Panoramic Imaging and Cinematic VR

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EE 267 Virtual Reality
Lecture 15
stanford.edu/class/ee267/
Overview

• overview
• panoramic imaging
• stereo / omnistereo panoramas
• camera rigs
Jaunt VR
Lytro
Nokia

W: 168.36mm / 6.7"
L: 262.95mm / 10.4"
W: 157.83mm / 6.3"
H: 262.95mm / 10.4"
Red
Samsung
Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation
Panorama v Stereo Movie v Stereo Panorama

Panorama

mono & head rotation
Panorama

mono & head rotation
Panorama v Stereo Movie v Stereo Panorama

Panorama
mono & head rotation
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Panorama

mono & head rotation

1 center of projection!
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

1 center of projection!
Stitching images together to make a mosaic
What kind of transformation do we need?

translation?

rotation?

does this look like perspective?
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.
Panoramas

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.

take CS 131, EE 368, EE 367!
Example: the Matterhorn

common picture plane of mosaic image

diagram shows perspective projection
Using 4 shots instead of 3
Cylindrical panoramas

- even works for 360° panorama
- project each image onto a cylinder
- a cylindrical image can be stored as a rectangular image
Cylindrical panoramas

- even works for 360° panorama

- project each image onto a cylinder
- a cylindrical image can be stored as a rectangular image
- to view without distortion, reproject part of the cylinder onto a picture plane representing the display screen
  - if your FOV is narrow, this view won’t be too distorted
Back to the Matterhorn

surface of cylinder

cylindrical projection
Back to the Matterhorn

Surface of cylinder

Blended
Spherical panoramas

- projections are to a sphere instead of a cylinder
- can’t store as rectangular image without extreme stretching
Panoramas

- see CS 178 and EE 368 course material for more detail

- now common in every image processing software and cellphone
Panorama vs Stereo Movie vs Stereo Panorama

Panorama: mono & head rotation

Stereo: stereo & no head rotation

Stereo Panorama: stereo & head rotation

1 center of projection!
Panorama v Stereo Movie v Stereo Panorama

Panorama
mono & head rotation

Stereo
stereo & no head rotation

Stereo Panorama
stereo & head rotation

1 center of projection!

2 centers of projection!
Panorama v Stereo Movie v Stereo Panorama

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1 center of projection!

2 centers of projection!
<table>
<thead>
<tr>
<th>Panorama</th>
<th>Stereo</th>
<th>Stereo Panorama</th>
</tr>
</thead>
<tbody>
<tr>
<td>mono &amp; head rotation</td>
<td>stereo &amp; no head rotation</td>
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</table>

- **1 center of projection!**
- **2 centers of projection!**
Head Rotation

could be IPD
Inter Pupillary Distance
Panorama vs Stereo Movie vs Stereo Panorama

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

1 center of projection!
2 centers of projection!
multiple centers of projection
Store image pair for each direction ➔ Problem: Too much data!!!
Omni-directional Stereo (ODS) Approximation

Peleg et. al 2001
Ishiguro et. al. 1990

full-frame left and right eyes

ODS-approximated left and right eyes

Image from Google Jump
Omni-directional Stereo (ODS) Approximation

Peleg et. al 2001
Ishiguro et. al. 1990

Image from Google Jump
https://developers.google.com/vr/jump/rendering-ods-content.pdf
Comparison: Mono and Stereo Panoramas

Central, a.k.a. Mono

Omnistereo, Multiperspective

Image Surface

Viewing Circle

Peleg et al. 2001
Omnistereo Panoramas

Omnistereo Format
Peleg et al. 2001

θ ➔

Left panorama

Right panorama

side by Hari Lakshman (EE 368)
Zero Disparity Distance

To control zero disparity distance: circularly shift left pano relative to right pano
Capture using Single Camera

right ray  left ray
image plane
field of view
camera

virtual left camera
virtual right camera

virtual camera rotation radius
actual camera rotation radius

Peleg et al. 2001
Panorama v Stereo Movie v Stereo Panorama

- **Panorama**
  - mono & head rotation

- **Stereo**
  - stereo & no head rotation

- **Stereo Panorama**
  - stereo & head rotation

Ricoh Theta

horizontal-only parallax
Omnistereo example

Sphere-to-plane distortions

Disparity

Left panorama

Right panorama

side by Hari Lakshman (EE 368)
Multiperspective Projection
Omnidirectional Stereo

Left Eye

Right Eye

widely used by YouTube VR, Google Daydream, Facebook, ...
Existing VR Cameras

Recorded Videos ~ 17 Gb/sec
Facebook’s Surround 360

RAW Data: 17 Gb/sec

Compute time: days to weeks on conventional computer, minutes to hours on data center
Facebook’s Surround 360

RAW Data: 17 Gb/sec

Compute time: days to weeks on conventional computer, minutes to hours on data center
4096 px line sensors

F/3.5 175 deg fisheye lenses
4096 px line sensors

F/3.5 175 deg fisheye lenses

mounting brackets

mounting platform

Konrad et al., arxiv 2017
Additional Information

- autostitch: http://matthewalunbrown.com/autostitch/autostitch.html