotation



1 center of projection!

Stereo

stereo & no head rotation



2 centers of projection!

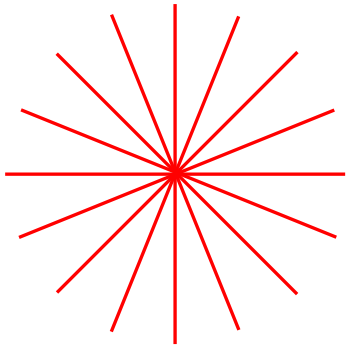
Stereo Panorama

stereo & head rotation

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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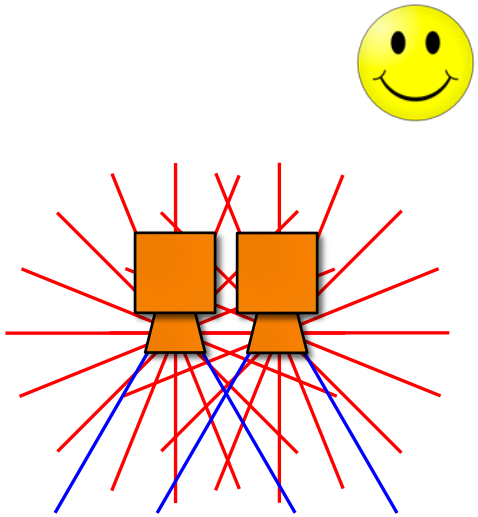
Stereo

stereo & no head rotation



2 centers of projection!

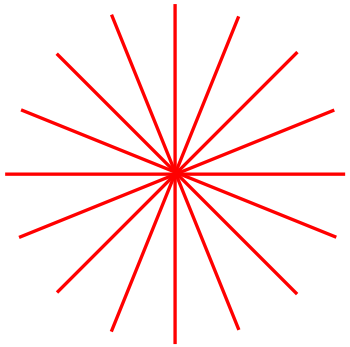
Stereo Panorama

stereo & head rotation

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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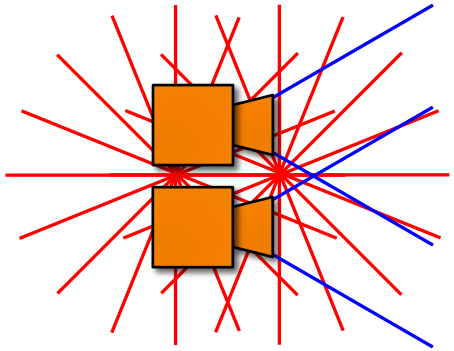
Stereo

stereo & no head rotation



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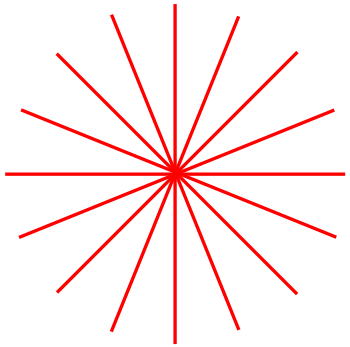
Stereo Panorama

stereo & head rotation

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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Stereo

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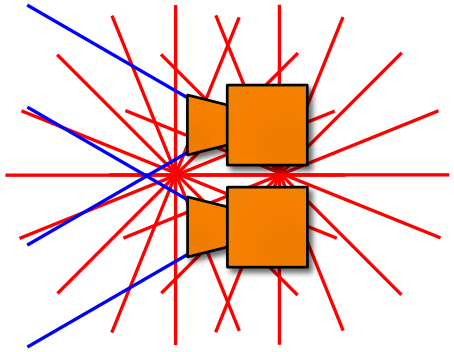

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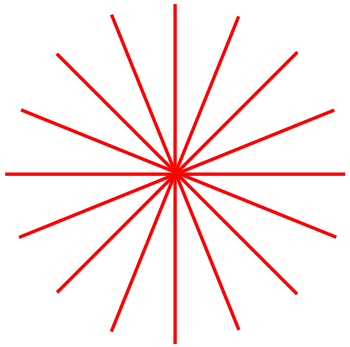
Stereo Panorama

stereo & head rotation

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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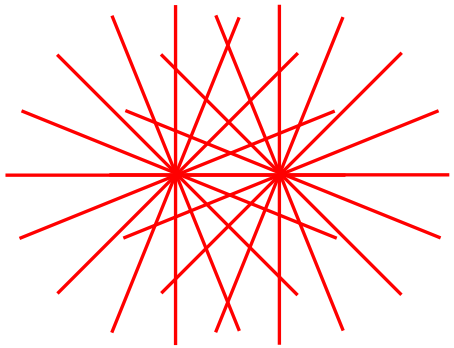
Stereo

stereo & no head rotation



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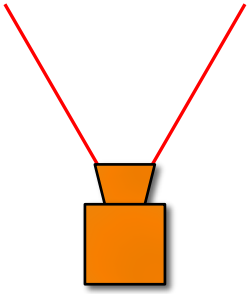
Stereo Panorama

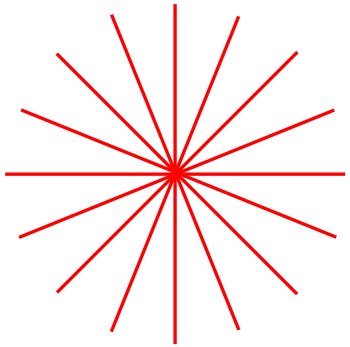
stereo & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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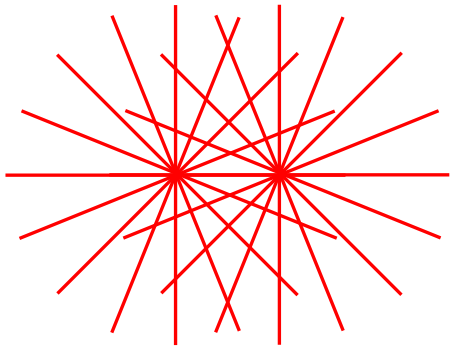
Stereo

stereo & no head rotation



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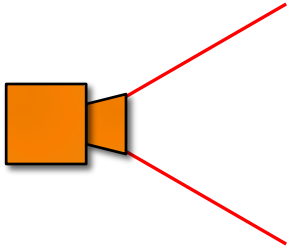
Stereo Panorama

