RoboJackets

CAT®

THE ARTHUR M. BLANK FAMILY FOUNDATION

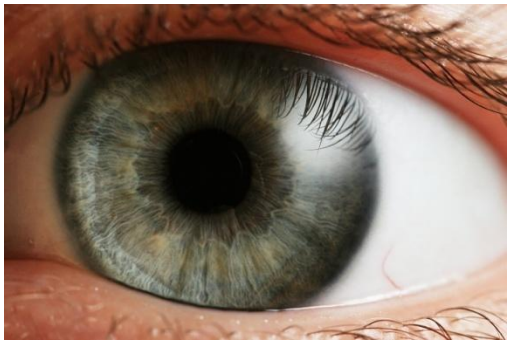
2007 Adv TE Sessions – Computer Vision

Andy Bardagjy

September 25, 2007

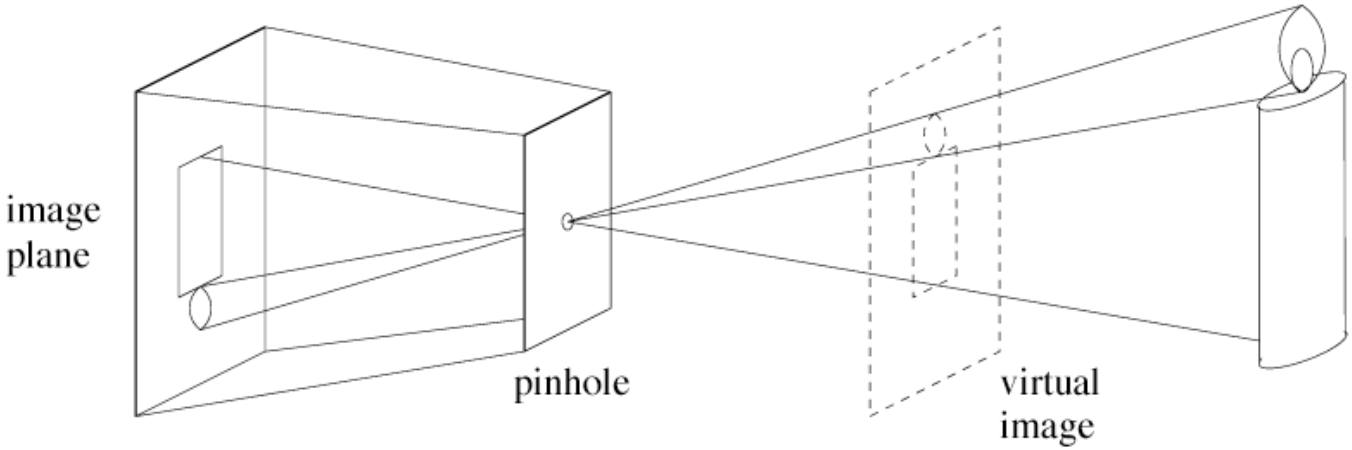
www.robojackets.org

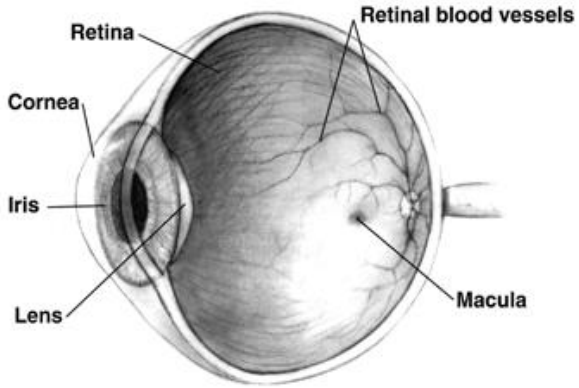
Why use vision?



- Tremendous amount of information
  - Spatial
  - Temporal
  - Radiometric
- Cost
- Passive
- Size
- Our “primary” sensor

