Other Non-Linear Filters

Slides from Cornelia Fermüller and Marc Pollefeys
Corner Detection (Non-linear filter)

- Corners have more edges than lines
- Should be easier
- But edge detectors fail – why?
  - Right at corner, gradient is ill-defined
  - Near corner, gradient has two different values
Moravec Operator

• Self-similarity
  – How similar are neighboring patches largely overlapping to me?
• Most regions - Very similar
• Edges - Not similar in one direction (perpendicular to edge)
• Corners – not similar in any direction
• Interest point detection – not only corners
Measuring self-similarity

- SSD = Sum of squared differences
- Corner is local maxima

\[ V = \sum_{i=1}^{9} (A_i - B_i)^2 = 2 \times 255^2 \]

\[ V = \sum_{i=1}^{9} (A_i - B_i)^2 = 3 \times 255^2 \]
Limitations

- Sensitive to noise
  - Responds for isolated pixel
- Larger patches for robustness
Limitations

• Responds also to diagonal edges
Limitations

- Anisotropic (Not rotationally invariant)
Harris & Stephens/Plessey Corner Detector

- Consider the differential of the corner score with respect to direction
- Describes the geometry of the image surface near the point \((u,v)\)

\[ A = \sum_u \sum_v w(u,v) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} = \begin{bmatrix} \langle I_x^2 \rangle & \langle I_x I_y \rangle \\ \langle I_x I_y \rangle & \langle I_y^2 \rangle \end{bmatrix}, \]

Hessian Matrix
(Second derivatives of multi-variate function)
How to find the corner?

- The eigenvalues are proportional to the principal curvatures
- If both small, no edge/corner
- If one big and one small, edge
- If both big, then corner
Rotationally Invariant

- If \( w \) is Gaussian, then this is isotropic

\[
A = \sum_u \sum_v w(u, v) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} = \begin{bmatrix} \langle I_x^2 \rangle & \langle I_x I_y \rangle \\ \langle I_x I_y \rangle & \langle I_y^2 \rangle \end{bmatrix},
\]
Median filter

- Replace by median of the neighborhood
- No new gray levels
- Removes the odd man out
  - Good for outlier removal
- Retains edges
Median filter

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Salt and Pepper Noise
Difference from Gaussian Noise

Gaussian

Salt and Pepper
Median Filter

original image

1px median filter

3px median filter

10px median filter