RoboJackets

CAT

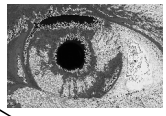
The Arthur M. Blank Family Foundation

2007 Adv TE Sessions – Computer Vision

Andy Bardagjy

September 25, 2007

Why use vision?



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

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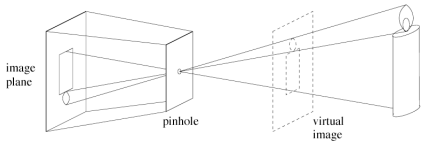
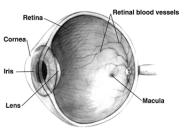
Image Formation





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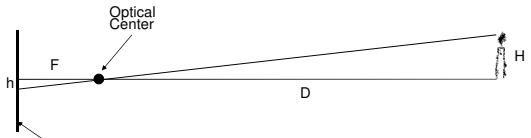
Distance?



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

By Similar Triangles

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

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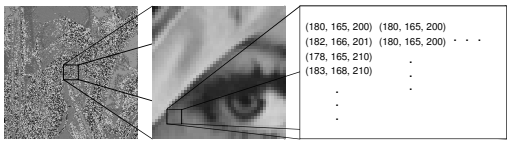
Image Representation



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

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Filtering

- Convolution
- Thresholding

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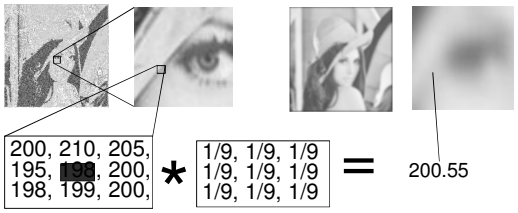
Convolution



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.

$$(g \ast f)(m) \equiv \sum_n f(n)\, g(m-n)$$
$$(g \ast f)(m) \equiv \int f(n)\, g(m-n)\, dn$$

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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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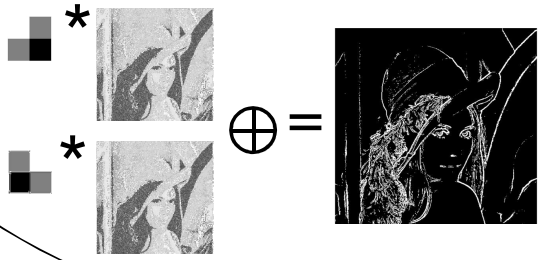
Other Masks...

Robert's Edge Detector



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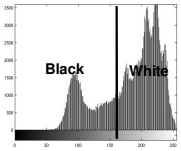
Thresholding



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

Useful for
- Color recognition
- Crude image compression

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Feature Detecting

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

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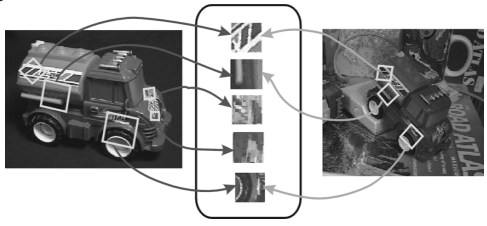
Feature Matching



- 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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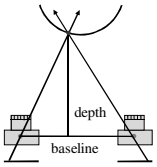
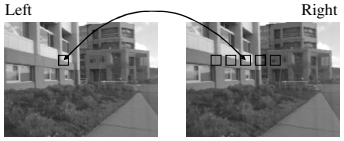
Stereo

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



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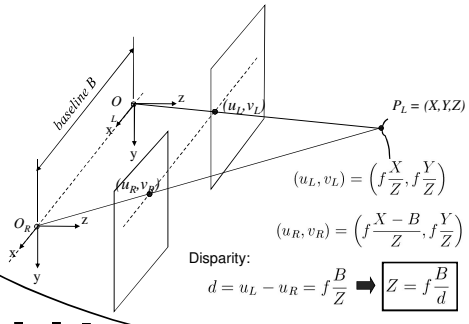
Stereo



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

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

Disparity:

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

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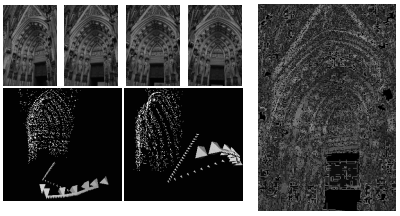
Wide Baseline Stereo



Video: PhotoSynth
Video: 4D Cities

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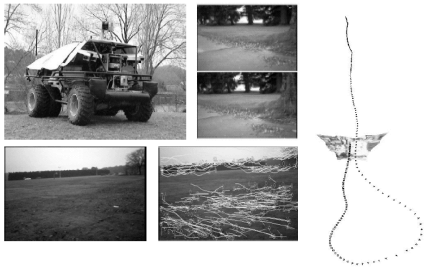
SLAM
Self Localization and Mapping

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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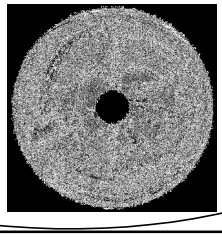
Image Courtesy Kang

Projections

Catadioptric Camera
(latin for mirror + lens)



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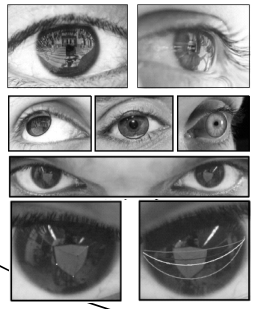
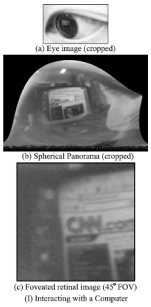
The World in an Eye





Nayar '04

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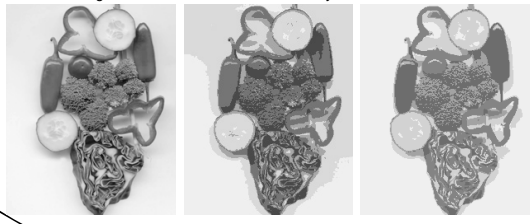
Clustering

Image | Clusters on intensity | Clusters on color



K-means clustering on intensity and color

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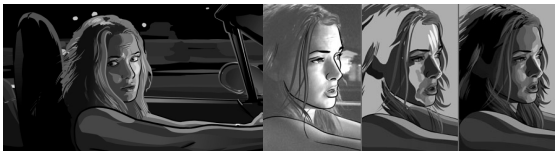
K-Means Clustering



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

- 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

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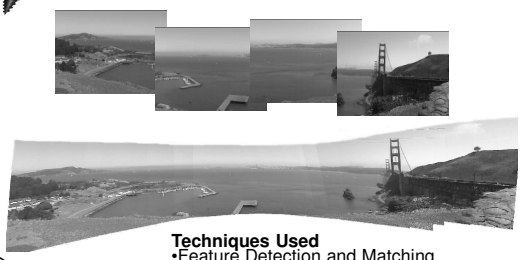
Mosaicking



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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