Image Formation





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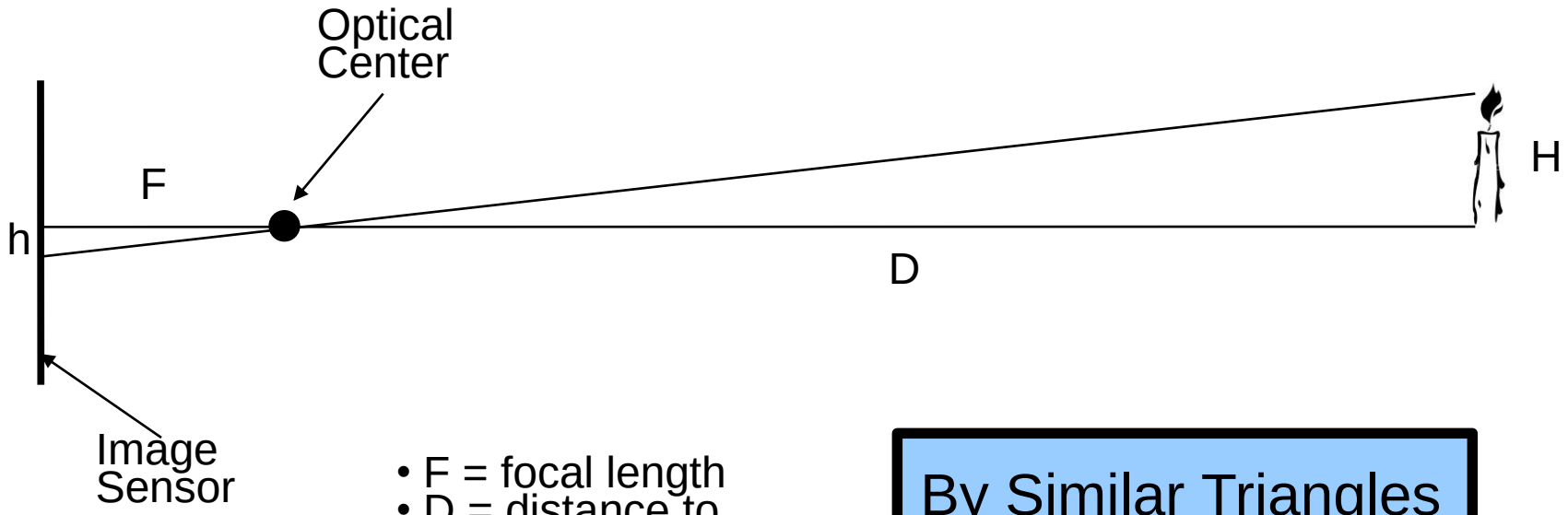
Distance?

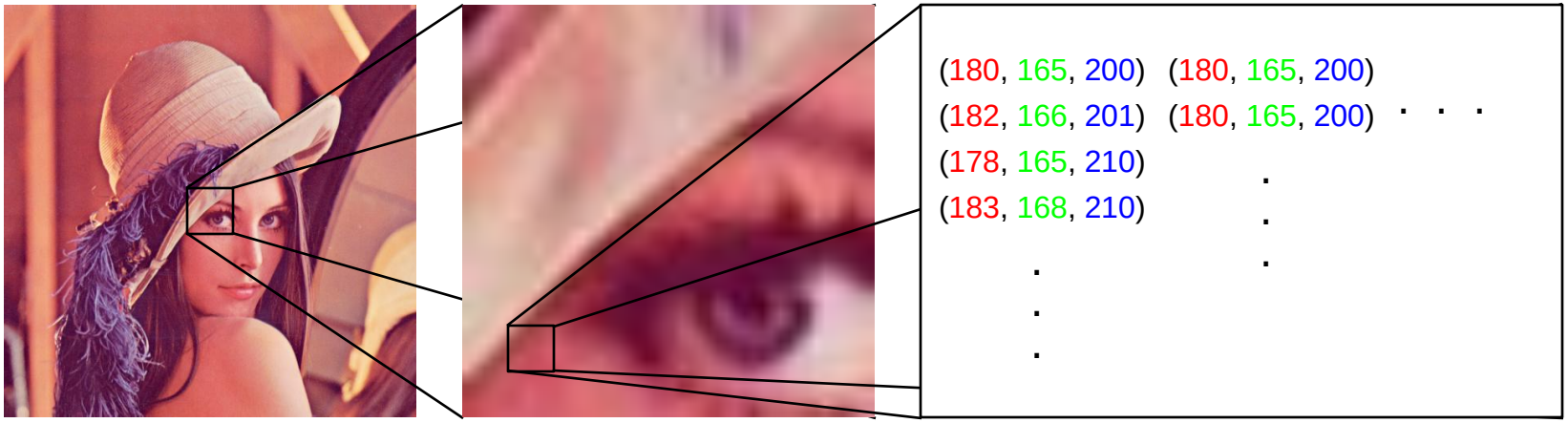


- F = focal length
- D = distance to object
- h = displacement on sensor
- H = height of object

