CSE 190: Virtual Reality Technologies

LECTURE #14: PANORAMIC IMAGING

Announcements

Homework project 4

- Last report deadline Monday 6/10 at 11:59pm
- Video due Tuesday 3pm
- Video viewing Tuesday 3-4pm in room 1242
- Demos group 1: 4-5pm in B210
- Demos group 2: 5-6pm in B210

Minecraft Earth AR

Presented in yesterday's Apple Worldwide Developers Conference (WWDC) keynote address

https://www.youtube.com/watch?v=RpGeIzYSAnU

3D Reconstruction from Images

3D reconstruction from photos with Agisoft Metashape:

- Tutorial at:
  - https://www.agisoft.com/index.php?id=32
- Time limited trial version available
- https://www.agisoft.com/community/showcase/

Autodesk ReCap:

- 30 day trial is free
- https://www.autodesk.com/products/recap/free-trial

3D Scanning in the VR Lab

Matter and Form 3D scanner

Scan accuracy

- Within ± 0.1mm

Maximum object size and weight

- Height: 9.8 in
- Diameter: 7.0 in
- Weight: 6.6 lbs

360˚ Photos and Video

360˚ Photos

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

Concept:

https://www.createholo.com/what-are-360-images-and-what-are-panoramas/

360° Video

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

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

Recommended specs for 3D-360 over-under on YouTube:

- Resolution: 5120 x 5120 and up to 8192 x 8192 (if under 5K, use the maximum possible resolution)
- Frame rate: 25, 29.97, 50, 59.94
- Format: MP4, MOV
- Codec: H.264, ProRes, DNxHR
- H.264 Bitrate: 150 - 360Mbps

Instructions:

- https://developers.google.com/vr/discover/360-degree-media

Youtube VR Channel

- https://www.youtube.com/channel/UCzuqhhs6NWbgTzMuM09WKDQ

Best VR 360 Video – 60M views!

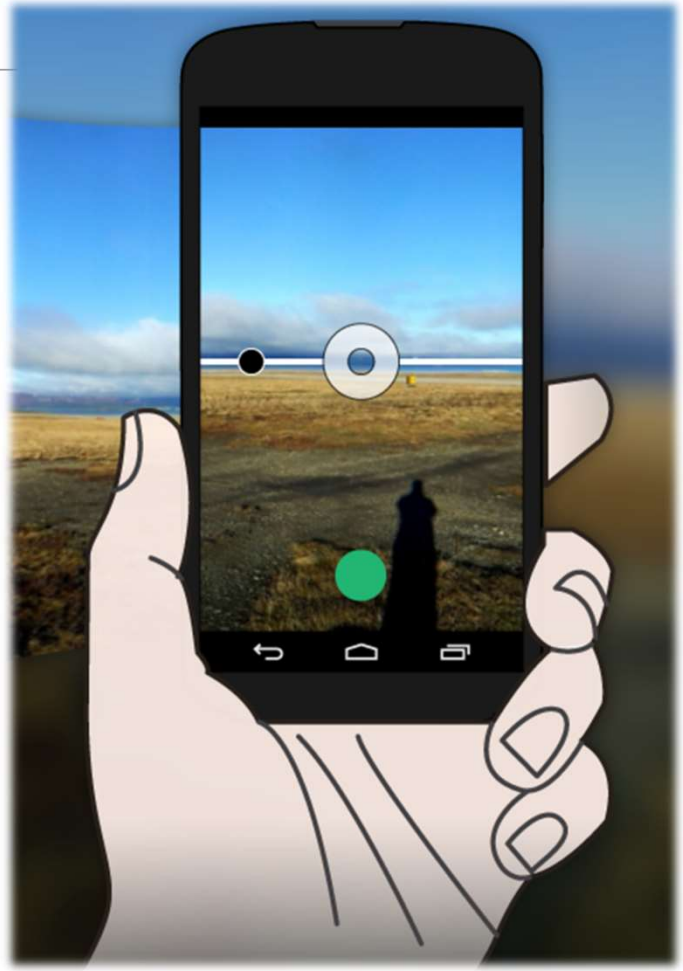
- https://www.youtube.com/watch?v=QKm-SOOMC4c

Capture Devices

Smartphone

Most smartphones have panorama photo capture modes/apps

Photos are 360 degrees but monoscopic



CAVECam
For full 360° by 180° Panoramas
By Tom DeFanti and Dan Sandin

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)

Nikon KeyMission 360

Released: 2017

Price: $500

360˚ Photos: 7744 x 3872 pixels

360˚ Videos: 3840 x 2160 @24fps

Storage: microSD

ISO Sensitivity: 100 - 1,600

Vuze

Price: $440

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 IMX-378

https://www.youtube.com/watch?time_continue=5&v=ukxacZQoDq4

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

Facebook/Red Manifold

Sensors: 16 8k RED Helium

Lenses: 180 degrees

Announced 9/2018

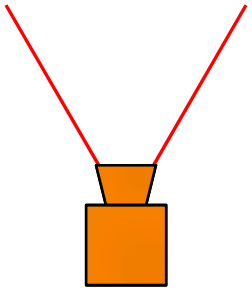
https://www.youtube.com/watch?v=kX-Iogzaed0

Panorama Capturing

Panorama v Stereo Movie v Stereo Panorama

Panorama

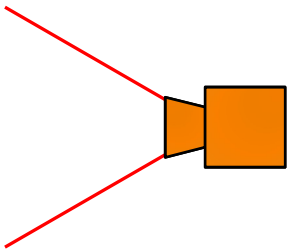
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

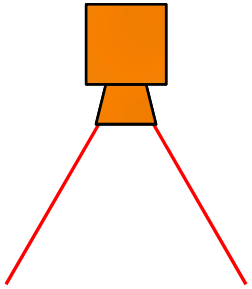
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

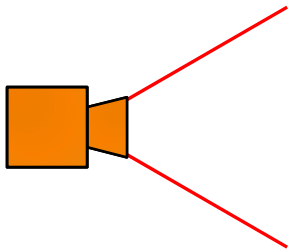
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

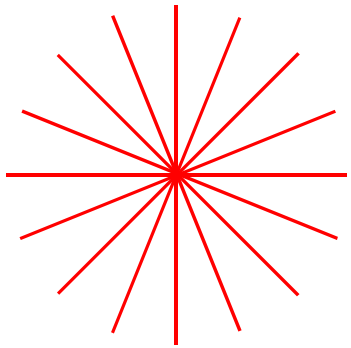
mono & head rotation



Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation

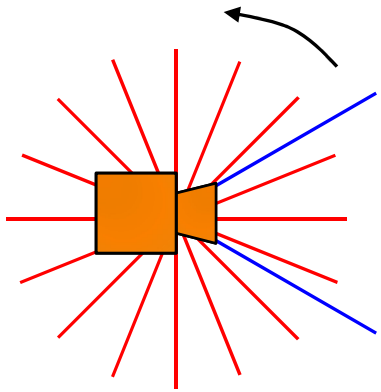


1 center of projection!

Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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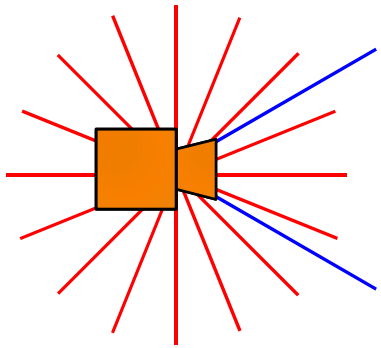
Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation



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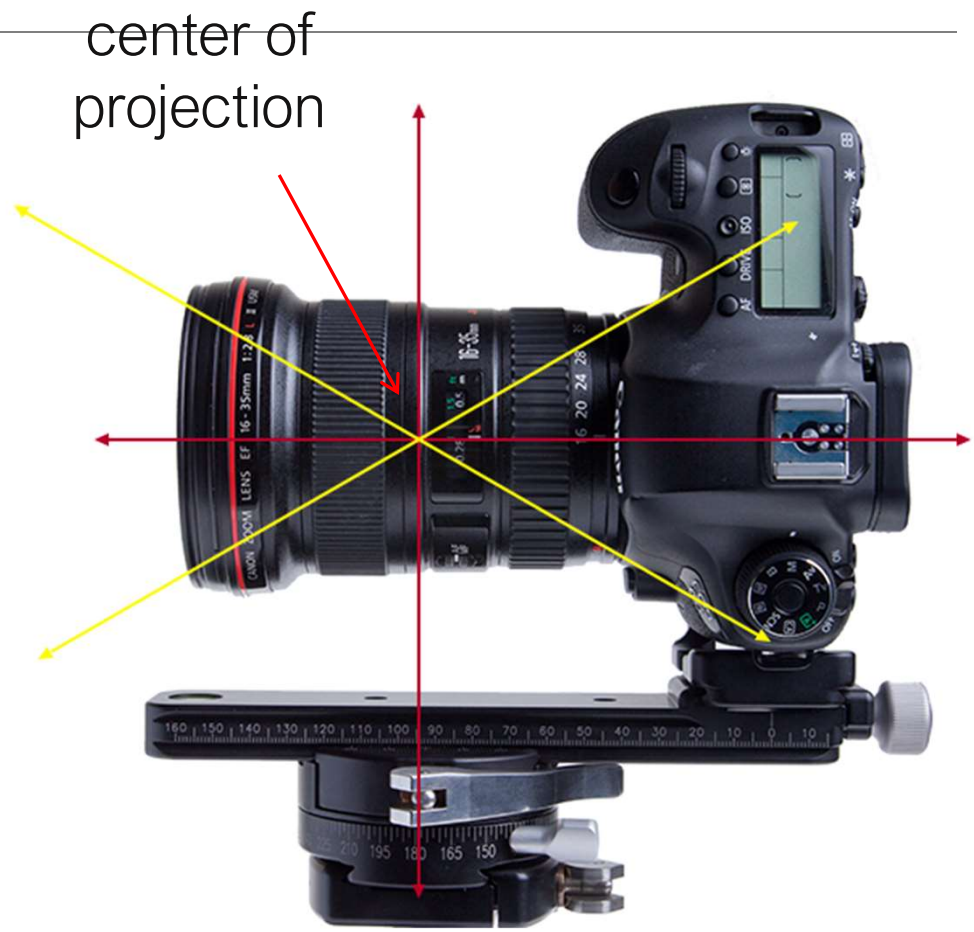
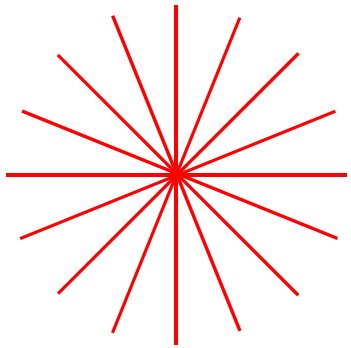


Panorama v Stereo Movie v Stereo Panorama

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



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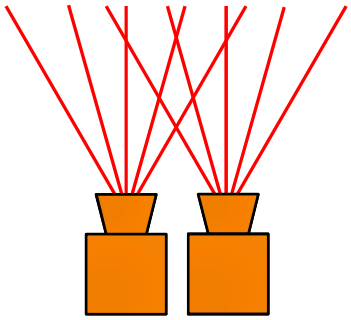
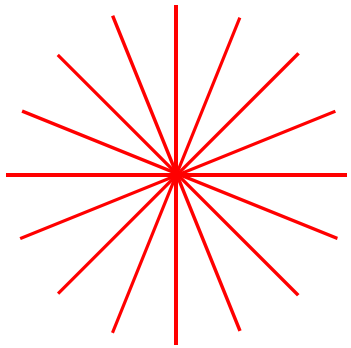


Panorama v Stereo Movie v Stereo Panorama

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



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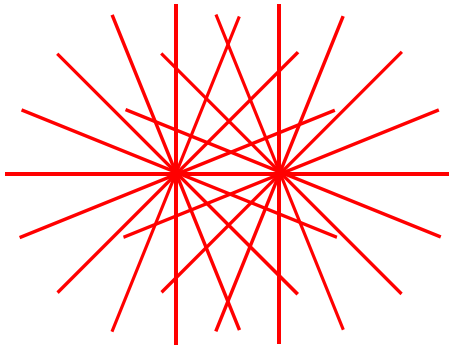
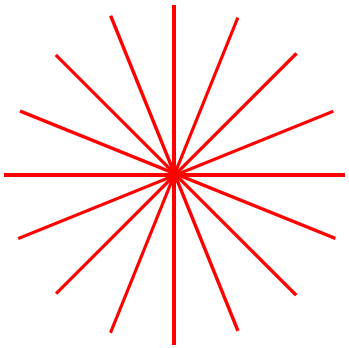


2 centers of projection!

Panorama v Stereo Movie v Stereo Panorama

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



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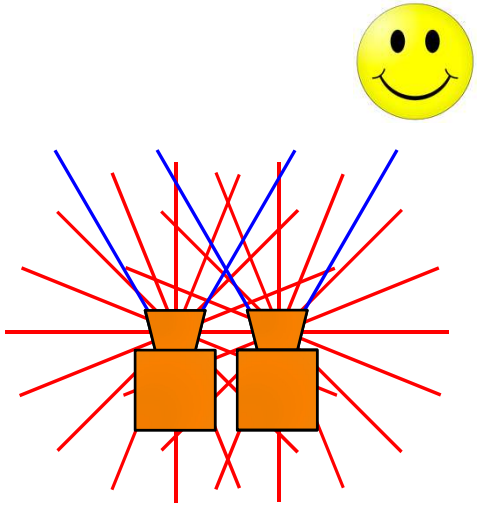
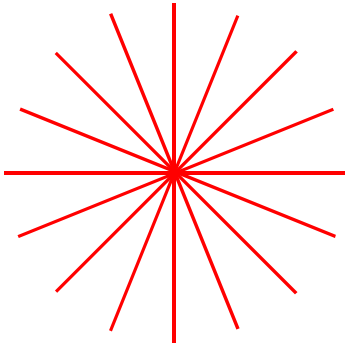


2 centers of projection!

Panorama v Stereo Movie v Stereo Panorama

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



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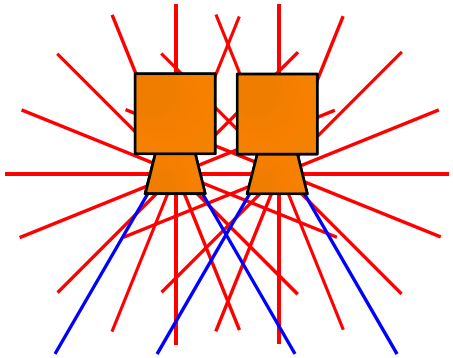

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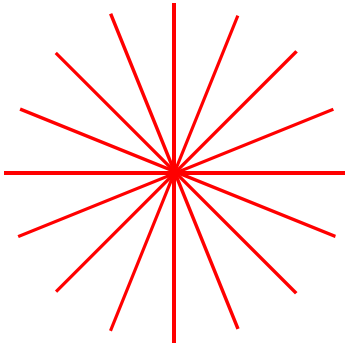
Panorama v Stereo Movie v Stereo Panorama