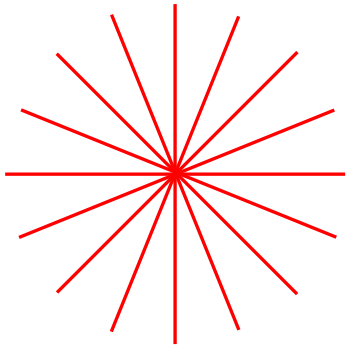
stereo & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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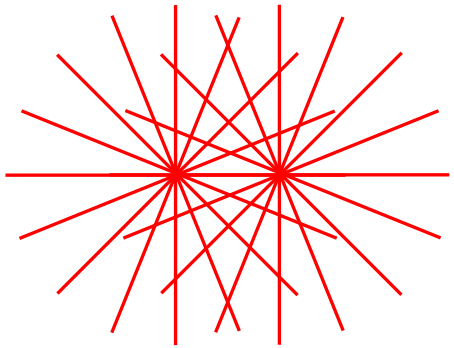
Stereo

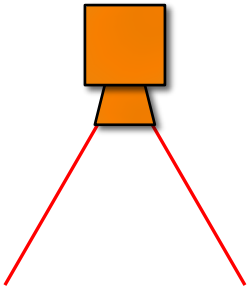
stereo & no head rotation



2 centers of projection!

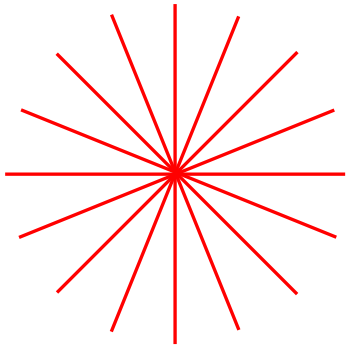
Stereo Panorama

stereo & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama	Stereo	Stereo Panorama
mono & head rotation	stereo & no head rotation	stereo & head rotation



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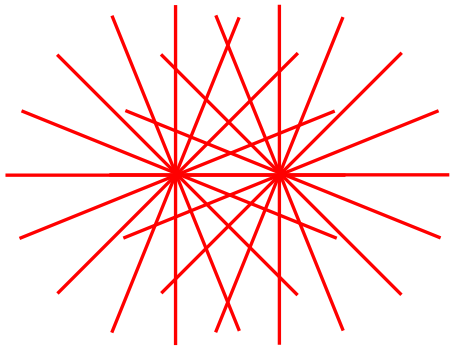

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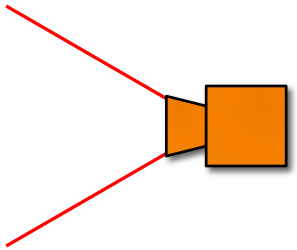
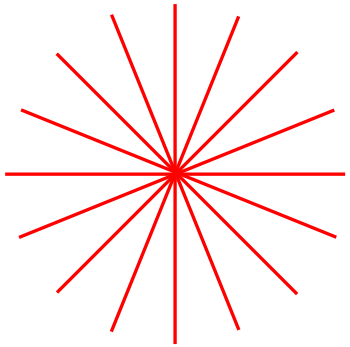


Panorama v Stereo Movie v Stereo Panorama

Panorama

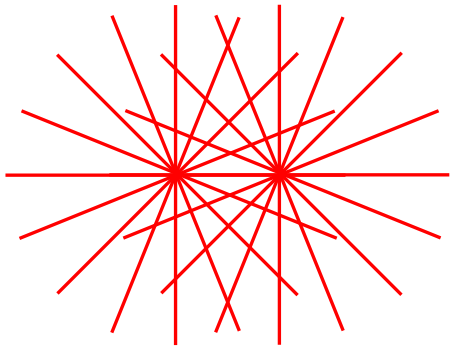
mono & head rotation



1 center of projection!

Stereo

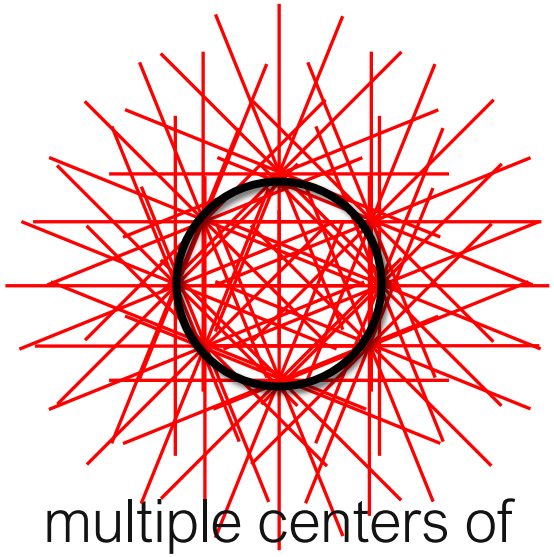
stereo & no head rotation



2 centers of projection!

Stereo Panorama

stereo & head rotation

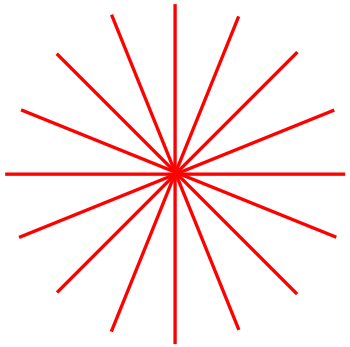


multiple centers of projection

Panorama v Stereo Movie v Stereo Panorama

Panorama

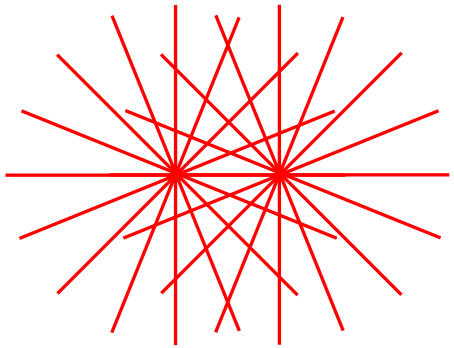
mono & head rotation



1 center of projection!