By Similar Triangles

$$\frac{h}{f} = \frac{H}{D}$$

Image Representation

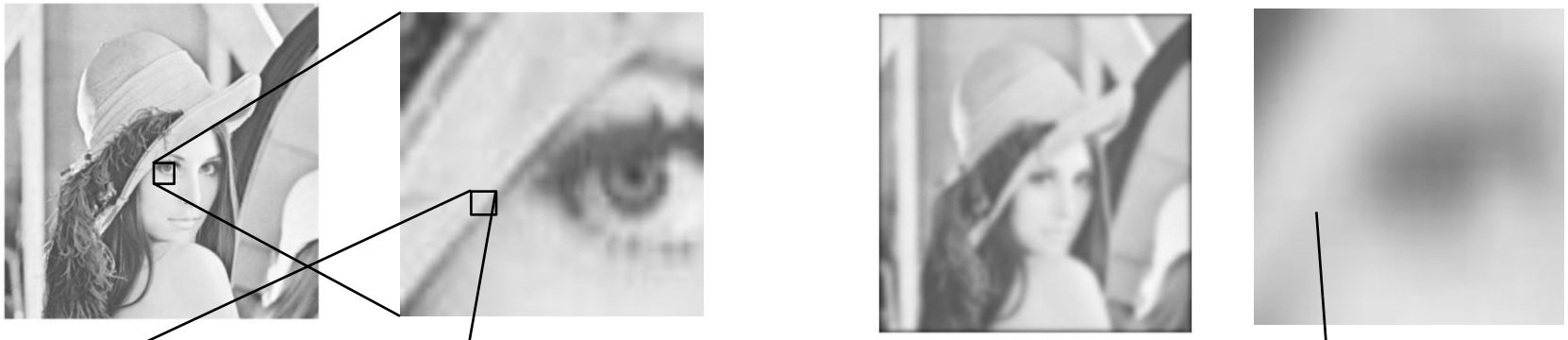


- Matrix representation of image data
- Data “cube”
- Origin at upper left

Filtering

- Convolution
- Thresholding

Convolution



200, 210, 205,
195, 198, 200,
198, 199, 200,

*

1/9, 1/9, 1/9
1/9, 1/9, 1/9
1/9, 1/9, 1/9

=

200.55

*This is an example of an averaging (“mean”) filter.

$$(g * f)(m) = \sum_n f(n)\, g(m-n)$$

$$(g * f)(m) = \int f(n)\, g(m-n)\, dn$$

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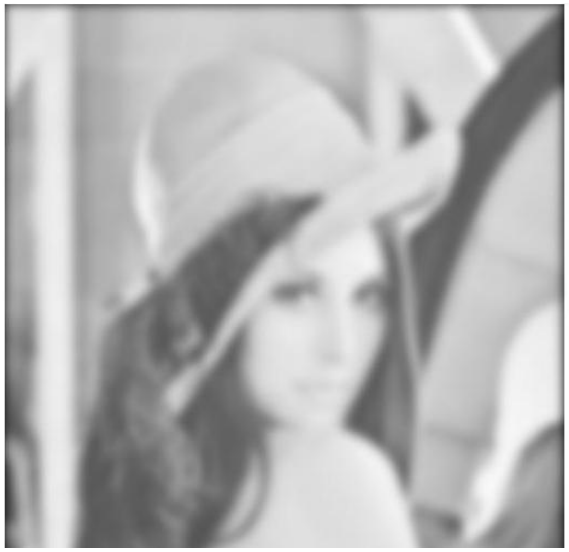
Other Masks...

Gaussian Blur

*

=



- More weight given to center pixel
- Approximates image resizing, real world blur.
- Resistant to outliers
- Enemy of noise

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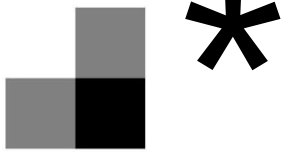
Other Masks...

