

The background features several large, stylized, overlapping swirls in shades of purple, green, and light blue. Interspersed among these swirls are numerous small, yellow, triangular shapes pointing in various directions, creating a dynamic and abstract visual effect.

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

		B1	B2	B3	
	A1	A2 B4	A3 B5	B6	
	A4	A5 B7	A6 B8	B9	
	A7	A8	A9		

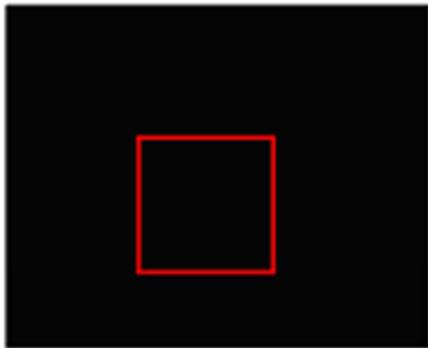
$$V = \sum_{i=1}^9 (A_i - B_i)^2 = 2 * 255^2$$

		B1	B2	B3	
	A1	A2 B4	A3 B5	B6	
	A4	A5 B7	A6 B8	B9	
	A7	A8	A9		

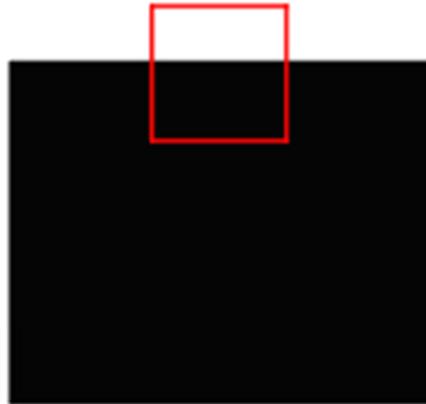
$$V = \sum_{i=1}^9 (A_i - B_i)^2 = 3 * 255^2$$

Limitations

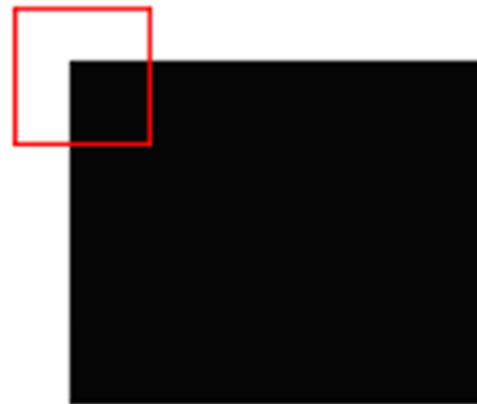
- Sensitive to noise
 - Responds for isolated pixel
- Larger patches for robustness



A. Interior Region
Little intensity variation
in any direction



B. Edge
Little intensity variation
along edge, large
variation perpendicular
to edge



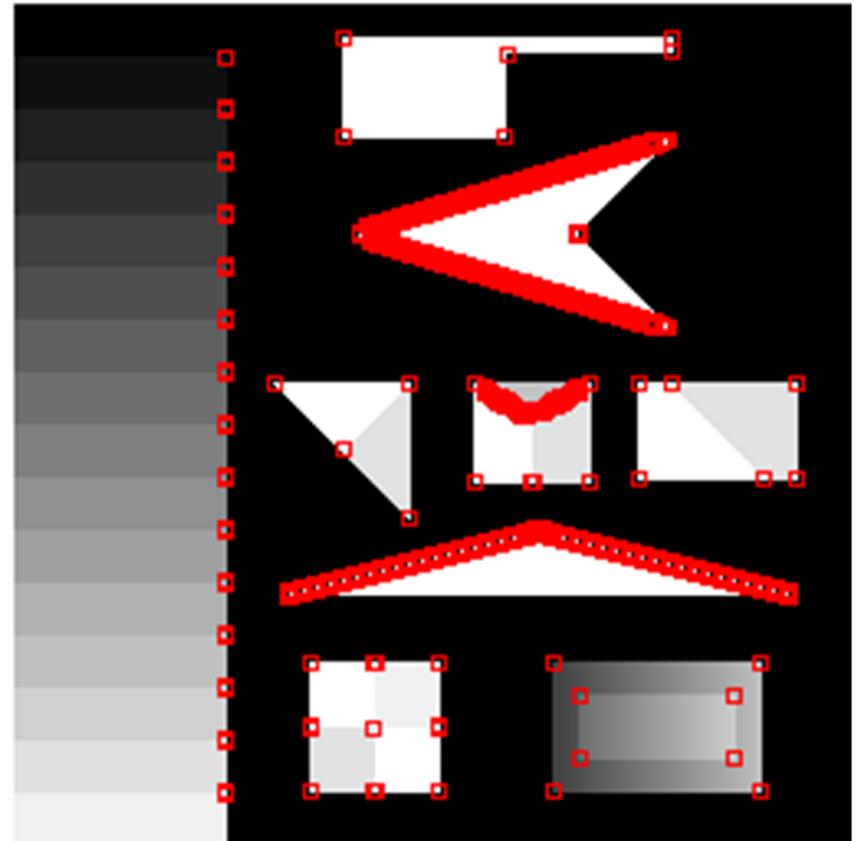
C. Edge
Large intensity variation
in all directions