Stereo

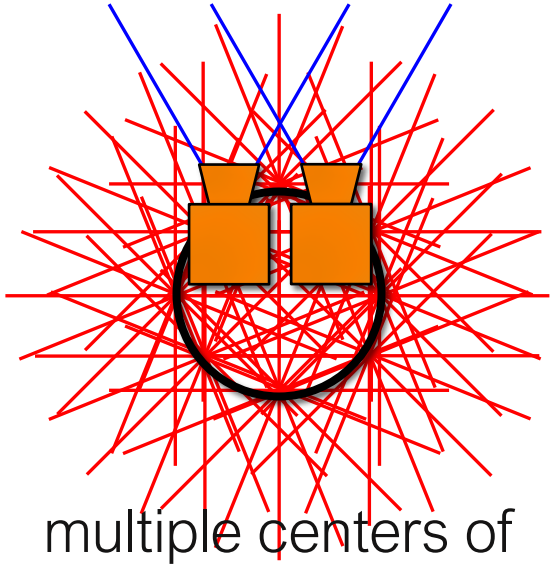
stereo & no head rotation



2 centers of projection!

Stereo Panorama

stereo & head rotation

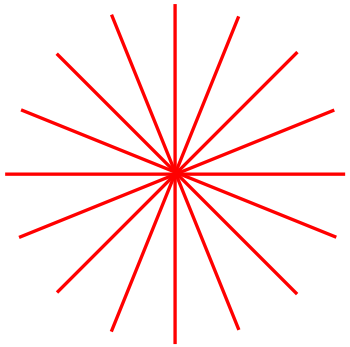


multiple centers of projection

Panorama v Stereo Movie v Stereo Panorama

Panorama

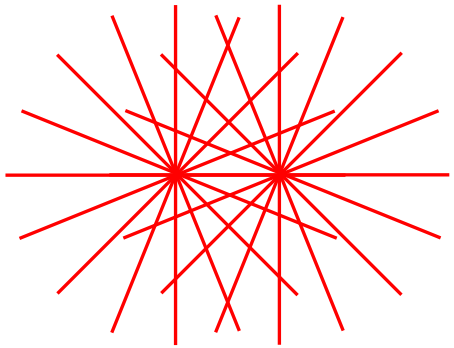
mono & head rotation



1 center of projection!

Stereo

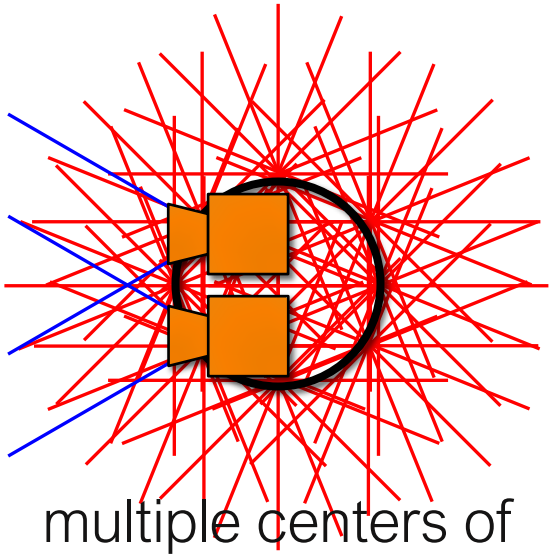
stereo & no head rotation



2 centers of projection!

Stereo Panorama

stereo & head rotation



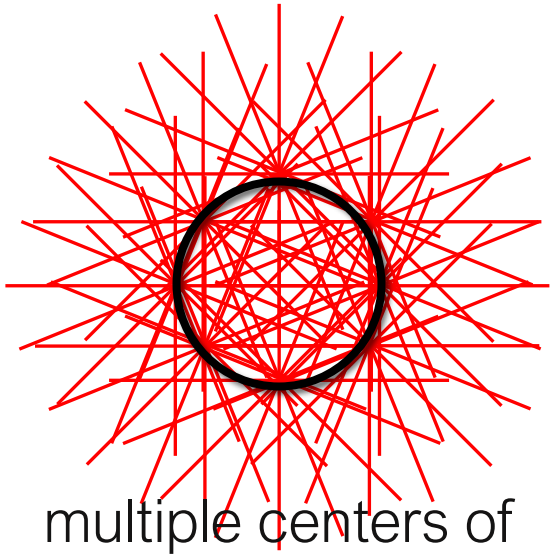
multiple centers of projection

Panorama v Stereo Movie v Stereo Panorama

Light Field!