Robert's Edge Detector



$*$

$*$

$\oplus =$

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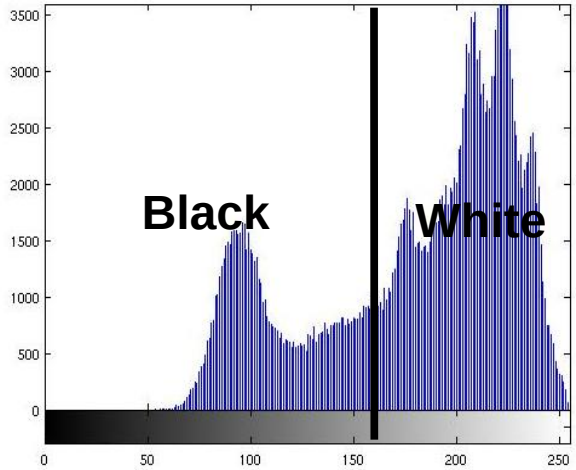
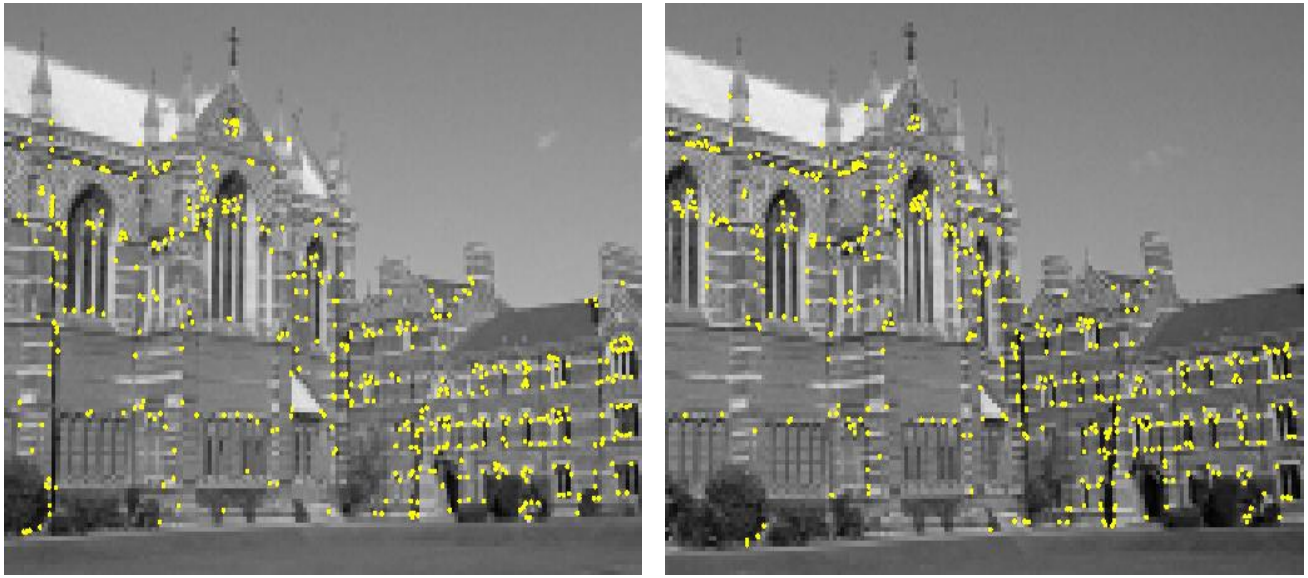
Thresholding



```
if (pixel > threshold)
white
else
black
```

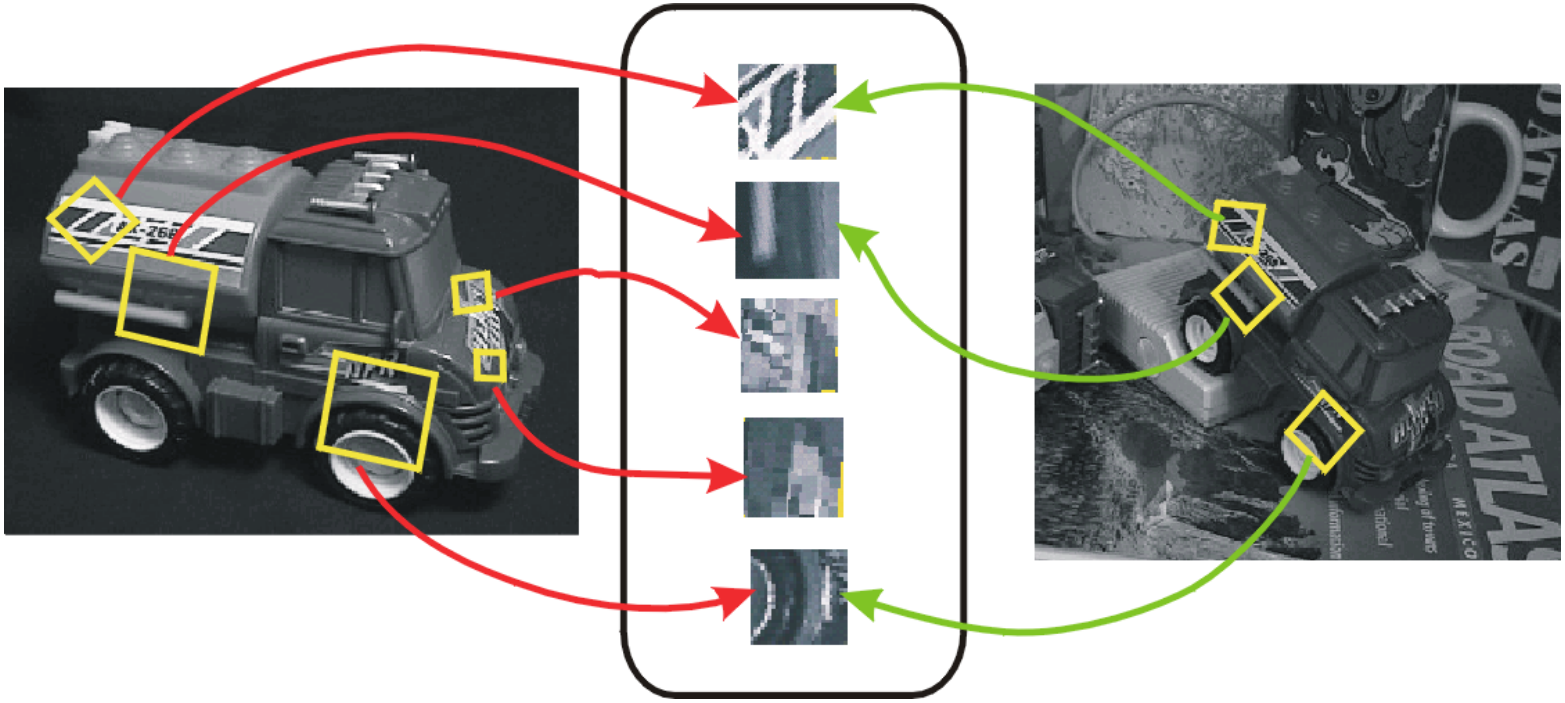
Useful for
- Color recognition
- Crude image compression