D. Edge
Large intensity variation
in all directions

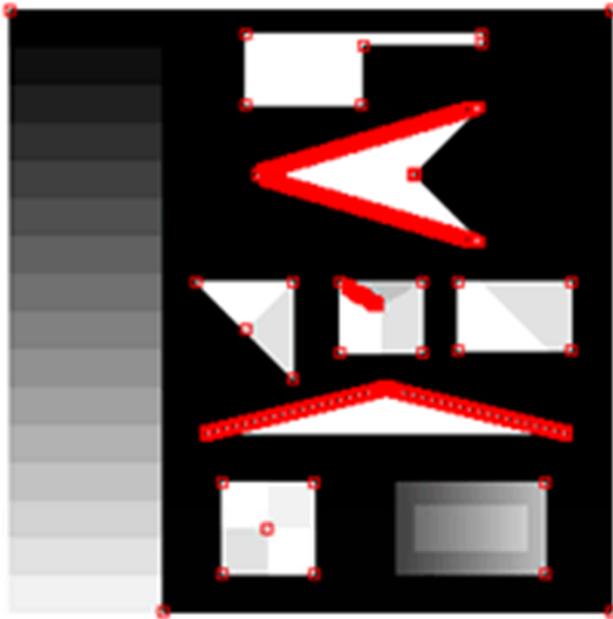
Limitations

- Responds also to diagonal edges



Limitations

- Anisotropic (Not rotationally invariant)