Stereo Panorama

stereo & head rotation



multiple centers of projection

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation

Stereo

stereo & no head rotation

Stereo Panorama

stereo & head rotation

horizontal-only parallax

Stitching

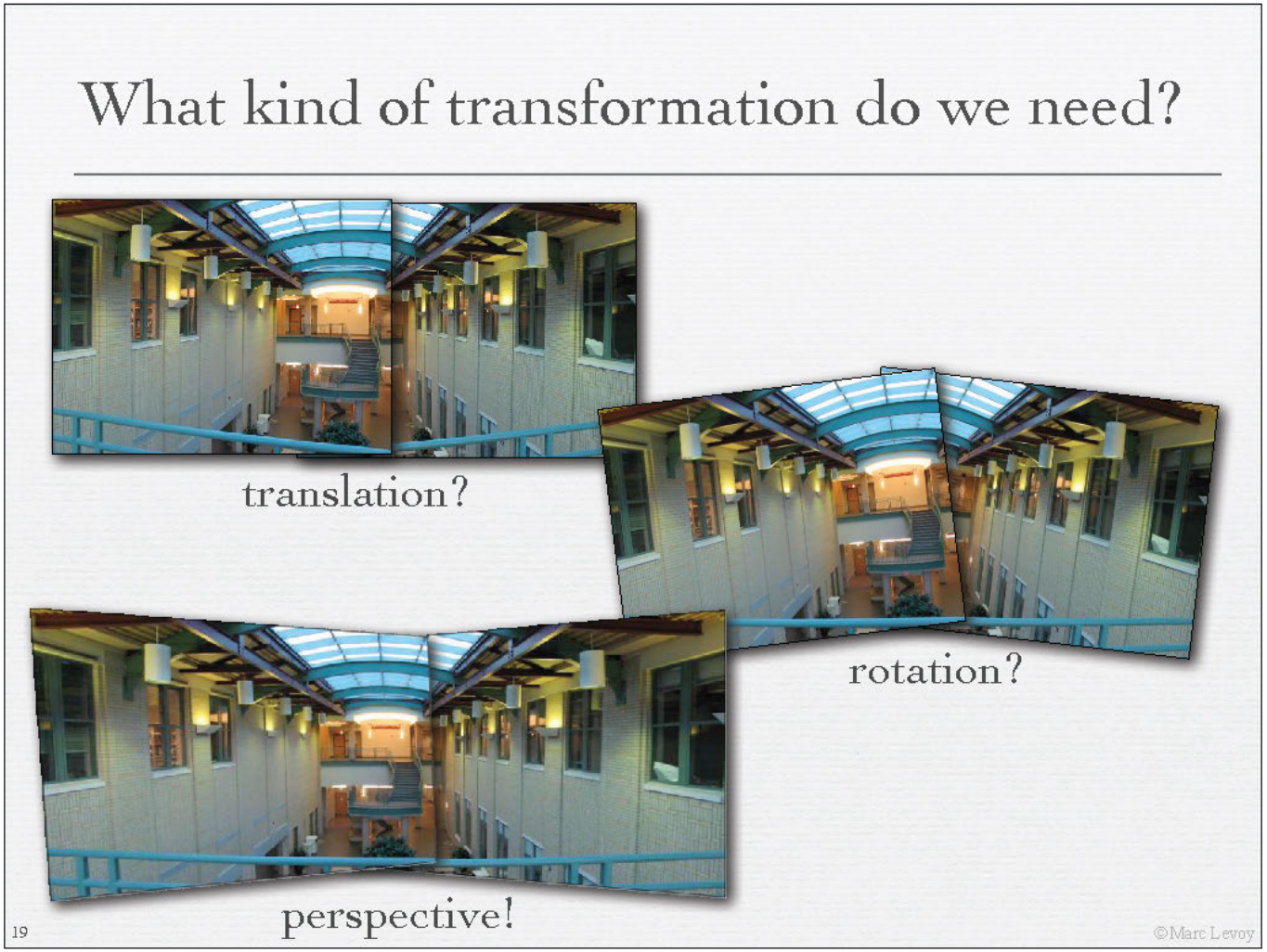
Panoramas

Slides from Marc Levoy's excellent CS 178 course

Stitching images together to make a mosaic

Panoramas

Slides from Marc Levoy's excellent CS 178 course



Panoramas

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Stitching images together to make a mosaic

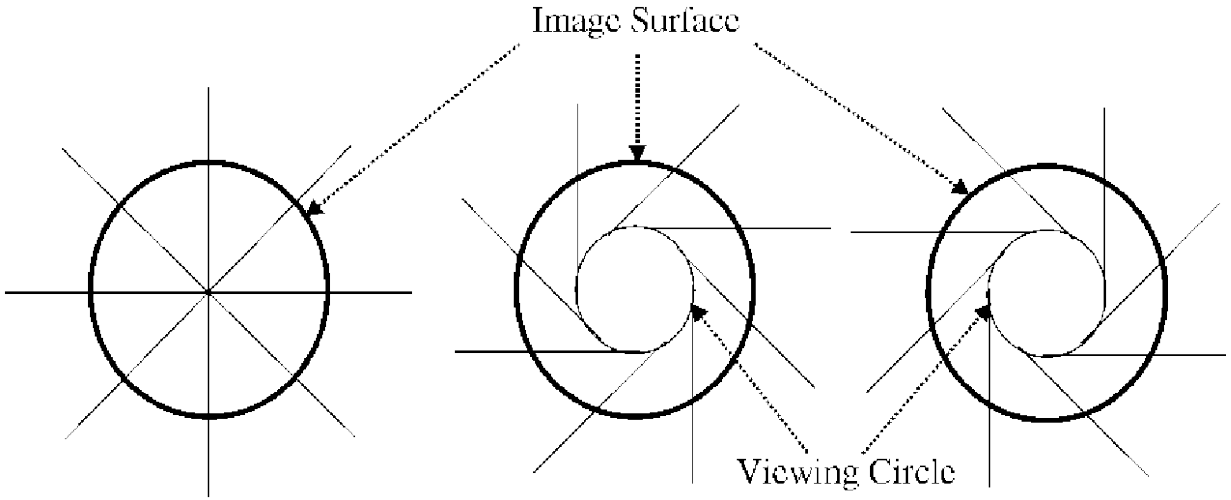
- step 1: find corresponding features in a pair of image
- step 2: compute perspective from 2nd to 1st image
- step 3: warp 2nd image so it overlays 1st image
- step 4: blend images where they overlap one another
- repeat for 3rd image and mosaic of first two, etc.

Omnistereo

Omnistereo

Can we display a 360 degree stereo panorama image in a surround screen virtual environment such as a CAVE so that multiple users can see a correct 3D image in all directions, without head tracking?

