Current subjects in computer science

Div. Ingeniería de Sistemas y Automática

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EDGE DETECTION
SIGNIFICANT POINT DETECTION

fachhochschule stralsund

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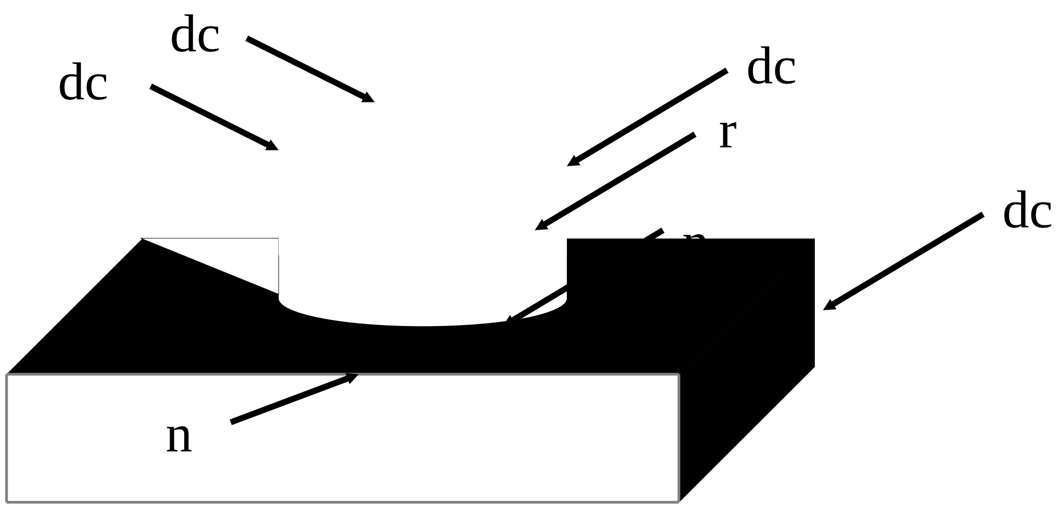
Edge definition

- An edge may be understood as a discontinuity over the intensity of an image.
- Edges characterize object boundaries and are therefore useful for segmentation →object recognition.

Edge definition

- Caused by:
  - Sudden change in object-camera distance (dc)
  - Sudden change in object's surface (n)
  - Change in object's properties (reflectance) (r)
  - Changes in illumination (s, shadows)