Original Image

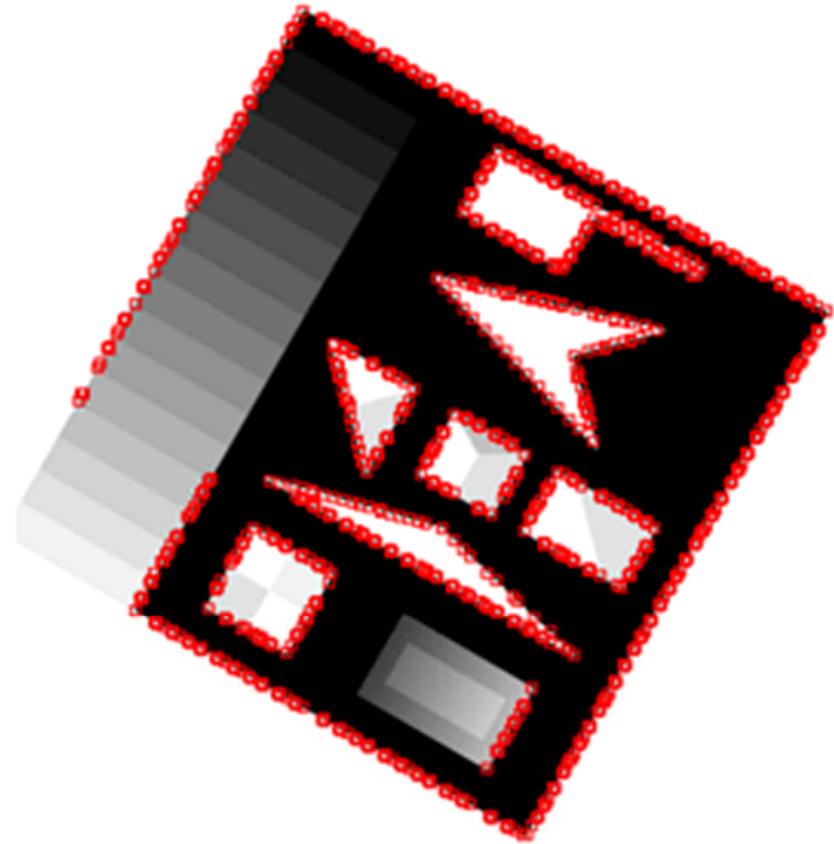


Image Rotated 30°

Harris & Stephens/Plessey Corner Detector

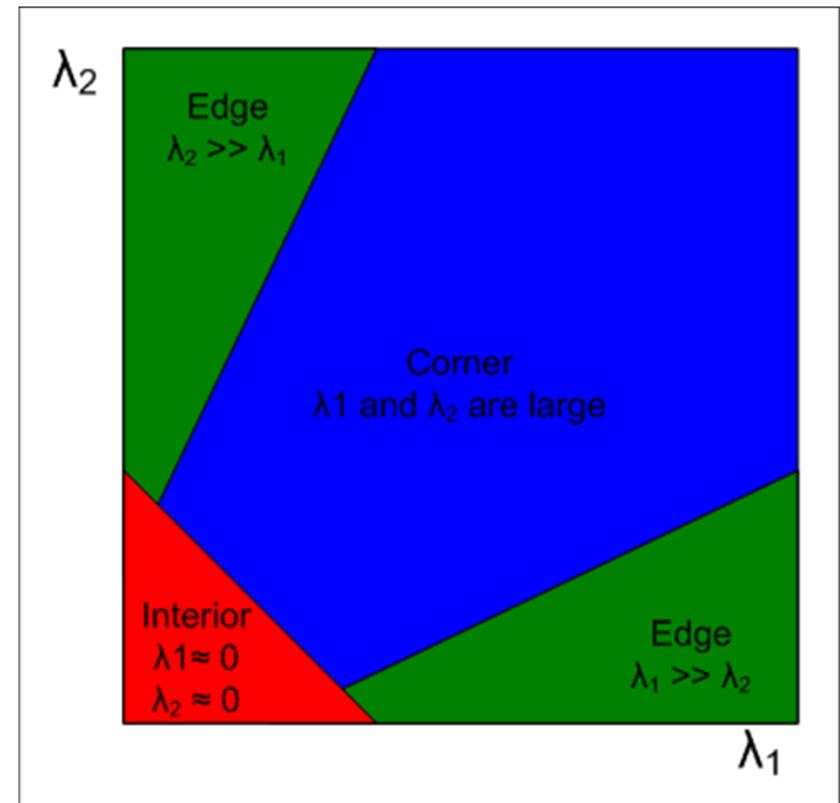
- Consider the differential of the corner score with respect to direction
- Describes the geometry of the image surface near the point (u, v)

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

Hessian Matrix
(Second derivatives of
multi-variate function)

How to find the corner?

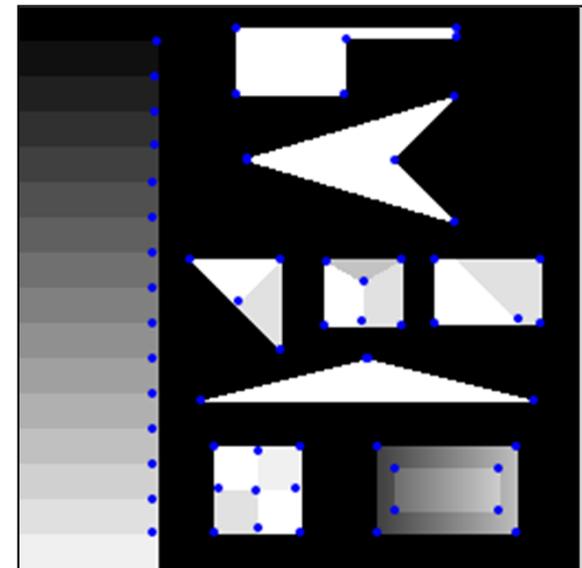
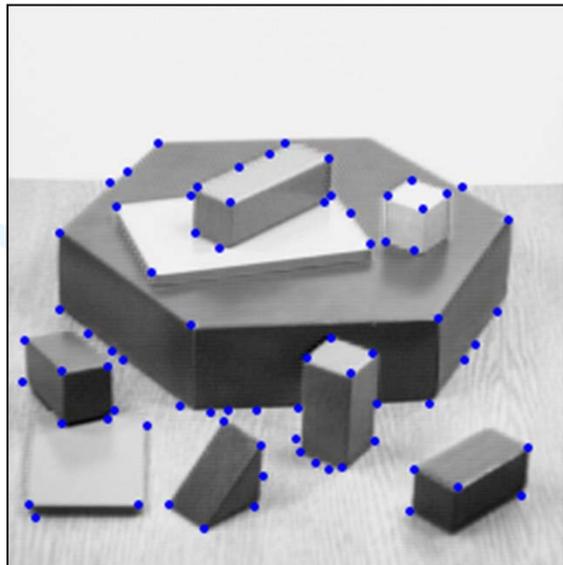
- The eigenvalues are proportional to the principal curvatures
- If both small, no edge/corner
- If one big and one small, edge
- If both big, then corner