Comparison: Mono and Stereo Panoramas



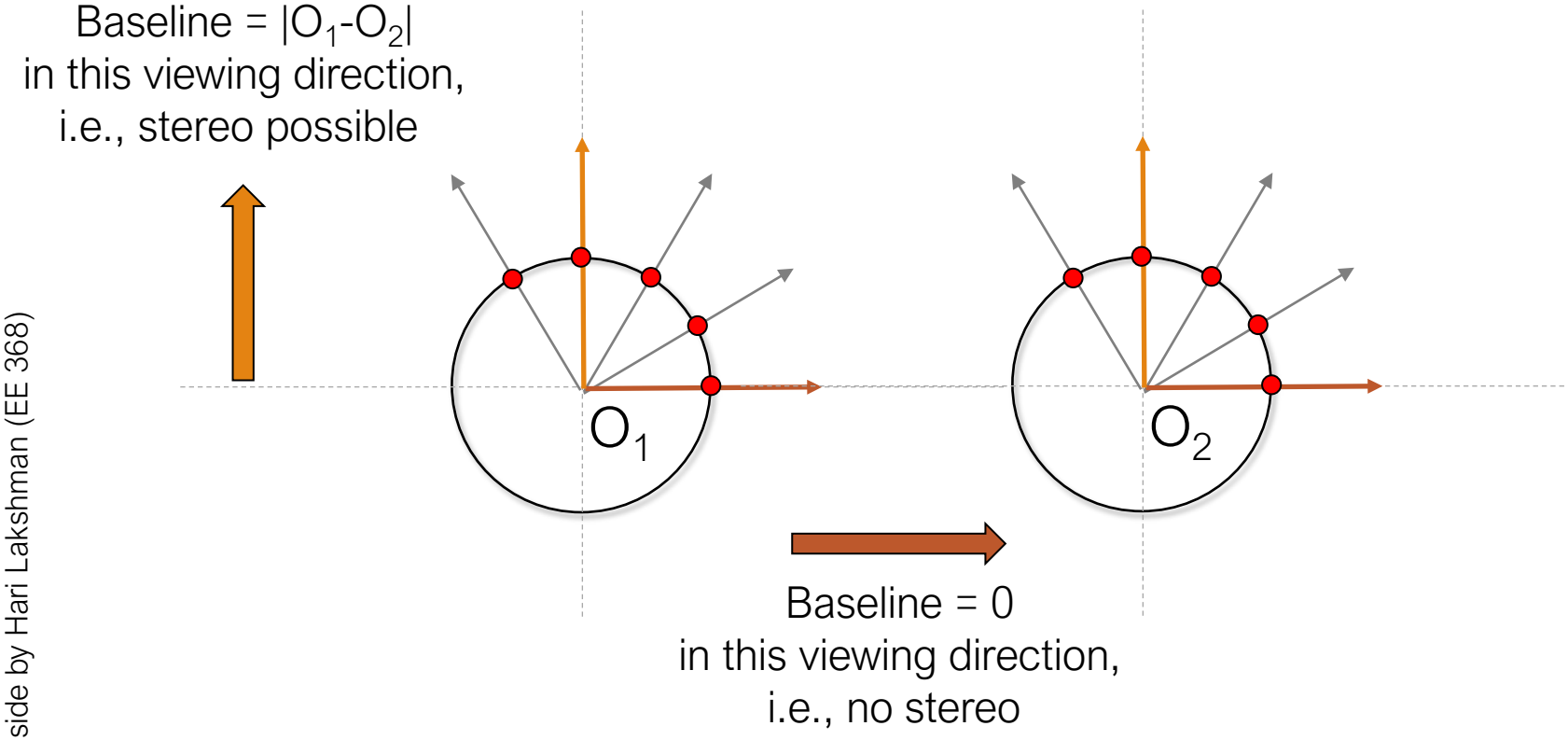
Central,
a.k.a. Mono

Omnistereo,
Multiperspective

Peleg et al. 2001

side by Hari Lakshman (EE 368)