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



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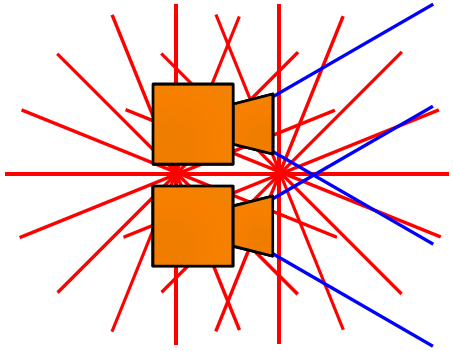

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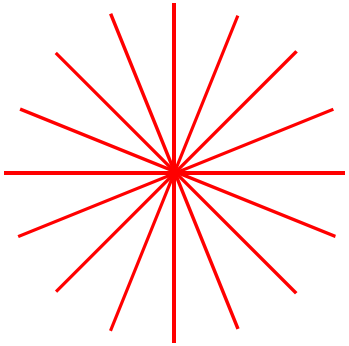
Panorama v Stereo Movie v Stereo Panorama

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



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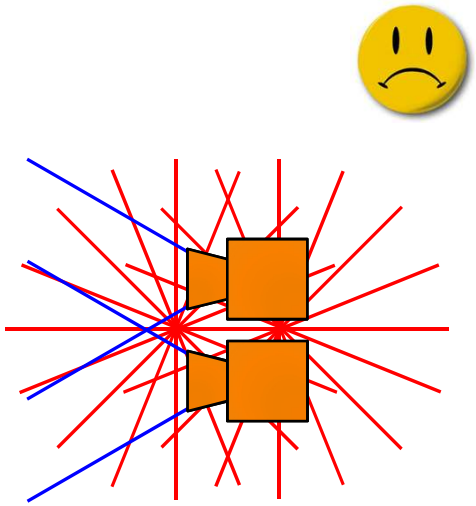

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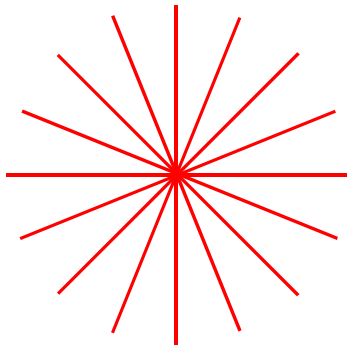
Panorama v Stereo Movie v Stereo Panorama

Panorama

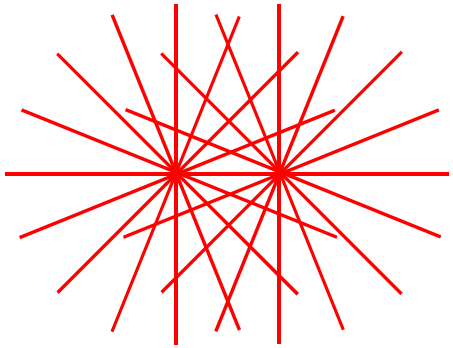
mono & head rotation



1 center of projection!

Stereo

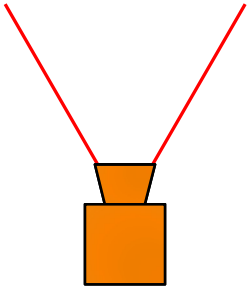
stereo & no head rotation



2 centers of projection!

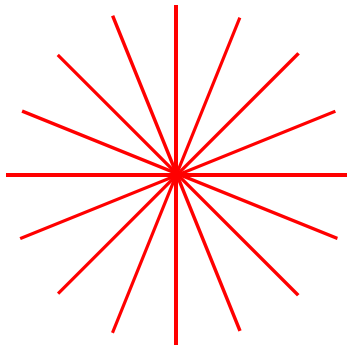
Stereo Panorama

stereo & head rotation



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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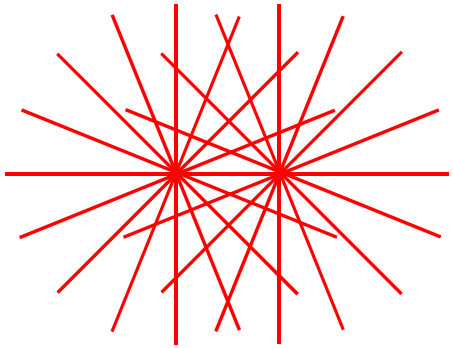

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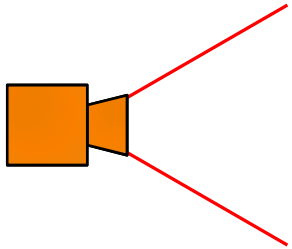

Panorama v Stereo Movie v Stereo Panorama

Panorama	Stereo	Stereo Panorama
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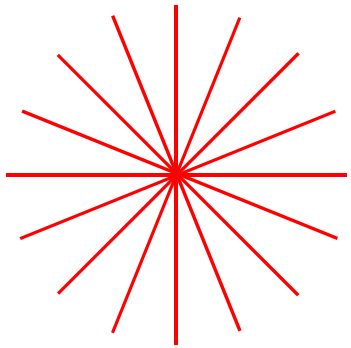

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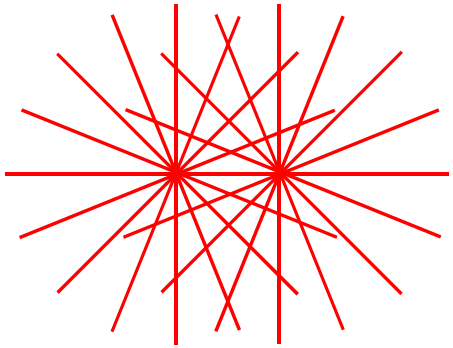

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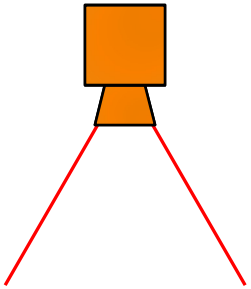
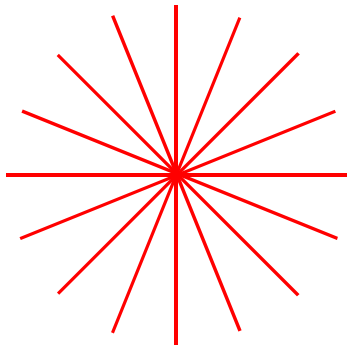


Panorama v Stereo Movie v Stereo Panorama

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



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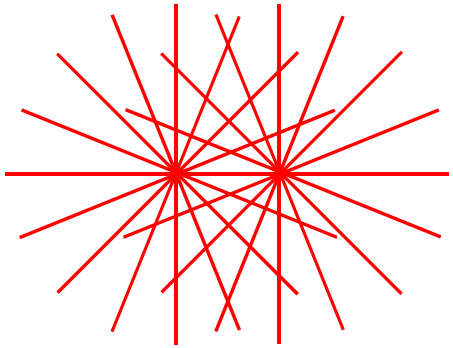