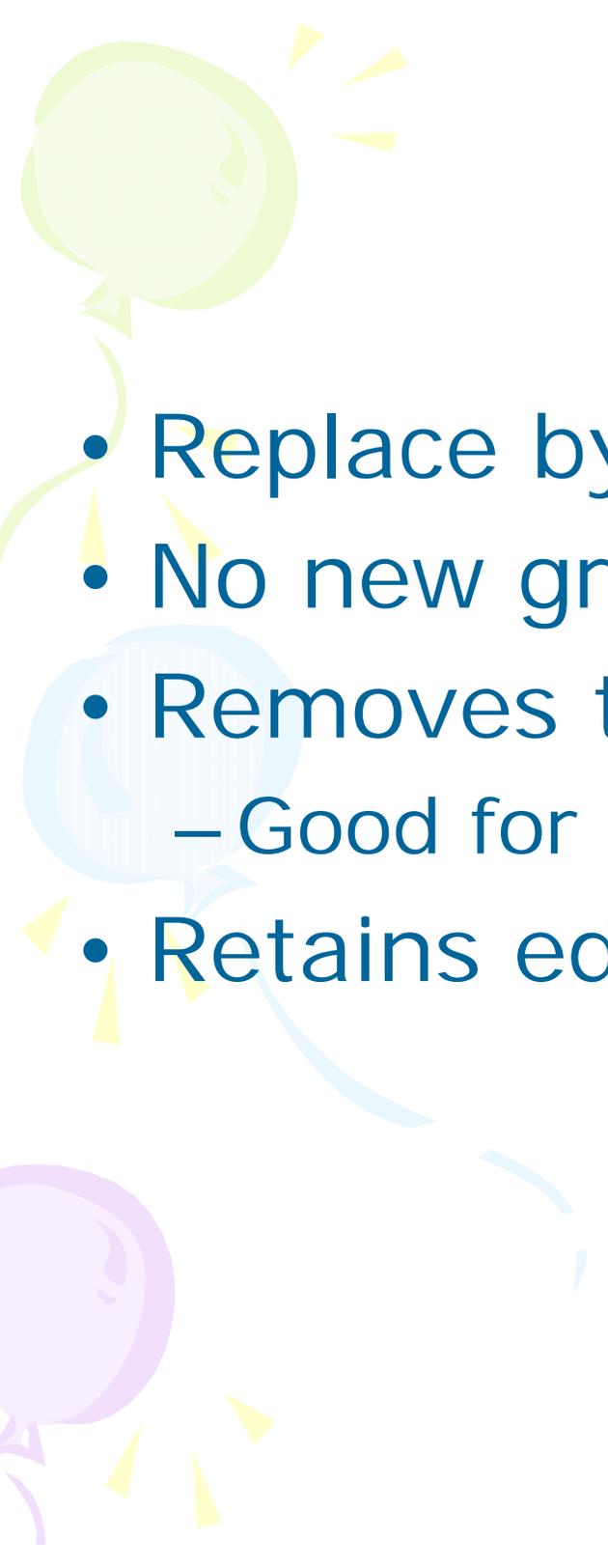


Rotationally Invariant

- If w is Gaussian, then this is isotropic

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

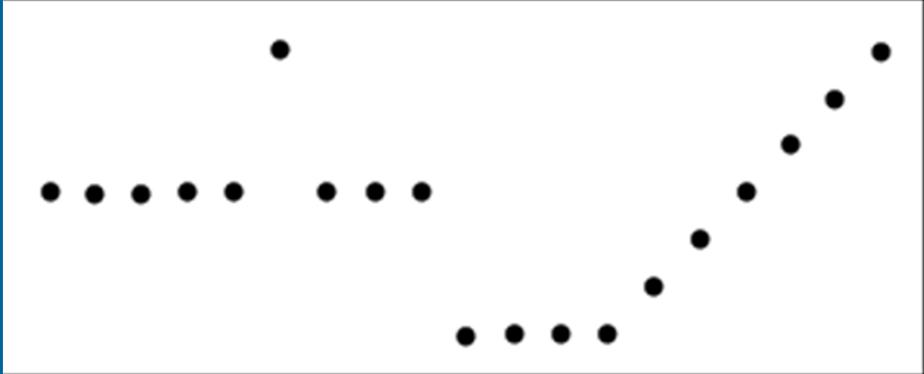




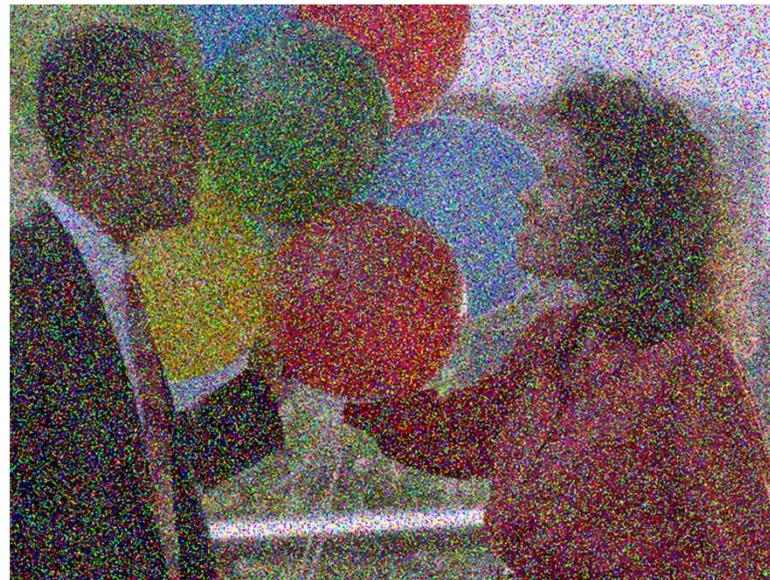
Median filter

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