A Pair of Mono Panoramas



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Head Rotation

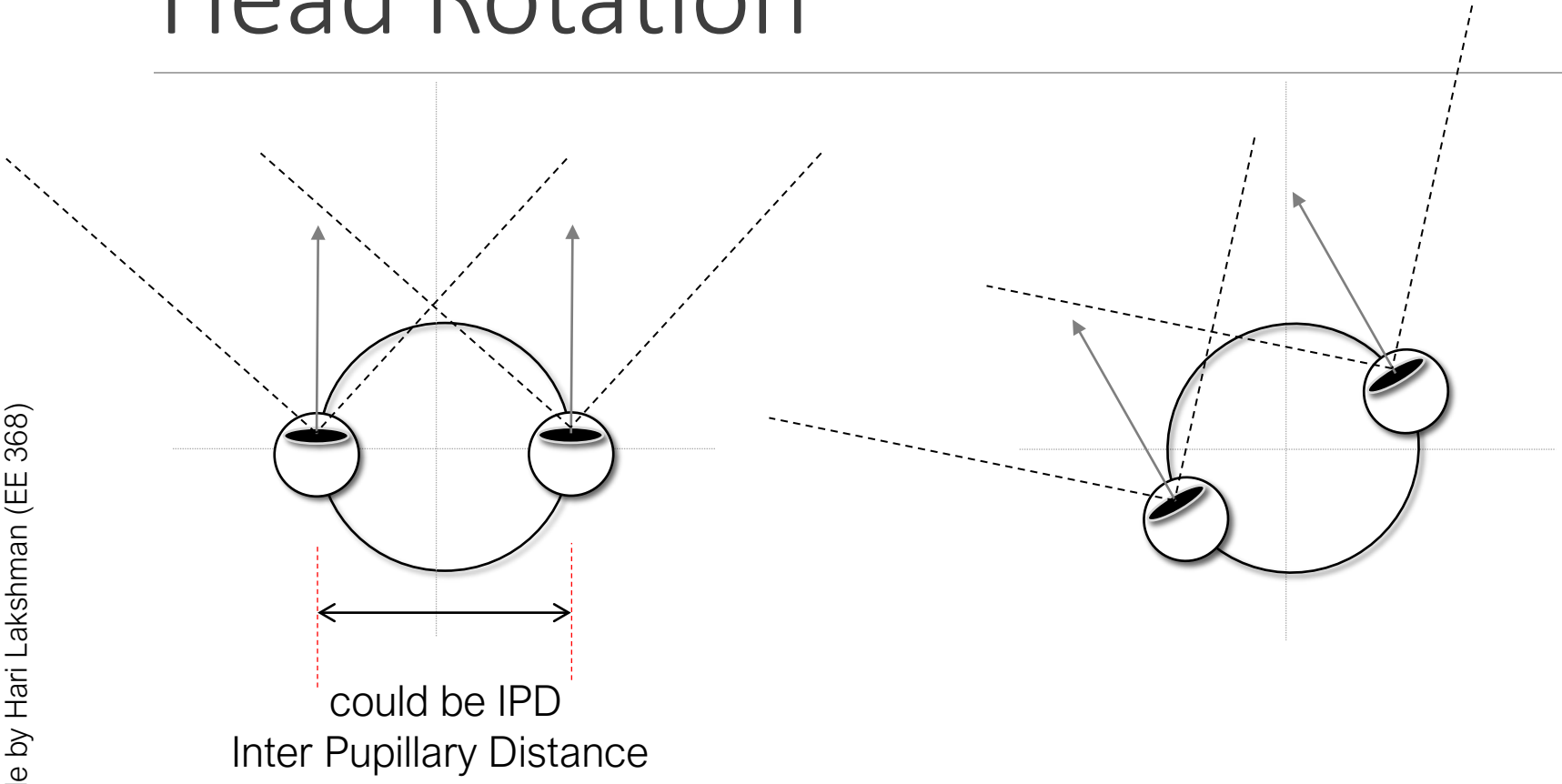

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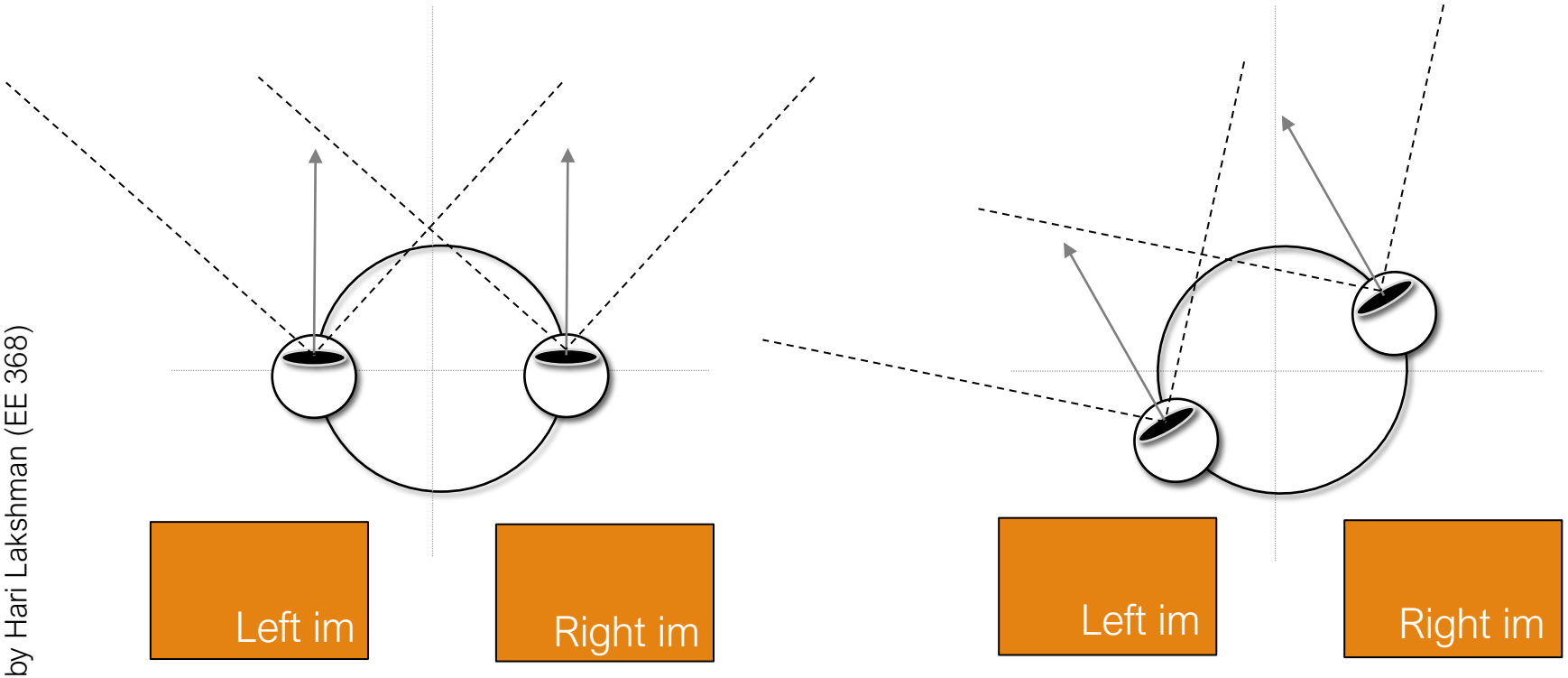
Image Pair for Each Direction



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

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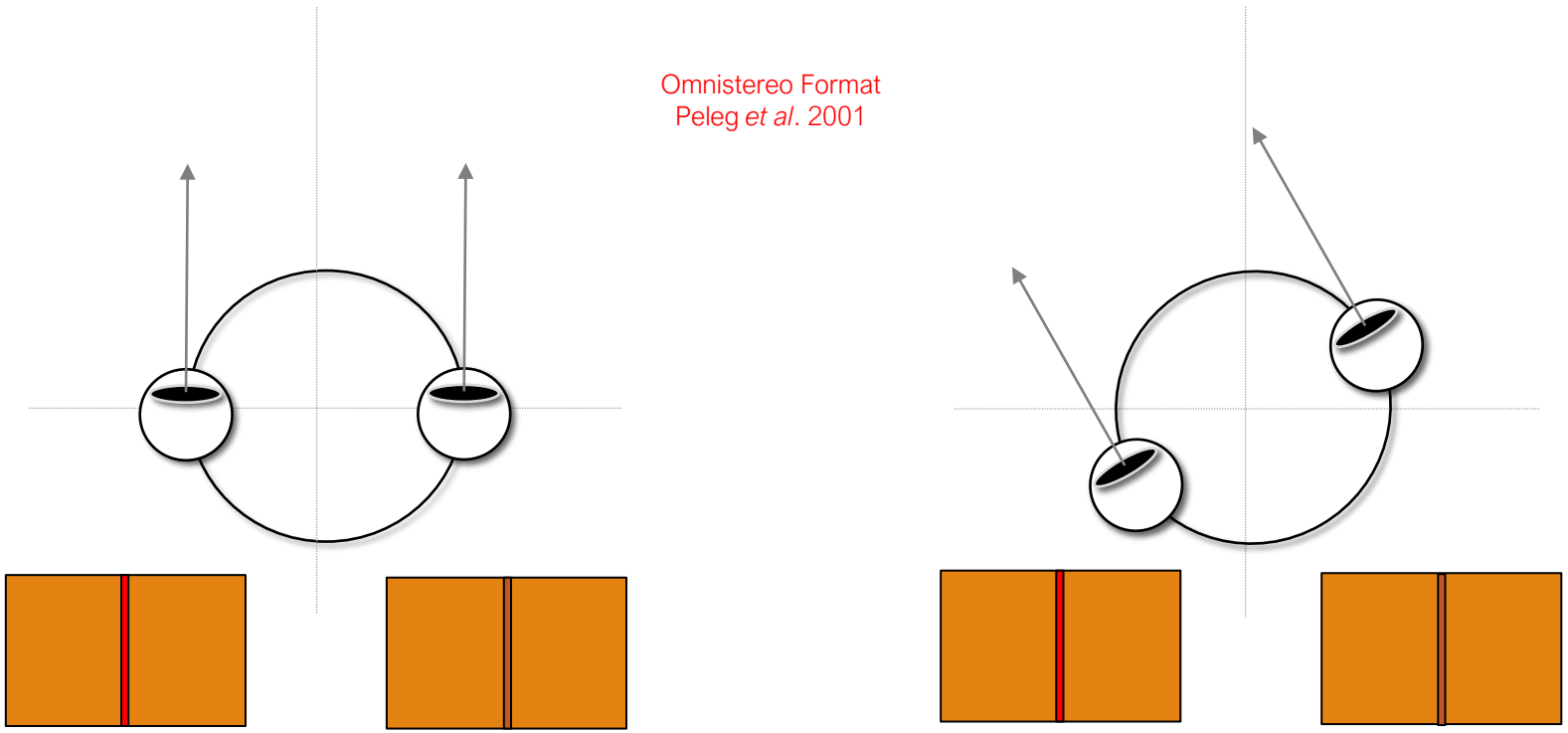
Approximation: Store only Middle Ray



