Harris Corner Detector

ISL / 강한솔

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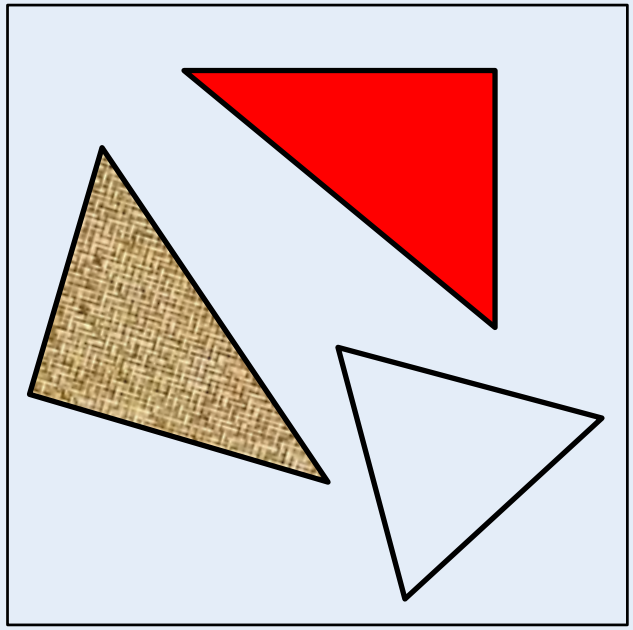
00 Intro



❖ Feature

- Point, boundary, edge, texture, color, etc.

❖ Good feature

- 물체의 형태나 크기, 위치가 변해도 쉽게 식별이 가능할 것.
- 카메라의 시점, 조명이 변해도 영상에서 해당 지점을 쉽게 찾아낼 수 있을 것.

01 Harris Corner Detector

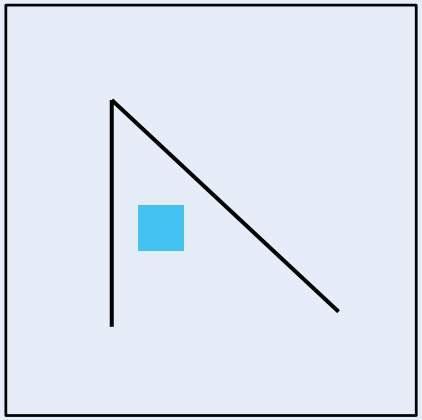
❖ Moravec's corner detector

Obstacle avoidance and navigation in the real world by a seeing robot rover.[1980]

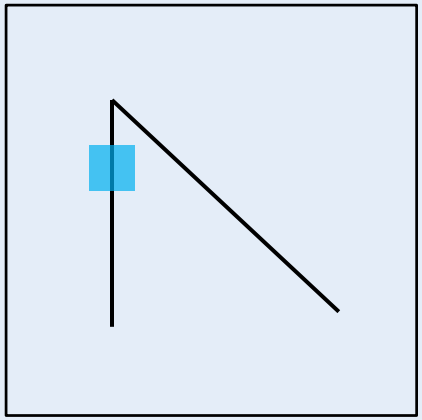
A. If the windowed image patch is flat, then all shifts will result in only a small change.

B. If window straddles an edge, then a shift along the edge will result in a small change, but a shift perpendicular to the edge will result in a large change.

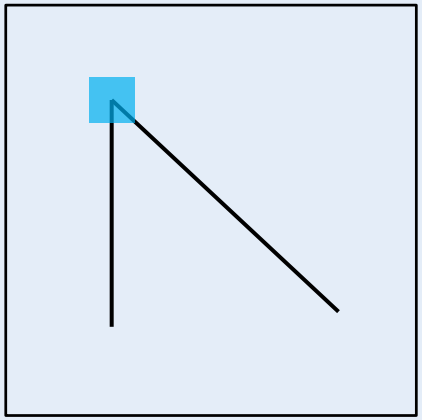
C. If the windowed patch is a corner or isolated point, then all shifts will result in a large change. A corner can thus be detected by finding when the minimum change produced by any of shifts is large.