Median filter

	INPUT
	MEDIAN
	MEAN

Salt and Pepper Noise



Difference from Gaussian Noise



Gaussian



Salt and Pepper

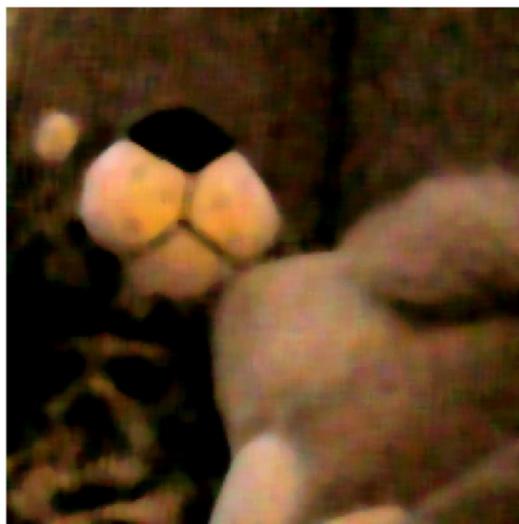
Median Filter



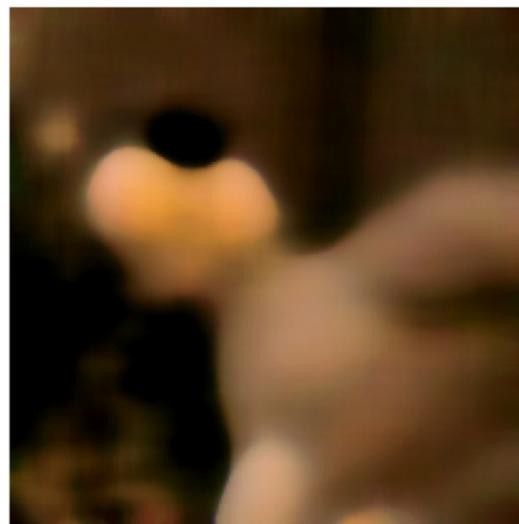
original image



1px median filter



3px median filter



10px median filter