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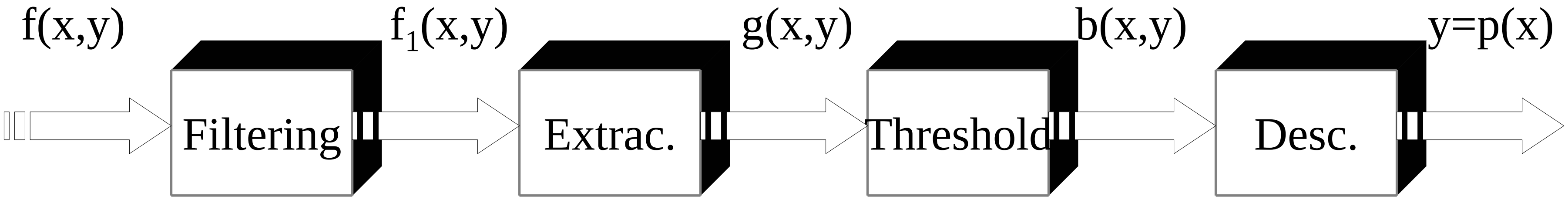
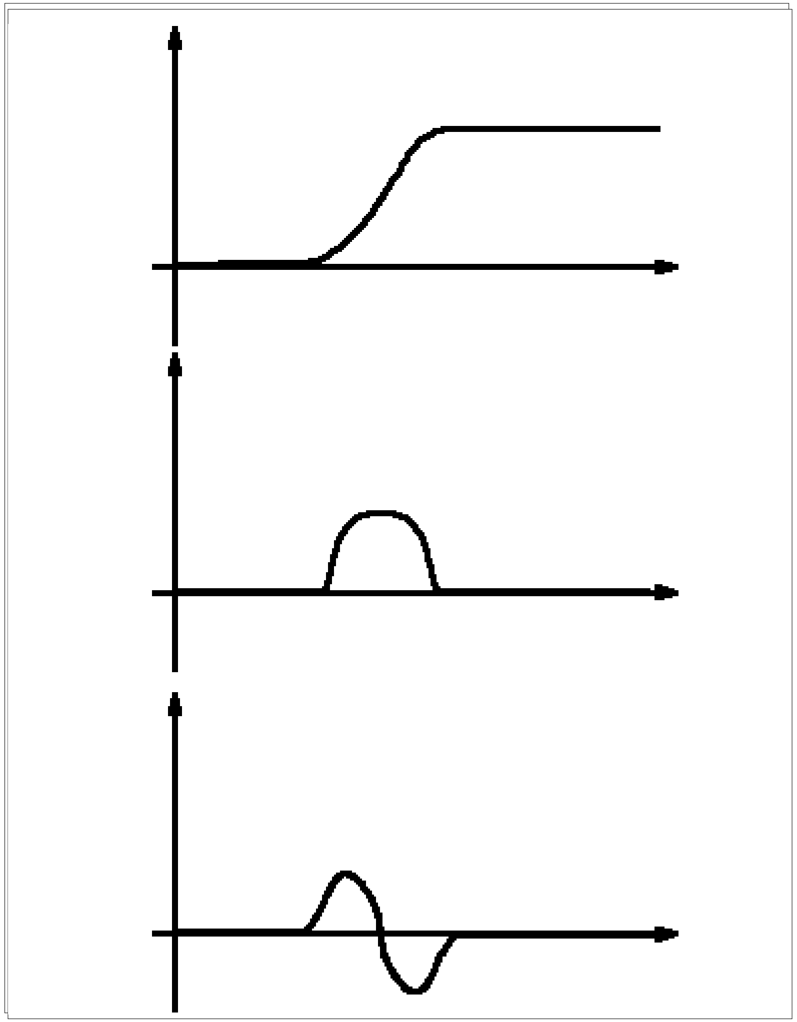
Edge extraction: General outline



- Filtering: Noise reduction
- Edge computation
- Thresholding:
  - Select only those pixels belonging to edges.
- Description:
  - Mathematical representation of the edges.

Gradient operators

- We know now what an edge is… but: How can we extract an edge?
- First derivative produces a significant effect in areas of non-uniform intensity
- First derivative is zero in areas of uniform intensity.
- The second derivative produces a change in the sign of the result.
  - ⇦Zero crossings



- **Gradient:** The gradient vector points to the direction of maximum variation of the image function *f(x, y)*.

$$\nabla f(x,y)=\begin{bmatrix}\dfrac{\partial f(x,y)}{\partial x}\\ \dfrac{\partial f(x,y)}{\partial y}\end{bmatrix}$$

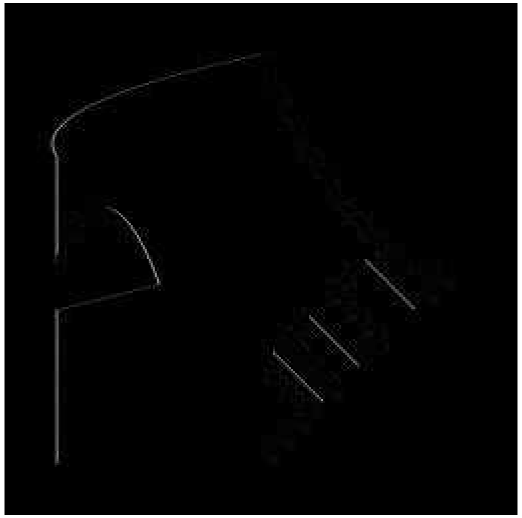
$$\mathrm{Mag}[\nabla f(x,y)]=\sqrt{\left(\frac{\partial f(x,y)}{\partial x}\right)^2+\left(\frac{\partial f(x,y)}{\partial y}\right)^2}$$

$$\theta = atan\left(\frac{\dfrac{\partial f(x,y)}{\partial x}}{\dfrac{\partial f(x,y)}{\partial y}}\right)$$