Feature Detecting



- Active area of research
- Harris Corner Detector
- SIFT Feature Detector
- By hand...

Feature Matching



- Active area of research
- Particle Filtering
- RANSAC
- Bundle Adjustment
- Expectation Maximization

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Video Google

Retrieved key-frames from three different shots

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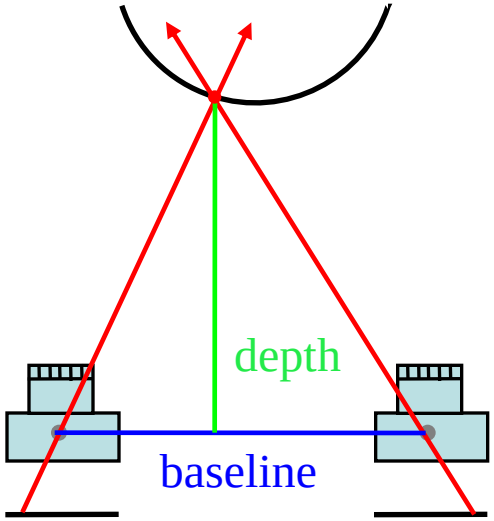
Stereo

Triangulate to find depth from the same feature in two (or more) images.

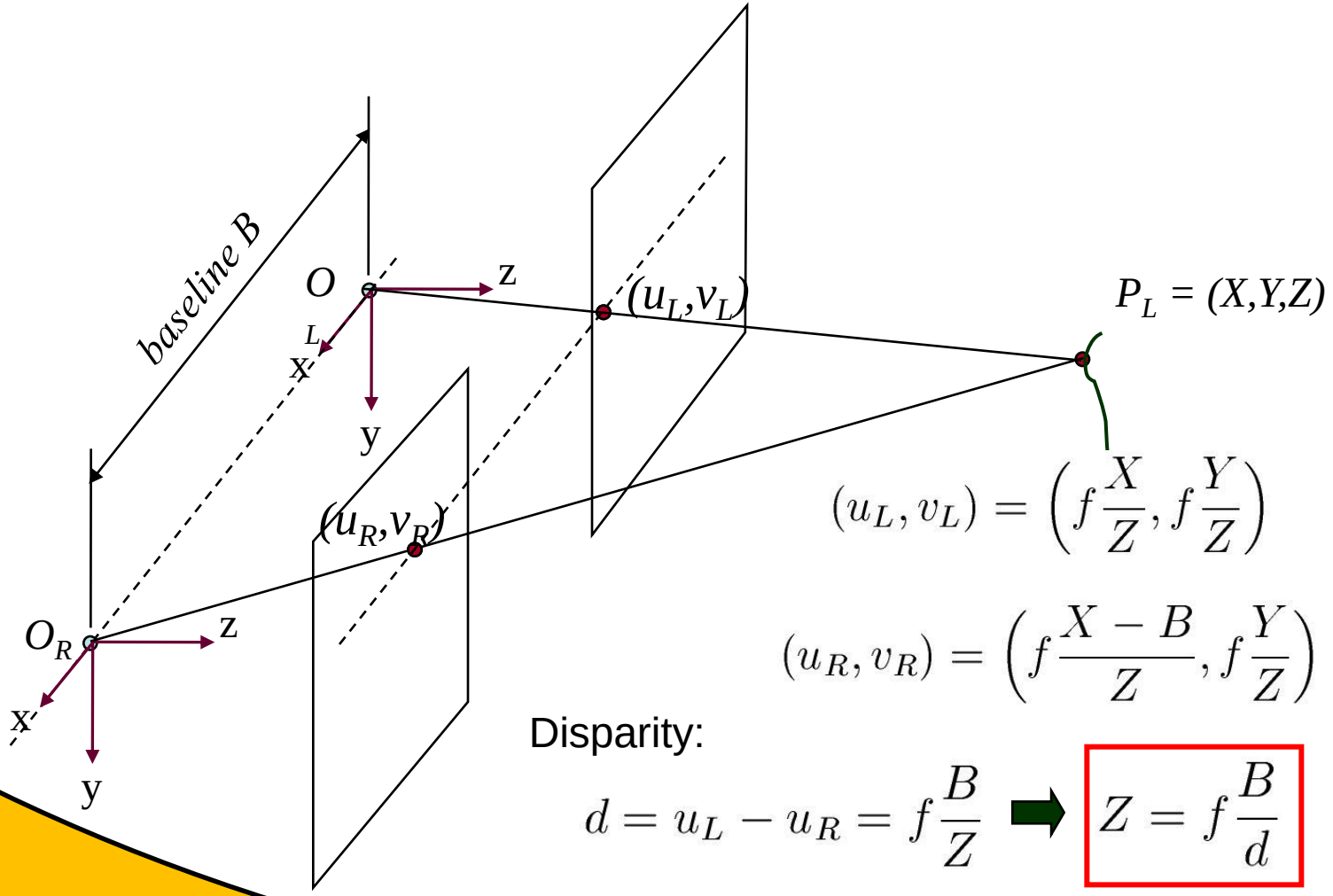


Requires
- Feature detection and matching across views (correspondence points)
- Calibrated cameras*

Left

Right

Stereo



$$(u_L, v_L) = \left(f\frac{X}{Z}, f\frac{Y}{Z}\right)$$

$$(u_R, v_R) = \left(f\frac{X-B}{Z}, f\frac{Y}{Z}\right)$$

Disparity:

$$d = u_L - u_R = f\frac{B}{Z} \Rightarrow \boxed{Z = f\frac{B}{d}}$$

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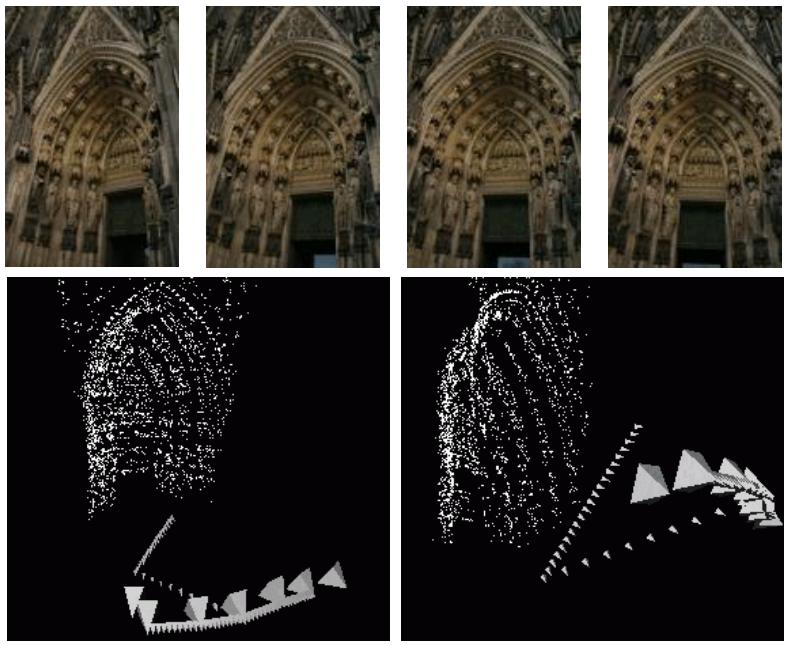
Wide Baseline Stereo