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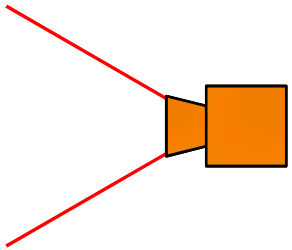
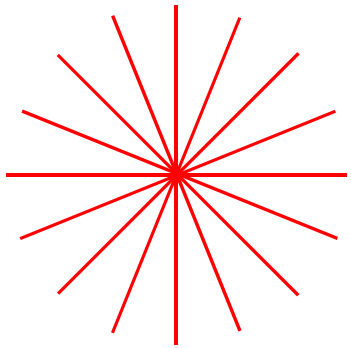
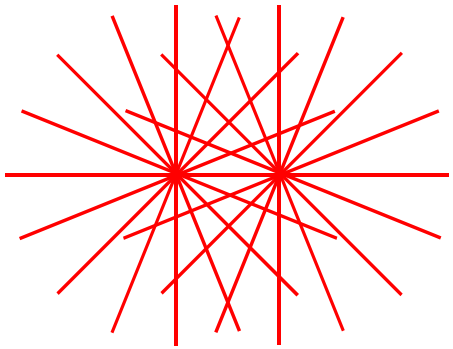
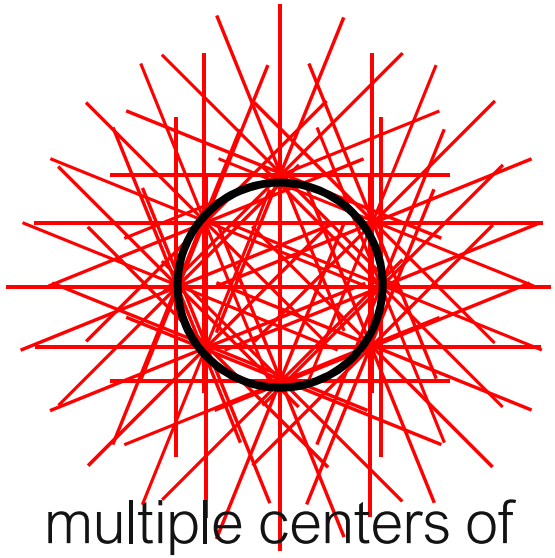


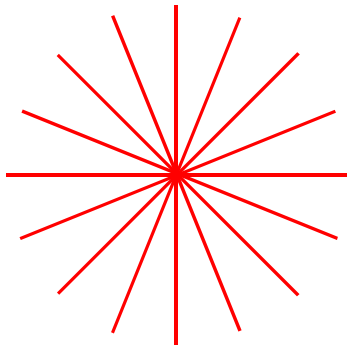
Panorama v Stereo Movie v Stereo Panorama

Panorama	Stereo	Stereo Panorama
mono & head rotation	stereo & no head rotation	stereo & head rotation
		
1 center of projection!	2 centers of projection!	multiple centers of projection

Panorama v Stereo Movie v Stereo Panorama

Panorama

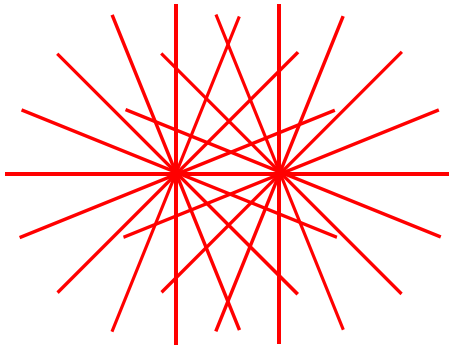
mono & head rotation



1 center of projection!

Stereo

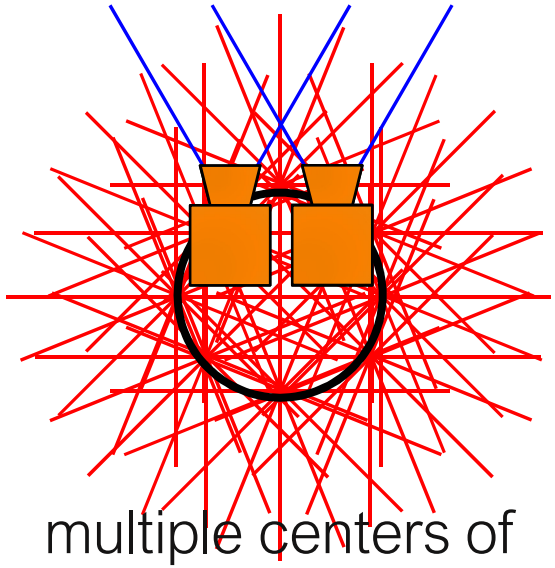
stereo & no head rotation



2 centers of projection!

Stereo Panorama

stereo & head rotation

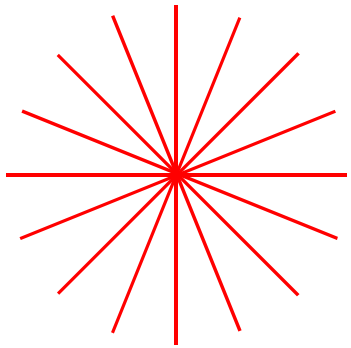


multiple centers of projection

Panorama v Stereo Movie v Stereo Panorama

Panorama

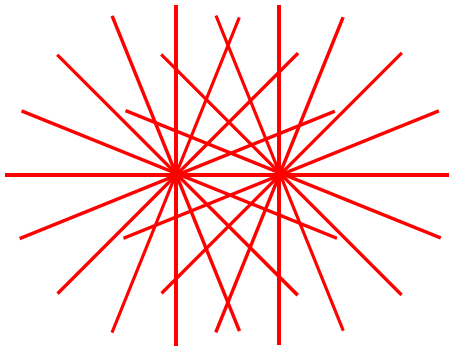
mono & head rotation



1 center of projection!

Stereo

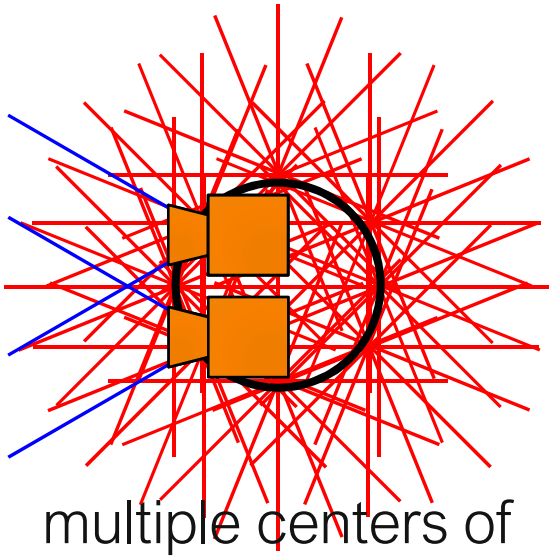
stereo & no head rotation



2 centers of projection!