Gradient vector discretization (X)

$$\frac{\partial f(x,y)}{\partial x} \approx \nabla_x f(x,y) = f(x,y) - f(x-1,y)$$

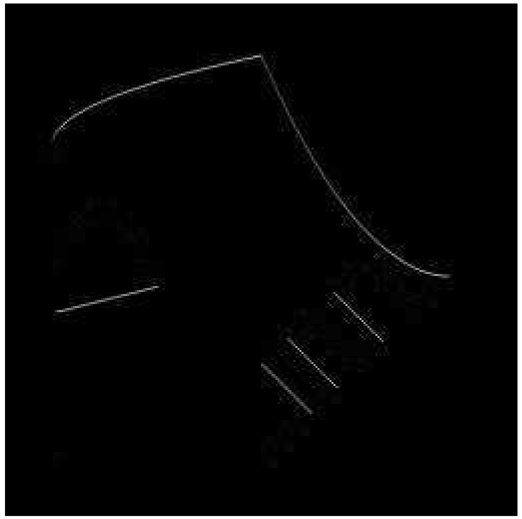
-1	1



Gradient vector discretization (Y)

$$\frac{\partial f(x,y)}{\partial y} \approx \nabla_y f(x,y) = f(x,y) - f(x,y-1)$$

-1
1



Gradient operators

- Prewitt operator

-1	-1	-1
0	0	0
1	1	1

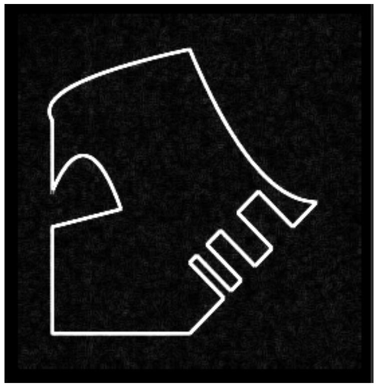
-1	0	1
-1	0	1
-1	0	1

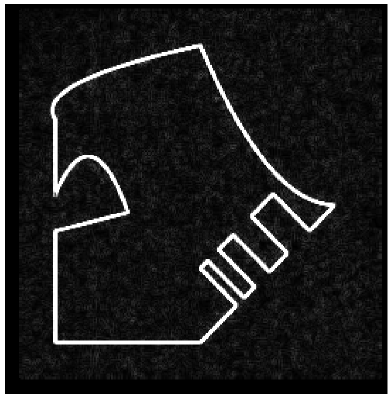
Sobel operator

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

- Computing the gradient on a neighbourhood reduces the effects of noise.
- Adding the result of both masks:





Gradient operators

⇦Roberts

-1	0
0	1

0	-1
1	0

Horizontal detector

-1	-1	-1
0	0	0
1	1	1

f_y

⇦Vertical detector

-1	0	1
-1	0	1
-1	0	1

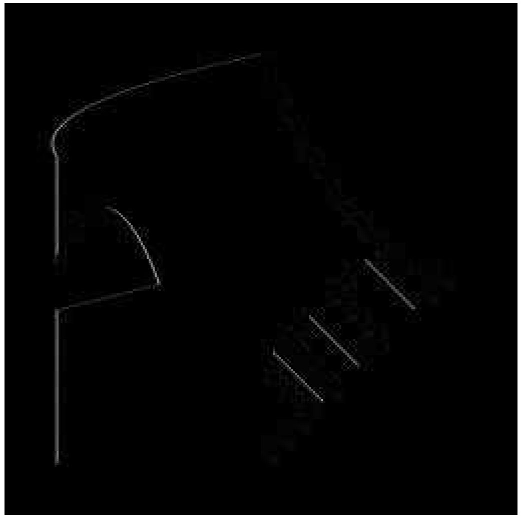
f_x

Diagonal detectors

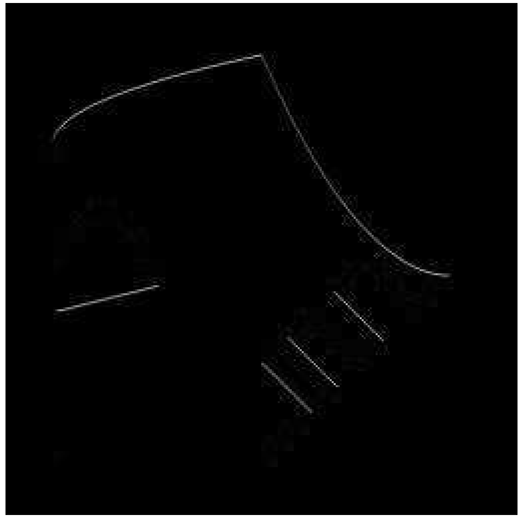
1	1	0
1	0	-1
0	-1	-1

0	1	1
-1	0	1
-1	-1	0

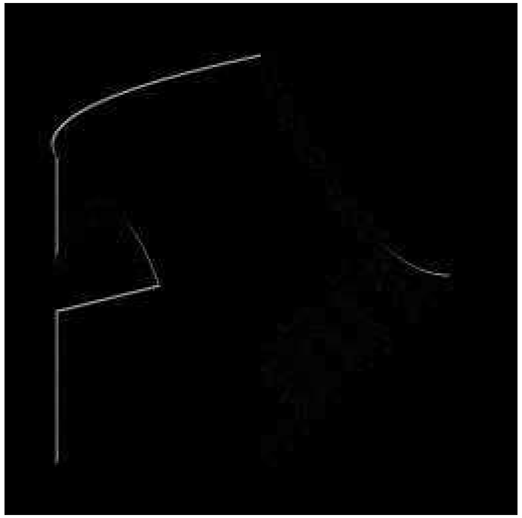
Gradient operators



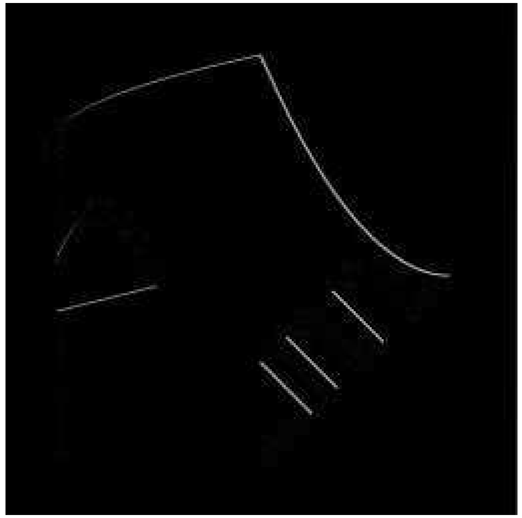
$\nabla_x f(x,y)$



$\nabla_y f(x,y)$



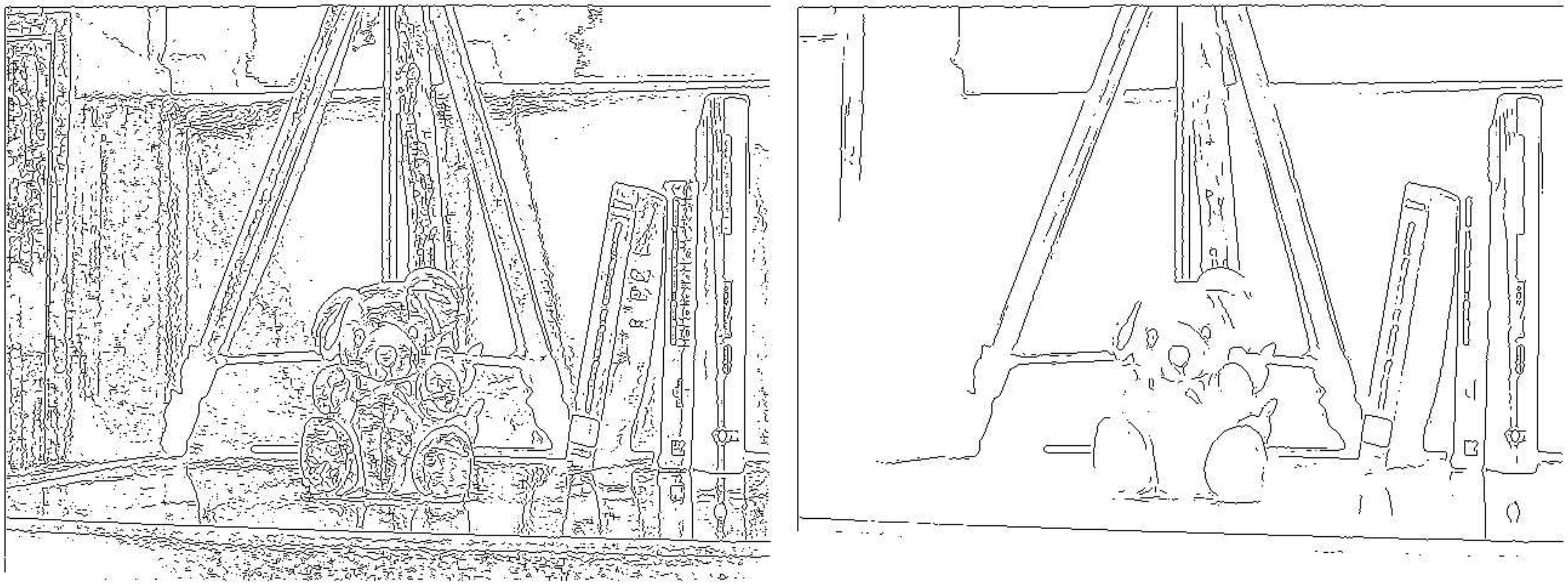
$\nabla_r f(x,y)$



$\nabla_c f(x,y)$

Gradient operators: Edge selection

- Roberts: Threshold T=10, T=20.
- ¿Which one is best?