Video: PhotoSynth
Video: 4D Cities

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SLAM
Self Localization and Mapping

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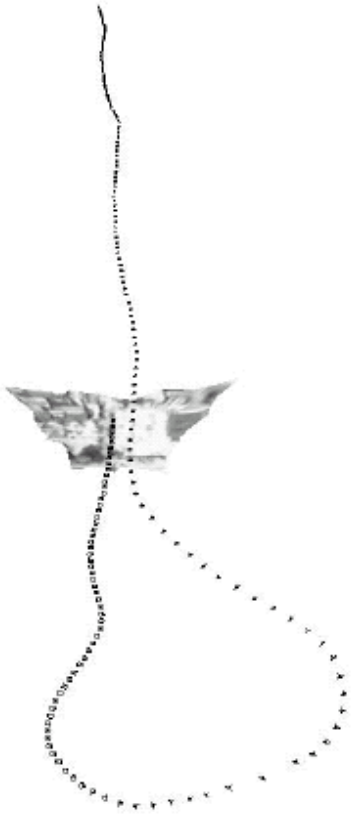
Uses features and stereo equations to compute its location and map it's environment

Equations solved, features still need work.

Without other sensors, no sense of scale.



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Bullet Time!

Video: The Matrix - Bullet Time

- Stereo
- View Morphing

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Image Courtesy Kang

Projections

Catadioptric Camera
(latin for mirror + lens)

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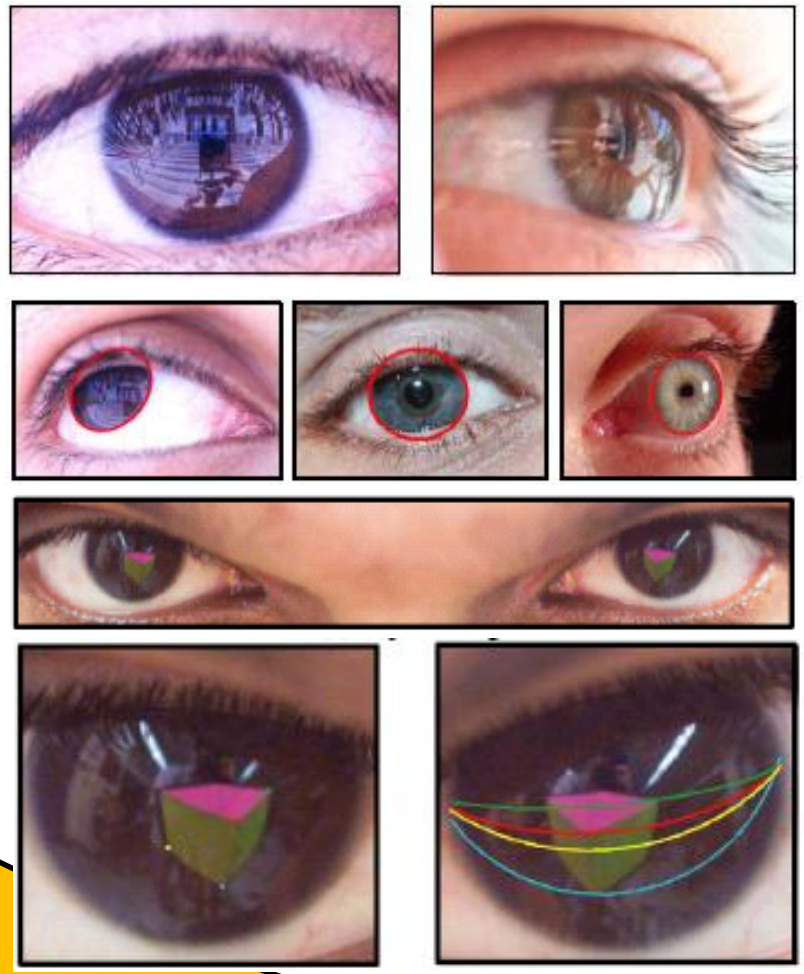
The World in an Eye



(a) Eye image (cropped)

(b) Spherical Panorama (cropped)