flat



edge



corner

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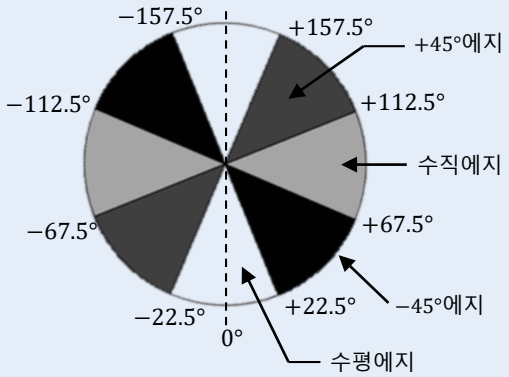
❖ Auto-Correlation Detector

1. The response is anisotropic because only a discrete set of shifts at every 45 degrees is considered



2. The response is noisy because the window is binary and rectangular

$$w_{u,v} = e^{-\frac{u^2+v^2}{2\sigma^2}}$$

3. The operator responds too readily to edges because only the minimum of E is taken into account

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❖ Auto-Correlation Detector

$$E(\Delta x, \Delta y) = \sum_w [I(x_i + \Delta x, y_i + \Delta y) - I(x_i, y_i)]^2$$

Taylor series

$$f(x) = \sum_{n=0}^{\infty} \frac{f^{(n)}(a)}{n!}(x-a)^n$$

if $\Delta x, \Delta y$ *are very small,*

$$I(x_i + \Delta x, y_i + \Delta y) \approx I(x_i, y_i) + \begin{bmatrix} \frac{\partial I}{\partial x} & \frac{\partial I}{\partial y} \\ I_x(x_i, y_i) & I_y(x_i, y_i) \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

$$E(\Delta x, \Delta y) \approx \sum_w \left[I(x_i, y_i) + \begin{bmatrix} I_x(x_i, y_i) & I_y(x_i, y_i) \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} - I(x_i, y_i) \right]^2$$

$$= \sum_w \left[\begin{bmatrix} I_x(x_i, y_i) & I_y(x_i, y_i) \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \right]^2$$

$$= \sum_w (A\Delta x)^2 + 2AB\Delta x\Delta y + (B\Delta y)^2 \qquad where\ A = I_x(x_i, y_i), B = I_y(x_i, y_i)$$

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$$= \sum_w (A\Delta x)^2 + 2AB\Delta x\Delta y + (B\Delta y)^2$$

$$= \sum_w [\Delta x \ \Delta y] \begin{bmatrix} A^2 & AB \\ AB & B^2 \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

$$= [\Delta x \ \Delta y] \begin{bmatrix} \sum_w A^2 & \sum_w AB \\ \sum_w AB & \sum_w B^2 \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

M

$$= [\Delta x \ \Delta y] \begin{bmatrix} \sum_w I_x(x_i, y_i)^2 & \sum_w I_x(x_i, y_i) I_y(x_i, y_i) \\ \sum_w I_x(x_i, y_i) I_y(x_i, y_i) & \sum_w I_y(x_i, y_i) \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

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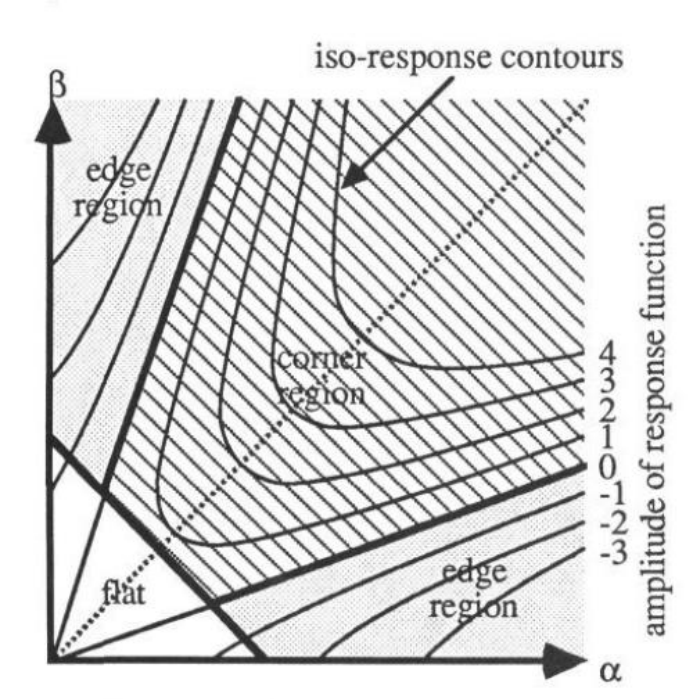
$$\det(\mathbf{M} - \lambda\mathbf{E}) = 0$$