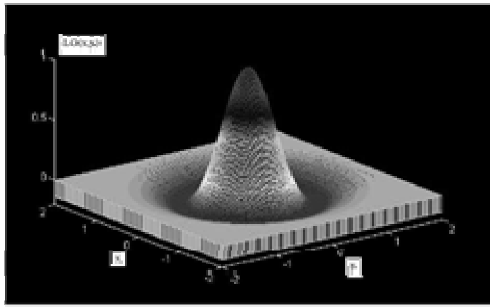
Operador Laplaciana de la Gaussiana

- Se aplica la Laplaciana a la imagen suavizada por el filtro gaussiano.

$$G(x,y) = -\frac{1}{\sqrt{2\pi\sigma}} e^{-(x^2+y^2)/2\sigma^2} \qquad \nabla^2 (f(x,y) * G(x,y)) = f(x,y) * (\nabla^2 G(x,y))$$

- Es decir: Se convoluciona la imagen con

$$\nabla^2 G(x,y) = K\left(2 - \frac{x^2+y^2}{\sigma^2}\right) e^{-(x^2+y^2)/2\sigma^2}$$



- Al suavizar la imagen se reduce el efecto del ruido.
- Permite trabajar a diferentes escalas al variar σ. Cuanto mayor es esta desviación, habrá un menor número de pasos por cero (no se detectan objetos pequeños).