Stereo Panorama

stereo & head rotation



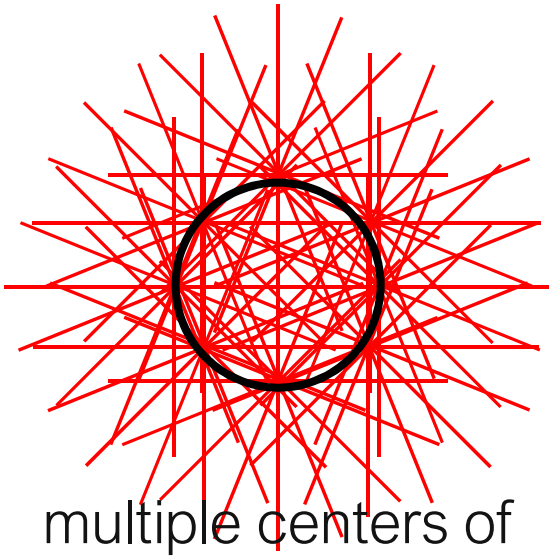
multiple centers of projection

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

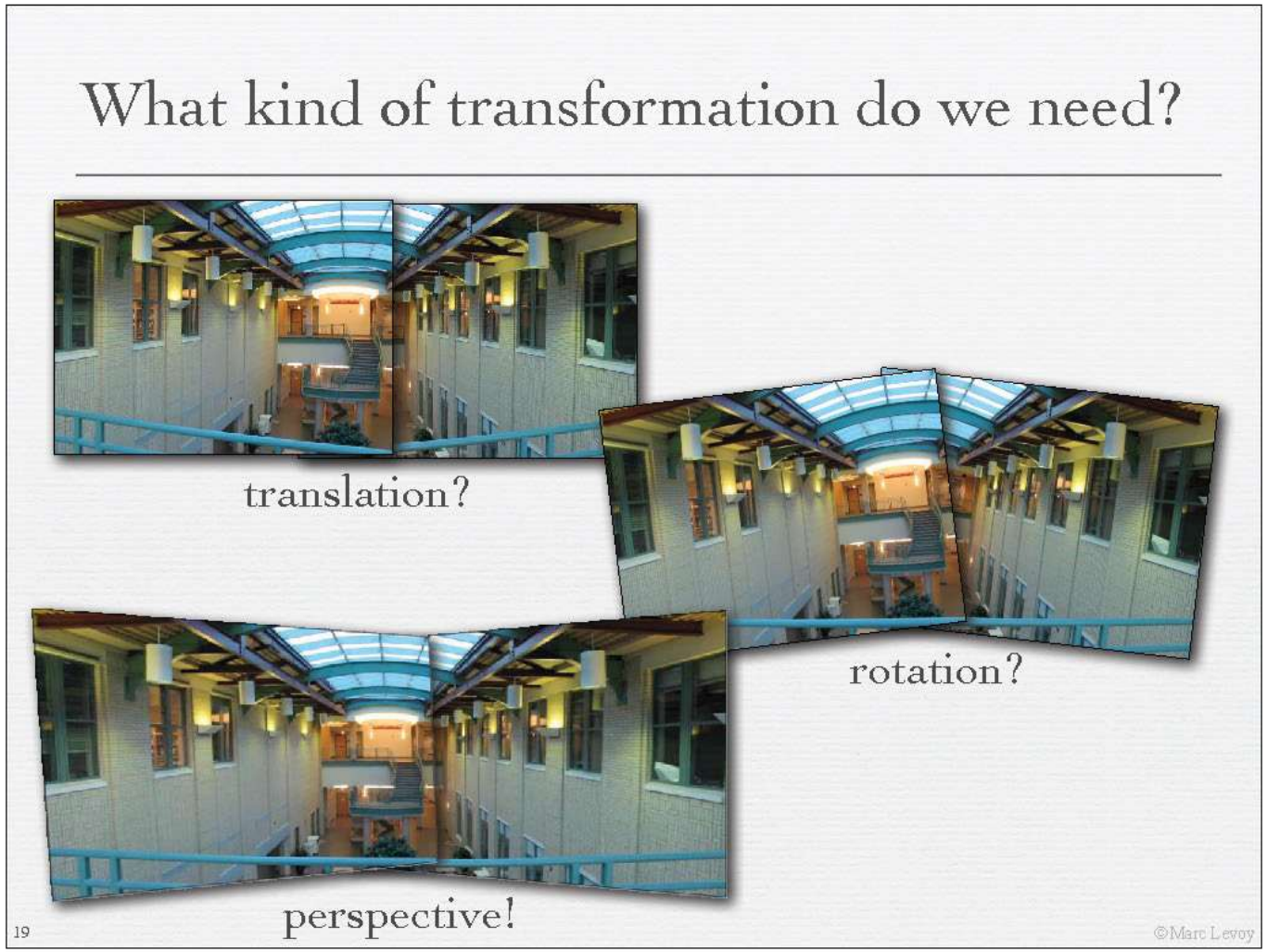
Panoramas

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

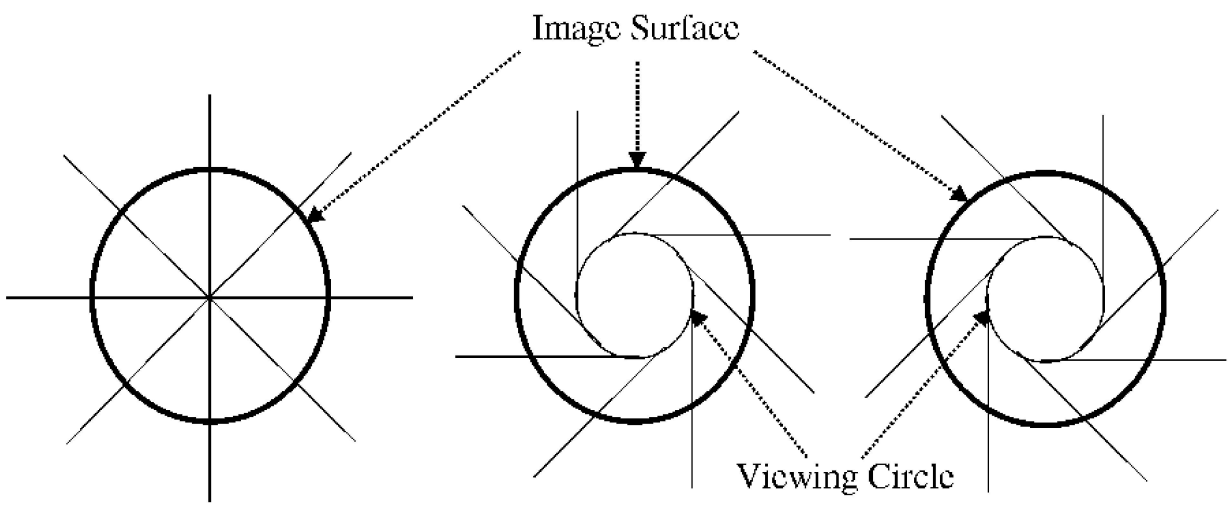
Slides from Marc Levoy's excellent CS 178 course