A. If both curvatures(eigenvalues) are small, so that the local autocorrelation function is flat.

B. If one curvature is high and the other low, so that the local auto-correlation function is ridge shaped.

C. If both curvatures are high, so that the local autocorrelation function is sharply peaked.



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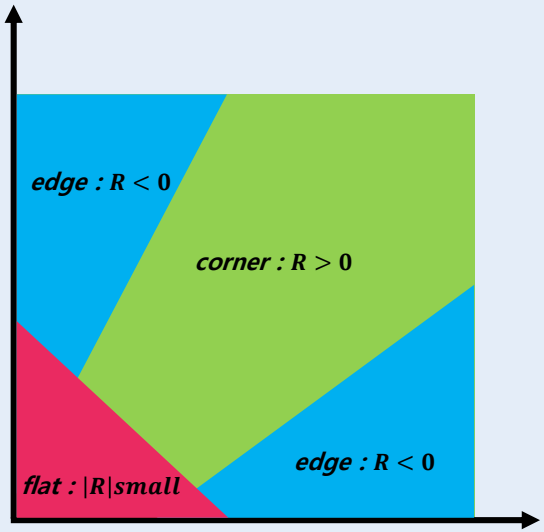
❖ Corner/Edge Response Function

$$\mathbf{R} = Det(\mathbf{M}) - k \cdot Tr(\mathbf{M})^2$$

R is positive in the *corner region*, negative in the *edge regions*, and small in the *flat region*.



k: 0.04~0.06

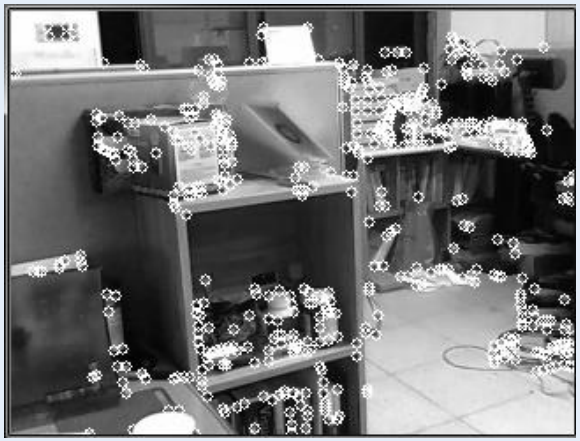
01 Shi & Tomasi Good feature to track

$$[\Delta x \ \Delta y]\begin{bmatrix} \sum_w I_x(x_i,y_i)^2 & \sum_w I_x(x_i,y_i)I_y(x_i,y_i) \\ \sum_w I_x(x_i,y_i)I_y(x_i,y_i) & \sum_w I_y(x_i,y_i) \end{bmatrix}\begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

$$\det(\mathbf{M}-\lambda\mathbf{E})=0 \qquad min(\lambda_1,\lambda_2)>k$$

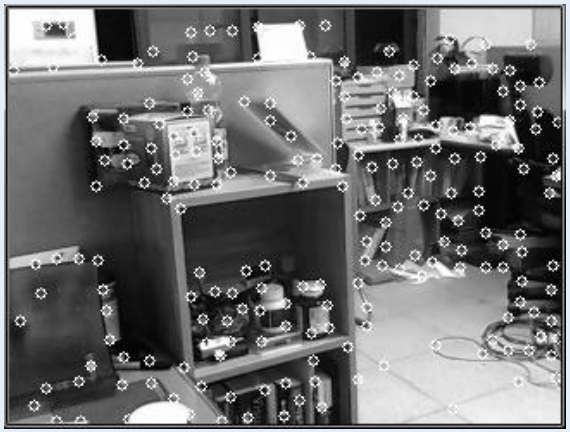
03 Results

❖ **Harris Corner Detector**



03 Results

❖ Shi & Tomasi Good Feature to Detector



Q & A