Omnidirectional Cameras

CS 535

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Cameras

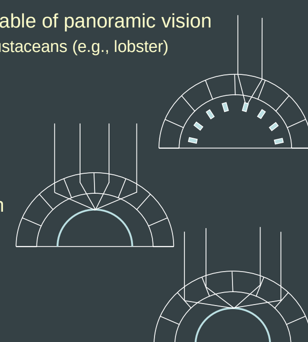
- Traditional camera
  - Pinhole Camera Model
    - Problems: aberrations, distortions
  - Tradeoff between aperture, shutter speed, focus, dynamic range
- Calibration
  - Fit an assumed camera model to an actual camera
- Omnidirectional cameras
  - Single camera, multiple cameras, etc
- Localization and pose estimation
  - Where is the camera relative to the object or environment

A little bit of history…

- Omnidirectional cameras are also called panoramic cameras
  - "Panorama" comes from the Greek phrase "all sight"
- Originally used for artistic purposes
- Robert Barker obtained a patent for the idea of a panorama in 1794
  - "A Painting without Equal"
- In 1800s, panorama became a common European word

A little bit of Biology…

- Some animals are capable of panoramic vision
  - e.g., certain insects, crustaceans (e.g., lobster)
- Diurnal Insect Vision
- Nocturnal Insect Vision
- Crustacean Vision



Taxonomy of Omnidirectional Camera Designs

- Single center-of-projection
  - Like a traditional camera, light rays meet at a single "focal point"
- Multiple center-of-projection
  - Camera does not have a single focal point
  - Sampled surfaces can be missing or duplicated in full image
  - Mathematical (re)projections are more complicated
- Single Camera/Image
  - One "view" is acquired per image
- Multiple Camera/Image
  - A single "view" composed by compositing several images

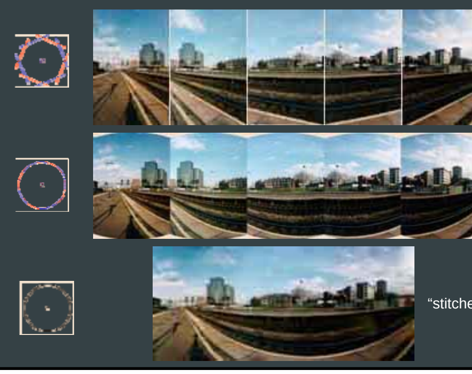
Example Omnidirectional Camera Designs

- Rotating camera design
- Fish-eye lens design
- Multiple camera planar mirror design
- Single camera curved mirror design

Rotating Camera Design

- Place a camera on a tripod and spin it around snapping pictures every so often
- Pros
  - Simple
- Cons
  - Multiple centers-of-projection
  - Multiple (overlapping images) to composite
  - Vertical “jitter”
  - Slow acquisition process

Rotating Camera Design



original

warped

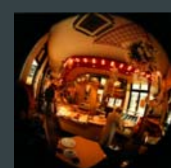
“stitched”

Examples

- Tienamen

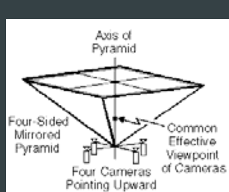
Fish-Eye Lens Design

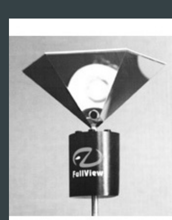
- Use a wide field-of-view lens (~180 degrees) placed in front of a traditional camera
- Pros:
  - Also relatively simple for users (making the lens can be troublesome for designers)
- Cons:
  - *Very* severe image distortion
  - Low resolution around perimeter of field-of-view
  - Almost a single center-of-projection



Multiple Camera Planar Mirror Design

- Catadioptric = reflective (mirror) + refractive (lens)
- http://www.fullview.com [Nalwa96]





Single Camera Curved Mirror Design

- Theoretical solutions to a single center-of-projection panoramic camera use mirrors that are subsets of swept conic sections
  - Cones
  - Spheres
  - Ellipsoids
  - Hyperboloids
  - Paraboloids

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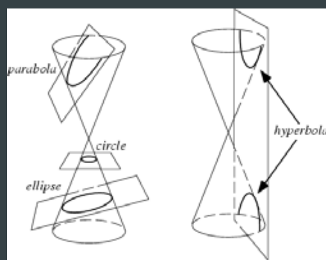


Examples

- Walking in the mirror
- Museum

Conical Mirror

Spherical Mirror

Ellipsoidal Mirror

Hyperboloidal Mirror

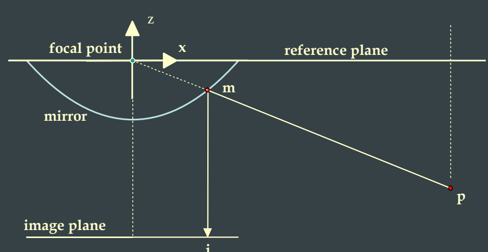
Paraboloidal Mirror

Catadioptric Paraboloidal Camera

Design by [Nayar97]

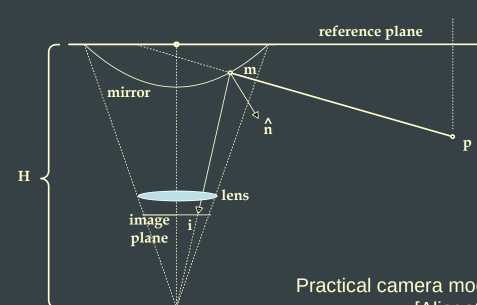
Motorized cart with camera, computer, battery, radio remote control [Aliaga01,02]

Catadioptric Paraboloidal Camera



Theoretical camera model

Catadioptric Paraboloidal Camera



Practical camera model [Aliaga01]

Catadioptric Paraboloidal Camera Calibration

- Assuming incident equals reflected angle:

$$\frac{i-m}{\|i-m\|}\cdot\frac{\hat{n}}{\|\hat{n}\|}=\frac{p-m}{\|p-m\|}\cdot\frac{\hat{n}}{\|\hat{n}\|}$$

- And given a 3D point *p*, mirror radius *r*, convergence distance *H*, we group and rewrite in terms of m_r:

$$m_r^5-p_r m_r^4+2r^2 m_r^3+(2p_r rH-2r^2 p_r)m_r^2+(r^4-4r^2 p_z H)m_r-(r^4 p_r+2r^3 H p_r)=0$$

Omnidirectional Vision Home Page

- http://www.cis.upenn.edu/~kostas/omni.html