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

Comparison: Mono and Stereo Panoramas



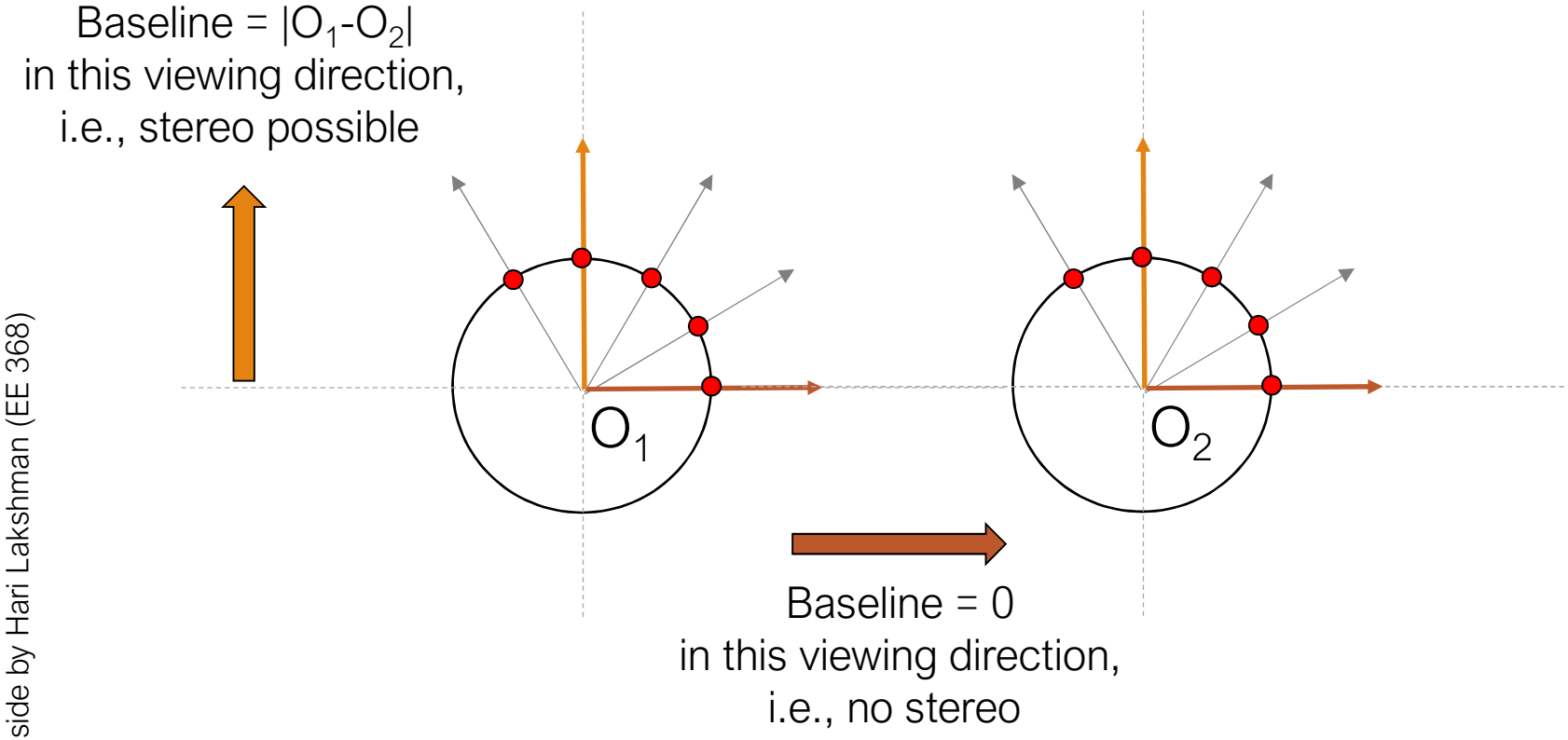
Central,
a.k.a. Mono

Omnistereo,
Multiperspective

Peleg et al. 2001

side by Hari Lakshman (EE 368)

A Pair of Mono Panoramas



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Head Rotation

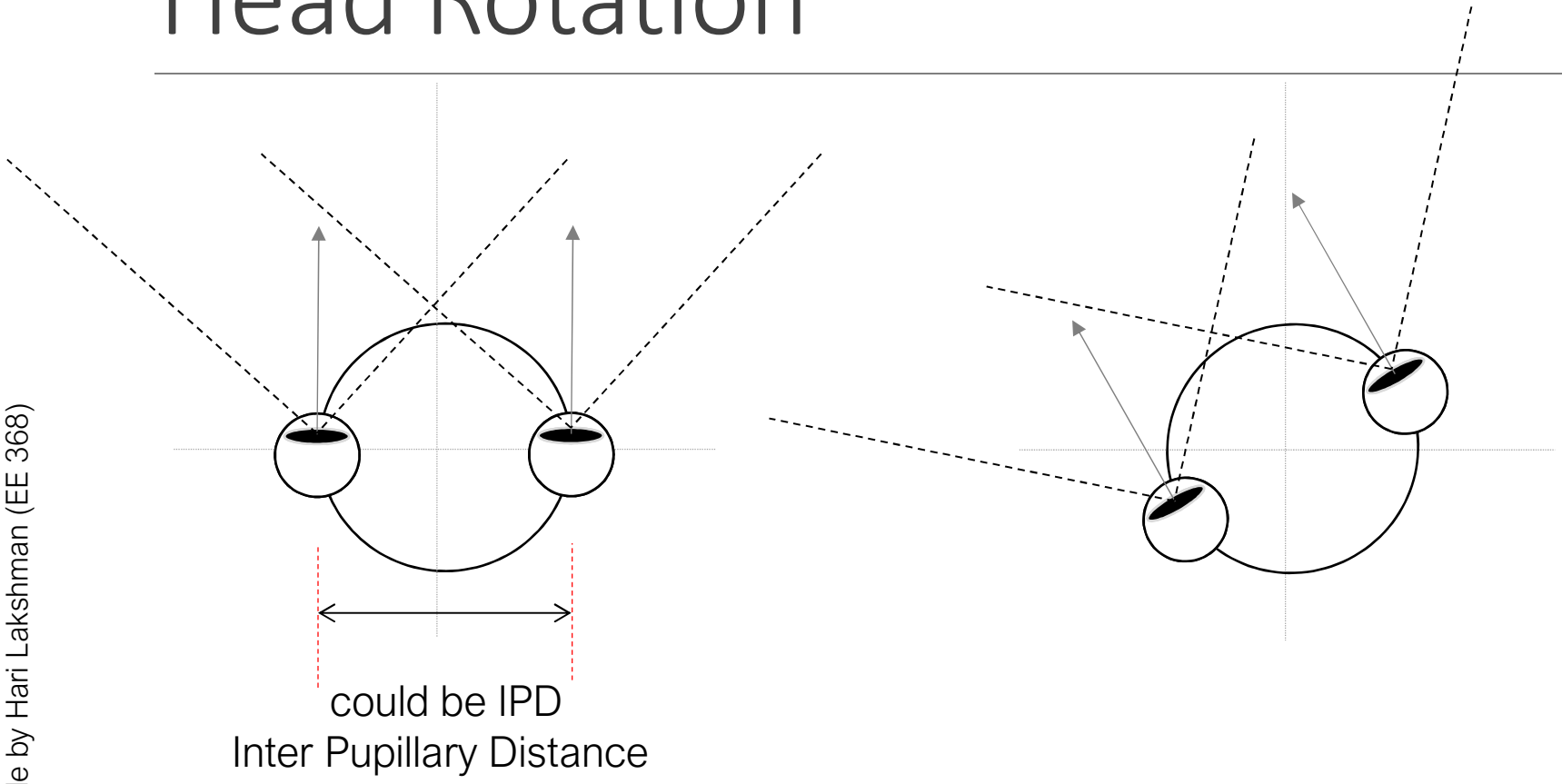

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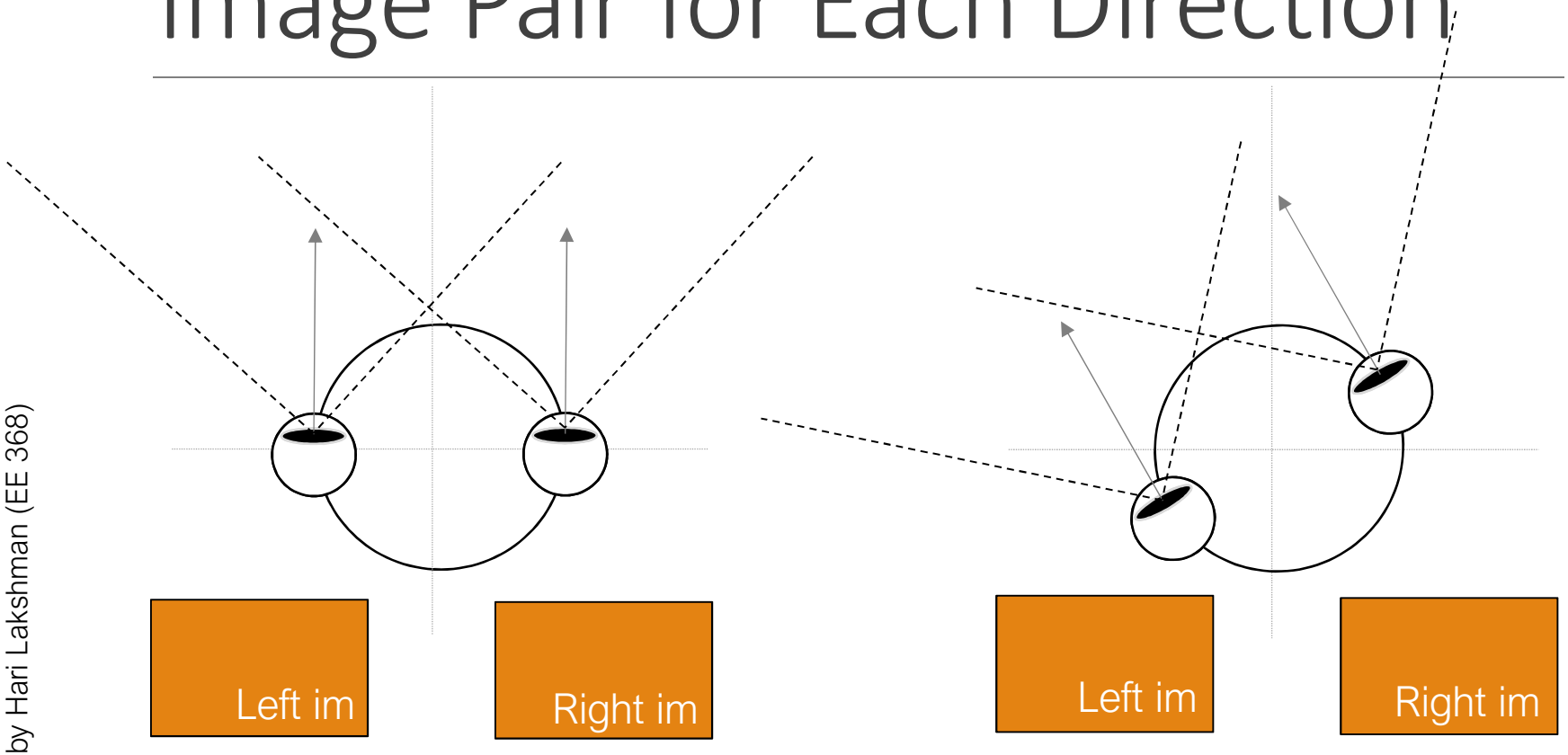
Image Pair for Each Direction