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

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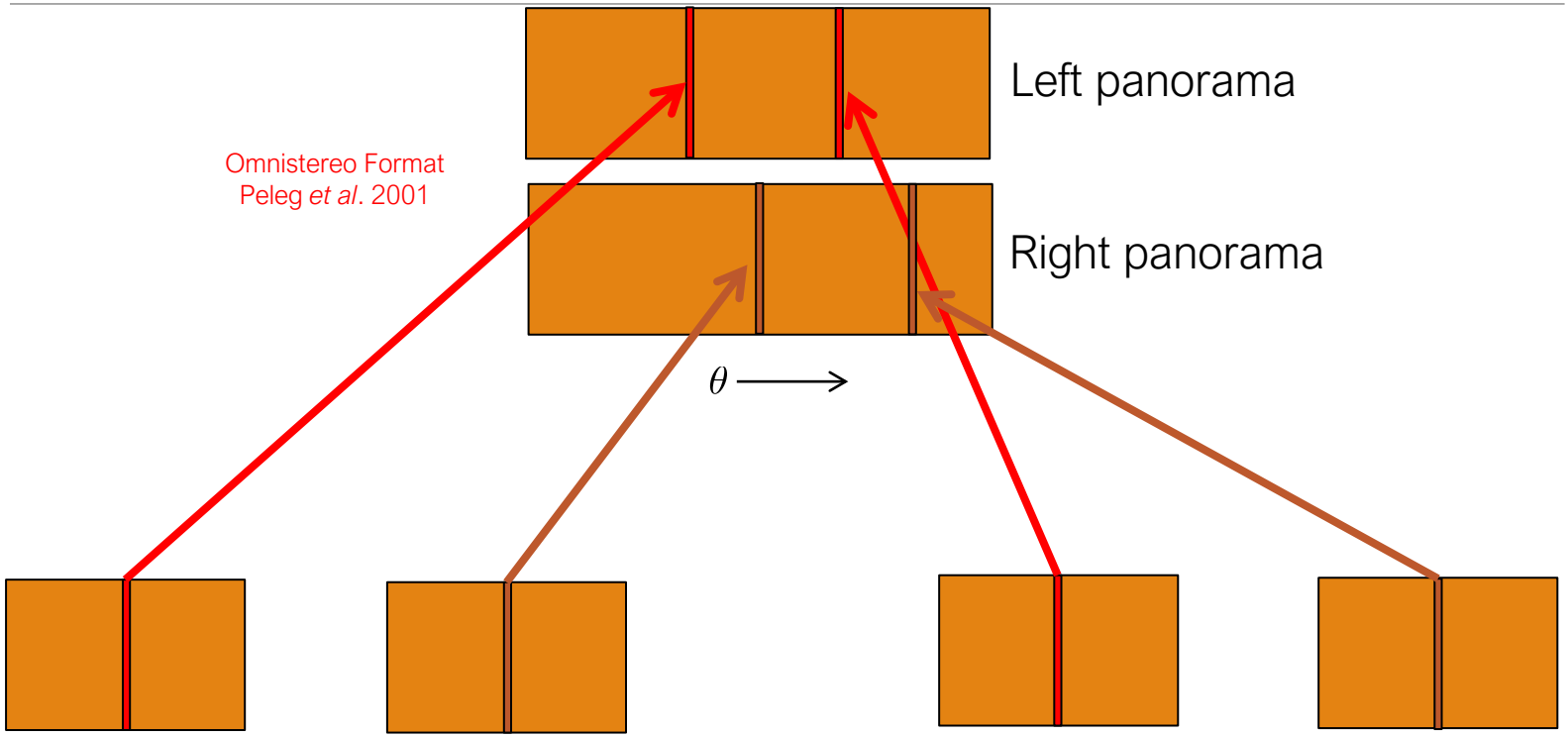
Omnistereo Panoramas



