IBMR: Week 7B

Applying $P^2$, $P^3$ Projections: Spherical Light Probes

Jack Tumblin
jet@cs.northwestern.edu

Reminders

- Project 2 overdue today (C* part optional)
- HW1 due Today, May 16
- Proj3 Due Thurs May 23
  HW2 assign on Tues (proposed)
- HW2 due Thurs May 30
  Proj4 Assign Thurs May 23
  HW 3 Assign Tues May 28
- Proj4 Due Tues June 11
- HW3 Due Tues June 11

Image Warping: General Idea

2D $\rightarrow$ 2D continuous coordinate map, a 'rubber sheet'
- Notation: input(x,y) $\rightarrow$ output(u,v)
- 'Forward Mapping' $u = u(x,y), v = v(x,y)$
- 'Inverse Mapping': $x = x(u,v), y = y(u,v)$
- 'Parameterized': $u = u(s,t), v = v(s,t)$
  $x = x(s,t), y = y(s,t)$
Panoramas: Planar ‘Bow-Tie’
- For limited-size mosaics only (angle limits)
- Find all \( H \) from correspondence in overlapped regions
- Choose a (central) reference image
- Reproject, cross-dissolve in reference image plane

Recall: Planar Panoramas
- Choose a ‘reference’ image plane, extend it
- Add images: for each one,
  - find \( H \) from overlap correspondences (in \( P^2 \))
  - transform new image to reference plane
  - re-sample, ‘blend’ (weighted sum)
  - to one image

Non-Planar Panoramas
Can’t use planar method beyond 180° FOV;
- Sphere or cylinder can ‘wrap around’ origin
- How? Spherical coords
  - write 3D sphere eqn in \( P^2 \) coords:
    \[ x_1 = \sin(\theta)\cos(\phi) \]
    \[ x_2 = \sin(\theta)\sin(\phi) \]
    \[ x_3 = \sin(\theta) \]
- ‘Inverse Map’ warp:
  - Output pixel m,n: \( \theta = 2\pi m/n_{max}, \phi = \pi(n/n_{max} - \frac{1}{2}) \)
  - Find \( x' = H^{-1}[x_1, x_2, x_3] \) for each image
  - Blend color(s) found at \( x' \) for each image
Side Note: Camera Distortions

Correct many camera/lens errors in P^2
- Place raw camera input at (x,y,1) plane
- Write equations for 3D ‘projection surface’
  Example: scaleable, offset sphere for spherical distortion
  \[ x_1 = a + b \sin(\theta) \cos(\phi), \quad x_2 = c + d \cos(\theta) \cos(\phi), \quad x_3 = e + f \sin(\theta) \]
- Scan projection surface to find output pixels
  Example: take equal-sized steps in (\theta, \phi); sample input image

Example: Spherical Panorama

Practical Panoramas: ‘Box Cross’
- Spherical maps oversample near poles;
- Cylindrical maps can’t see floor, ceiling spot
- Nice solution: ‘Box Cross’
  - ‘unwrap’ a cube around origin
  - 6 square planar images
  - Easy!
    - for each image,
    - for each box side,
    - find reprojection \( \mathbf{H} \)
    - find pixels on box
    - rework as needed (cyl, sphere, etc.)
Panoramic Cameras

Panoramics without ‘stitching’:
• ‘Fisheye’ Lenses, conics,…
• Slit-scan: (WideLux, Noblex, PanoScan, …)
  – cyl. or spherical image
  – slow! no action shots
• Multiple Planar Cams
  – Fast, flexible, expensive
  – can do panorama movies
• History: 1843…

Light Probes: What?

• Photograph a mirrored sphere
• warp image to find irradiance vs. direction
1 picture == half-sphere
High contrast? Full sphere? More Pictures!

Light Probes

• Example images (see Debevec’s site)
High Contrasts too!

Acquiring the Light Probe

(Try it yourself—I’d like to…)

Sources of Mirrored Balls

2-inch chrome balls ~ S24 ea.
Kring Bearing, Inc.
Applied Industrial Technologies

6-12 inch gazing balls (blown glass)
Baker’s Lawn Ornamentals

578 HERLIND PLANK ROAD
SOMERSET, NJ 08873

Mirror Ball → Panorama Conversion

Makes an offset ‘virtual’ half-sphere camera located at mirror ball center:

• How can we write this in $P^2$ and/or $P^3$?
Light Probes: Daydreams

- Debevec: ‘Light Stage 2.0’

- Go further!
  - Sphere of projectors set incoming light field
  - CAVE / Light Stage corrupted by interreflections
  - Probe(s) measure ACTUAL incoming light
  - Math: Remove interreflected amounts from computed display

Light Probes

- ‘Two-shot’ panoramic camera
- Clever, fast, simple, cheap, flexible
- Probe position ≠ Camera position; telephotos…
  - Allows small probes in tight, risky spaces
  - Little/no image alignment / mosaicing
- Drawbacks:
  - Highly non-uniform sampling
  - Camera ALWAYS in the image
- Daydreams: a better probe?
  - Huge: mirrored weather balloon?
  - Tiny, stochastic: bubbles in a liquid?
  - Dynamic shapes: whirling mirror on arm?
  - Other shapes: Nayyar, Carlbom, ?He(MSRchina) etc.

END