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

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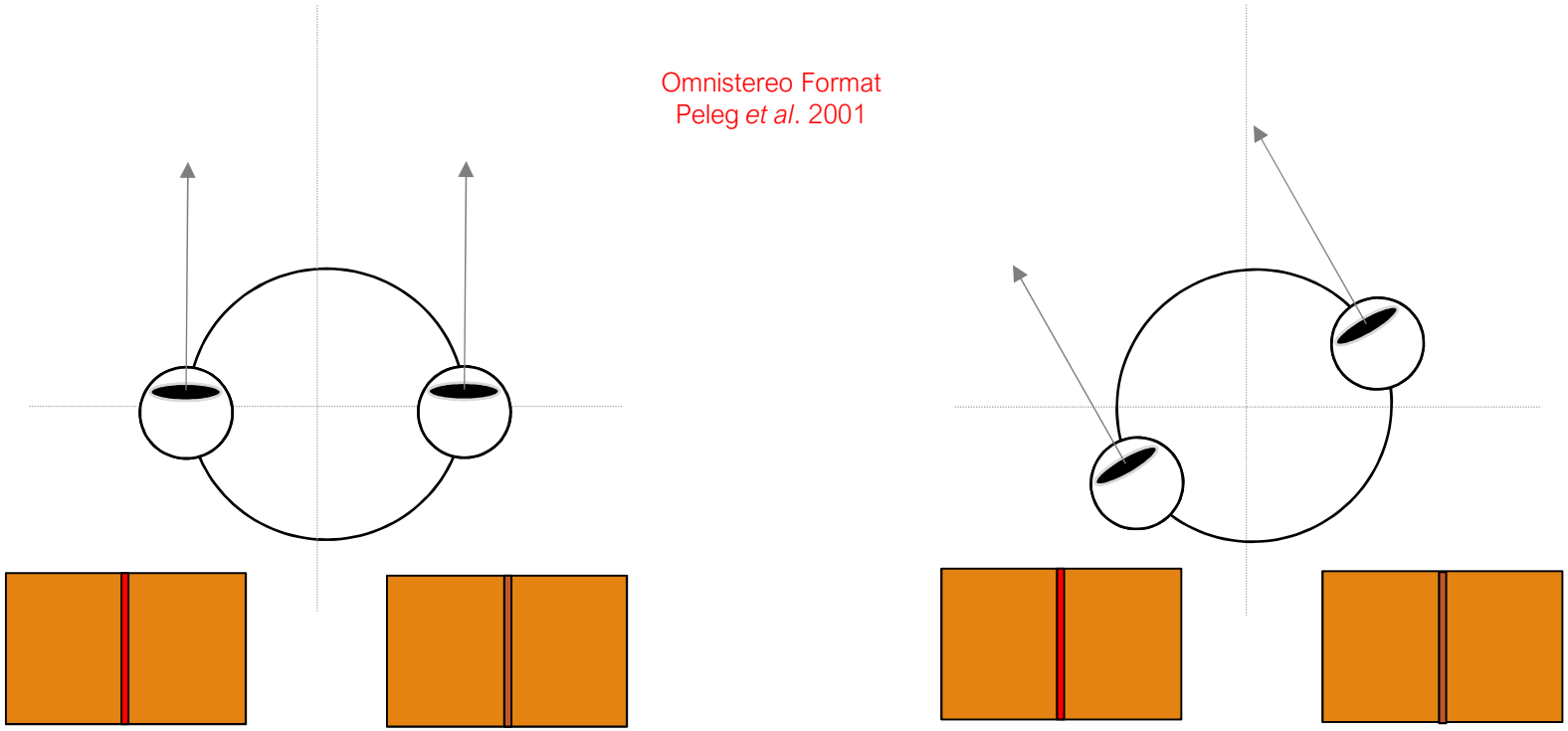
Approximation: Store only Middle Ray



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

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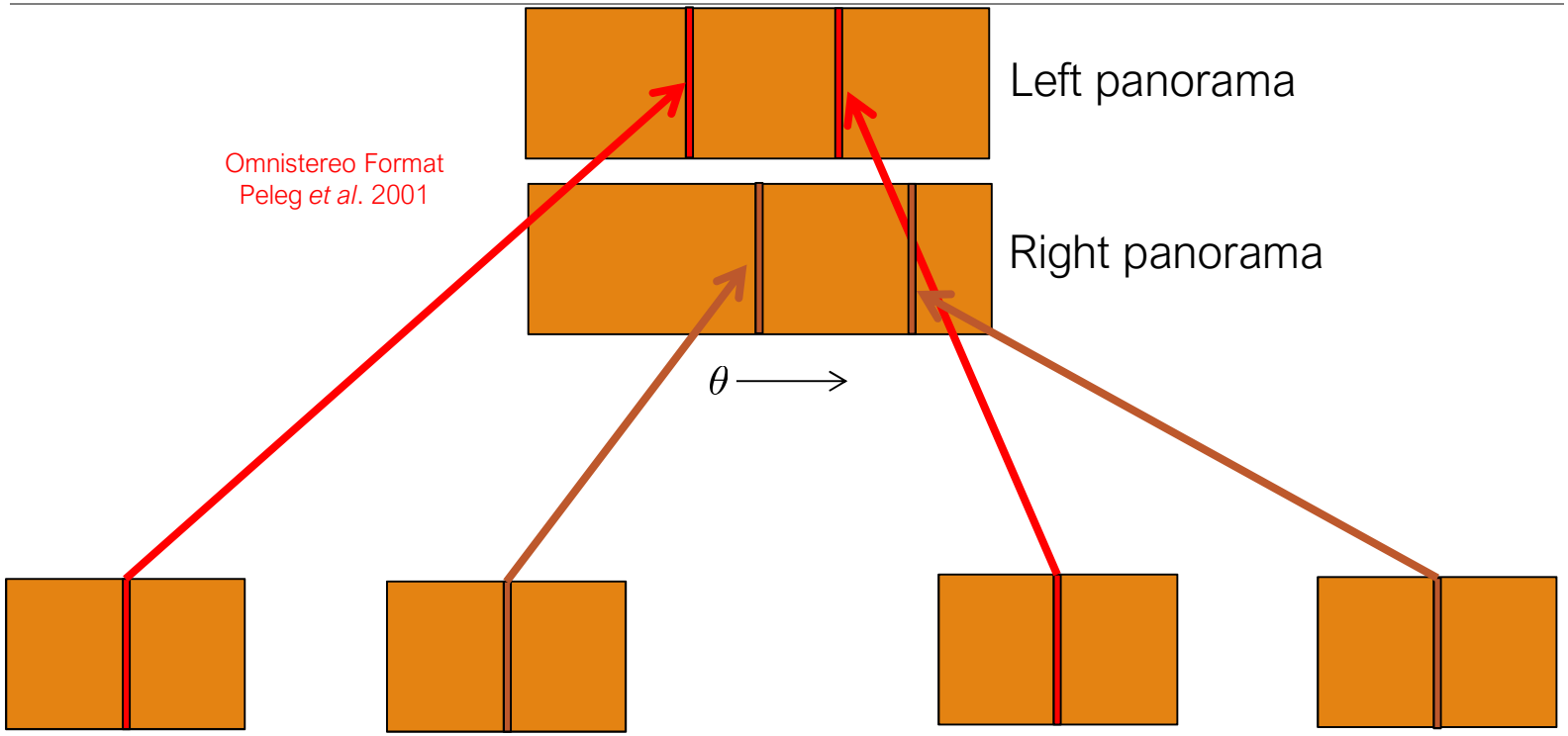
Omnistereo Panoramas