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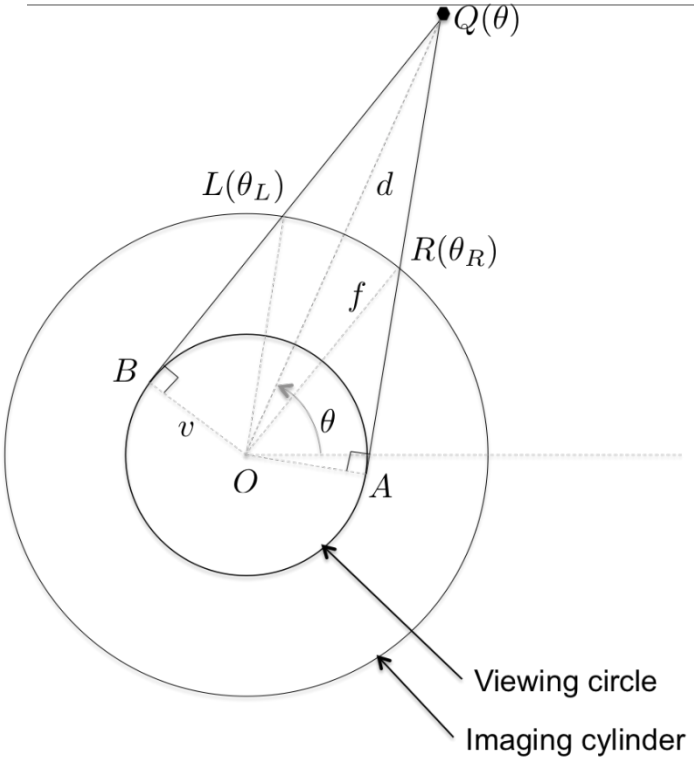
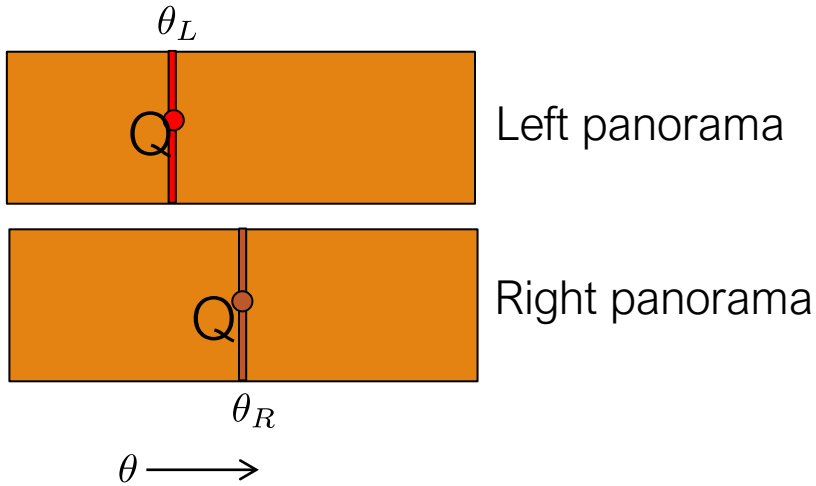
Omnistereo: Geometry Details



Q: scene point
d: distance to Q from origin
v: viewing circle radius
f: imaging cylinder radius
L, R: coordinates of Q in panoramas



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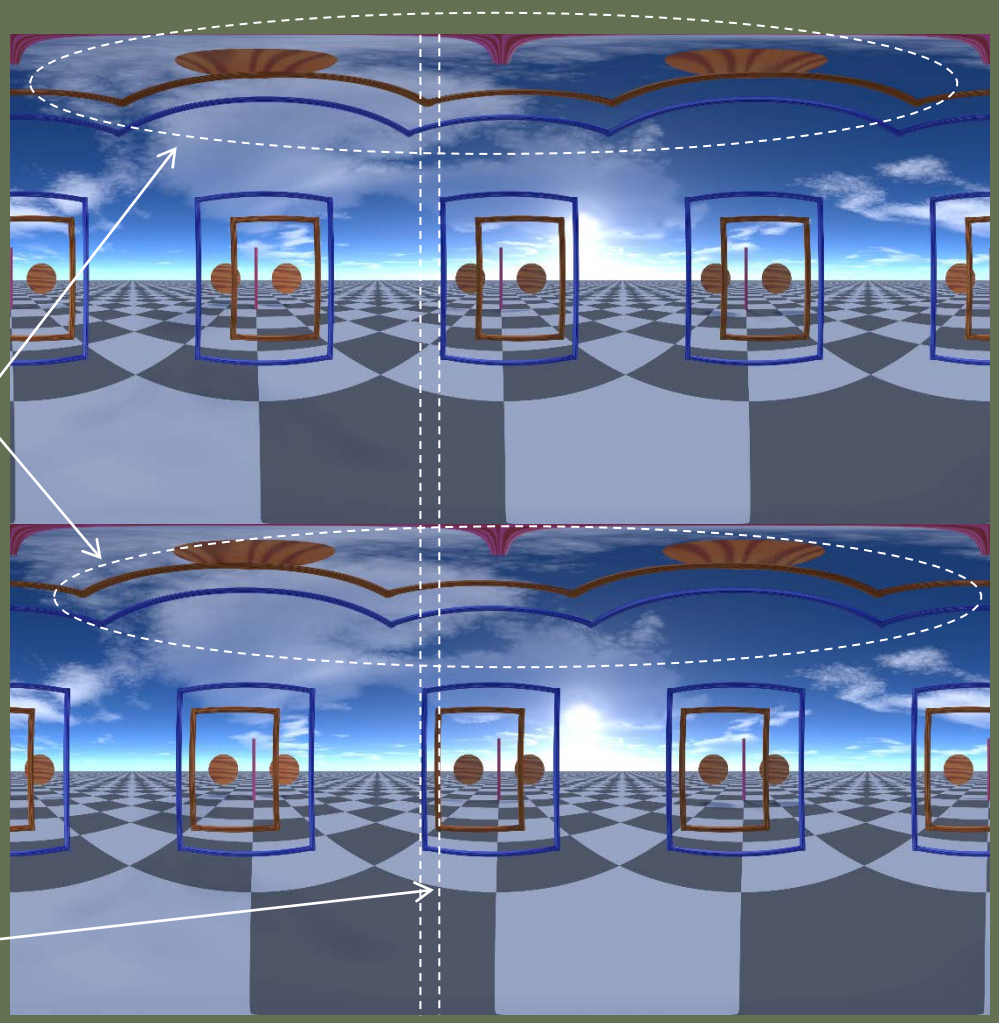
Omnistereo example



Left panorama

Sphere-to-plane distortions

Right panorama

Disparity

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