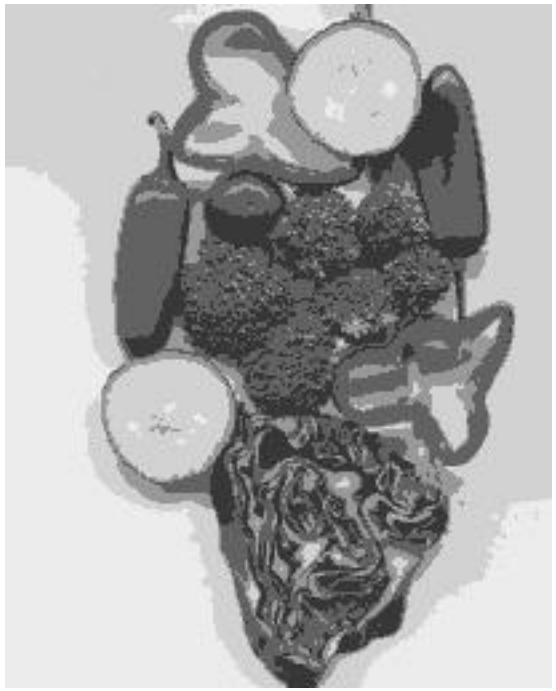
(c) Foveated retinal image (45° FOV)

(I) Interacting with a Computer

Clustering

Image

Clusters on intensity



Clusters on color

K-means clustering on intensity and color

K-Means Clustering

Algorithm

- Fix cluster centers and allocate points to closest center.
- Find centroid of clusters and recompute.
- Stop when no points change alliegences.

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Rotoscoping

A Scanner Darkly

Done semiautomaticlly in the movie, techniques exist to do it automatically.

Techniques Used
- Linear Filtering
- Clustering
- Edge Detection

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Expectation Maximization

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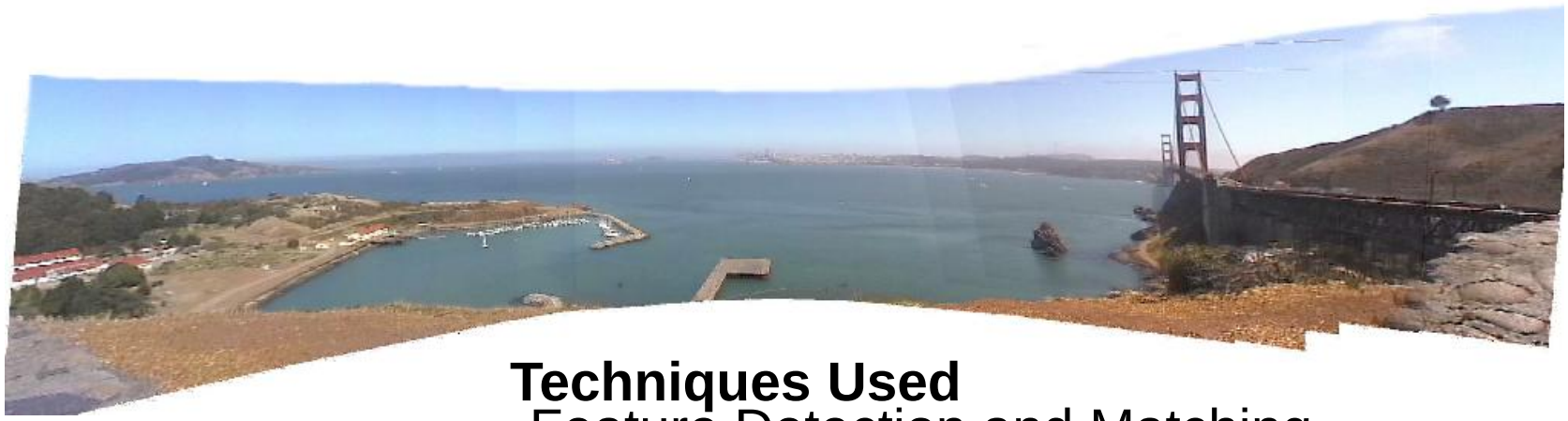
- Objective:
  - Robust fit of a model to data S
- Algorithm
  - Randomly select s data points
  - Make a model with those points
  - Get consensus set S
  - If |S|>T, terminate and return model
  - Repeat for N trials, return model with max |S|
  - Optional: refine returned model

Mosaicking



Techniques Used

- Feature Detection and Matching
- Model Fitting
  - Expectation Maximization
  - Graph Cuts (optional)

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Images Courtesy Frank Dellaert

Driving

Competitions
- DARPA Grand Challenge
- DARPA Urban Challenge
- IGVC
- LAGR

Applictions
- Structured and unstructured road following
- Lane detection
- Pedestrian detection / avoidance
- Signal detection
- Cruise control
- Merge assistance
- Driver impairment detection

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Legal

These slides and more are available at

http://www.robojackets.org

For more information contact the RoboJackets. (contact info available via the web)

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