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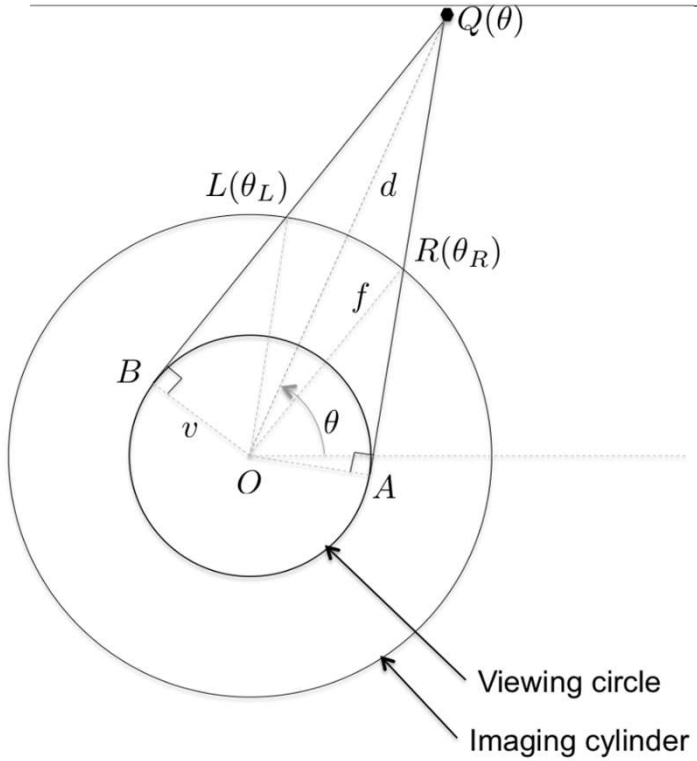
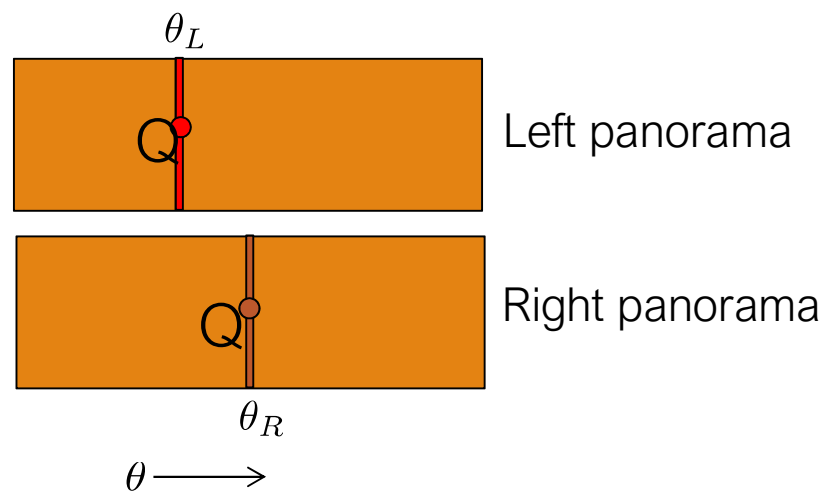
Omnistereo: Geometry Details



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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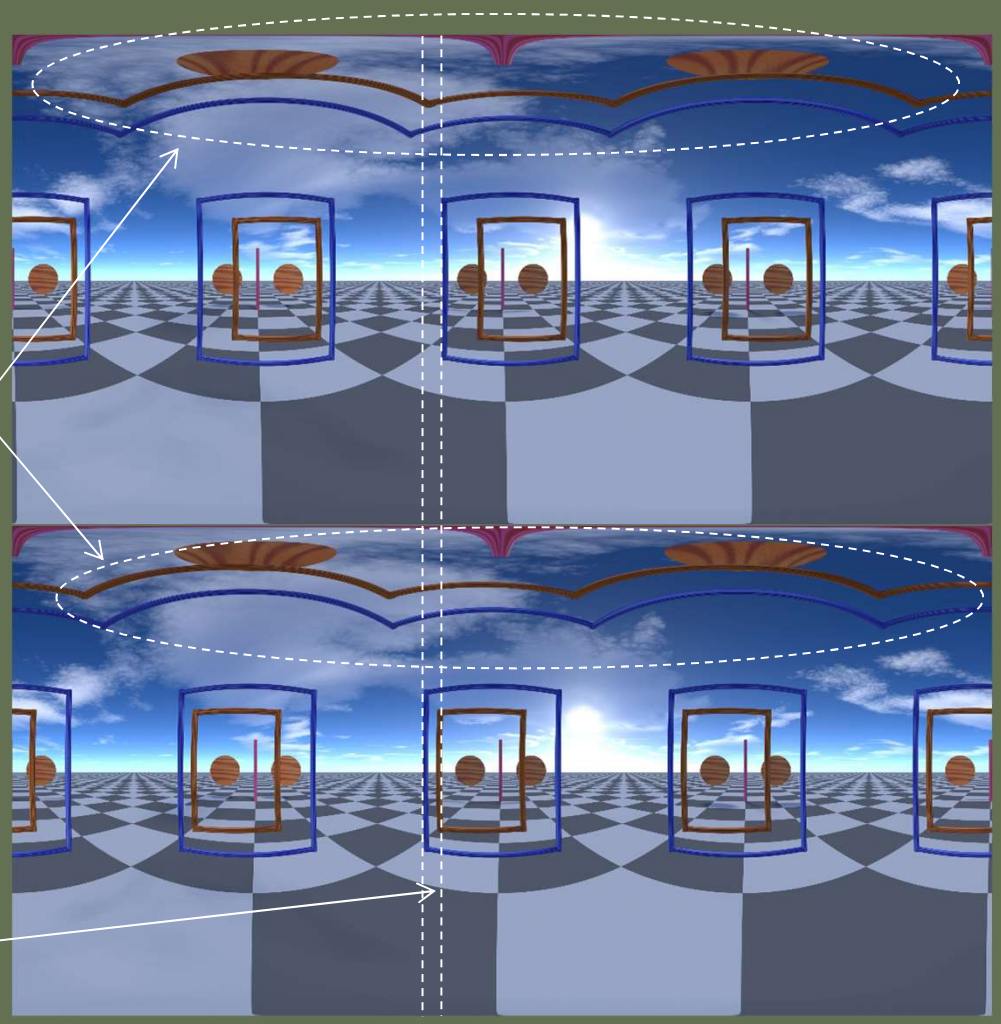
Omnistereo example



Left panorama

Sphere-to-plane distortions

Right panorama

Disparity

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