Announcements

- Today
  - Midterm returned
  - Stereo continued

Midterm

Mean: 76.5
Median: 77.0
Std. dev: 13.0
Max: 100
Min: 43

Line Fitting

Problem: minimize

\[ E(a, b, d) = \sum_{i=1}^{n} (ax_i + by_i - d)^2 \]

with respect to \((a, b, d)\).

1. Minimize \(E\) with respect to \(d\): Where \((\bar{x}, \bar{y})\) is the mean of the data points

\[ \frac{\partial E}{\partial d} = 0 \Rightarrow d = \frac{1}{n} \sum_{i=1}^{n} ax_i + by_i = \bar{x} \bar{y} \]

Shape-from-X

(i.e., Reconstruction)

- Methods for estimating 3-D shape from image data. X can be one (or more) of many cues.
  - Stereo (two or more views, known viewpoints)
  - Motion (moving camera or object)
  - Shading
  - Changing lighting (Photometric Stereo)
  - Texture variation
  - Focus/blur
  - Prior knowledge/context
  - Structured light/lasers

Binocular Stereopsis: Mars

Given two images of a scene where relative locations of cameras are known, estimate depth of all common scene points.

Two images of Mars
Stereo Vision Outline

- Offline: Calibrate cameras & determine "epipolar geometry"
- Online
  1. Acquire stereo images
  2. Rectify images to convenient epipolar geometry
  3. Establish correspondence
  4. Estimate depth

Two Approaches

- A) From each image, process "monocular" image to obtain cues.
- B) Establish correspondence between cues.
- C) Directly compare image regions between the two images.

Random Dot Stereograms

Epipolar Constraint

- Potential matches for \( p \) have to lie on the corresponding epipolar line \( l' \).
- Potential matches for \( p' \) have to lie on the corresponding epipolar line \( l \).
Family of epipolar Planes
(standard approach)

Properties of the Essential Matrix

\[ p'E'p = 0 \quad \text{with} \quad E = [t, \cdot]R \]

- \( E' \) is the epipolar line associated with \( p' \).
- \( E'p \) is the epipolar line associated with \( p \).
- \( E' = 0 \) and \( E'e = 0 \).
- \( E \) is singular.
- \( E \) has two equal non-zero singular values (Huang and Faugeras, 1989).

Calibration

Determine intrinsic parameters and extrinsic relation of two cameras

The Eight-Point Algorithm (Longuet-Higgins, 1981)

\[ \begin{pmatrix} F_{13} & F_{12} & F_{11} \\ F_{23} & F_{22} & F_{21} \\ F_{33} & F_{32} & F_{31} \end{pmatrix} \begin{pmatrix} u' \\ v' \\ 1 \end{pmatrix} = 0 \]

Set \( F_{13} \) to 1

\[ \begin{array}{c|ccc|c|c}
\hline
n & u & v & w & t \\
\hline
1 & u_1 & v_1 & w_1 & t_1 \\
2 & u_2 & v_2 & w_2 & t_2 \\
3 & u_3 & v_3 & w_3 & t_3 \\
\hline
\end{array} \]

Minimize:

\[ \sum_{i=1}^{n} (p_i^T F p_i)^2 \]

under the constraint

\[ |F| = 1. \]