Compass operators

- Compass operators measure gradients in a selected number of directions.
- Magnitude and direction is found by selecting the mask that maximizes the result.

$$g(x,y,i) = \text{máx}\{f(x,y) * h_i(u,v)\}$$

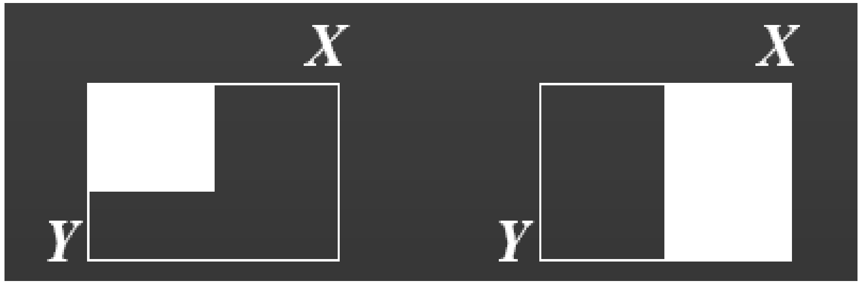
K_0 0º	K_1 45º	K_2 90º	K_3 135º	K_4 180º	K_5 235º	K_6 270º	K_7 315º
-3 -3 5	-3 5 5	5 5 5	5 5 -3	5 -3 -3	-3 -3 -3	-3 -3 -3	-3 -3 -3
-3 0 5	-3 0 5	-3 0 -3	5 0 -3	5 0 -3	5 0 -3	-3 0 -3	-3 0 5
-3 -3 5	-3 -3 -3	-3 -3 -3	-3 -3 -3	5 -3 -3	5 5 -3	5 5 5	-3 5 5

Gradient magnitude = Maximum
Direction = The one corresponding to the maximum

- ✓ Edge definition
- ✓ Edge computation
- Corner definition
- Corner detection

Corners

- Corners:
  - Elements in space that can be easily detected from different viewpoints
  - In a corner, gradient magnitude should be significant in both directions.
  - In an edge, the variation in f(x,y) is significant in one direction and low in the perpendicular direction.



- Useful for:
  - Stereo vision
  - Movement estimation from images
  - Object recognition
- Different methods:
  - Harris
  - Kanade Lucas (KLT)
  - Kitchen Rosenfeld

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- ✓ Edge definition
- ✓ Edge computation
- ✓ Corner definition
- Corner detection

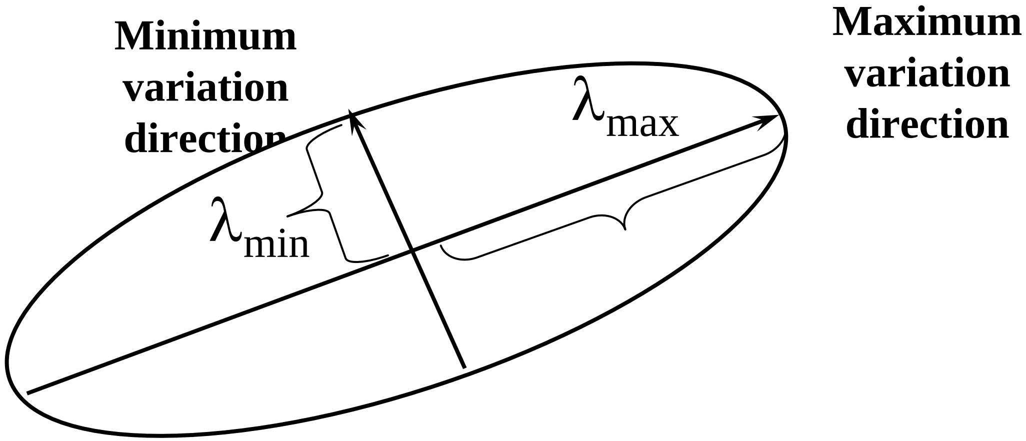
- It is based on the following matrix, that is computed on a pxq neighbourhood

$$C = \begin{bmatrix} \sum I_x^2 & \sum I_x I_y \\ \sum I_x I_y & \sum I_y^2 \end{bmatrix}$$

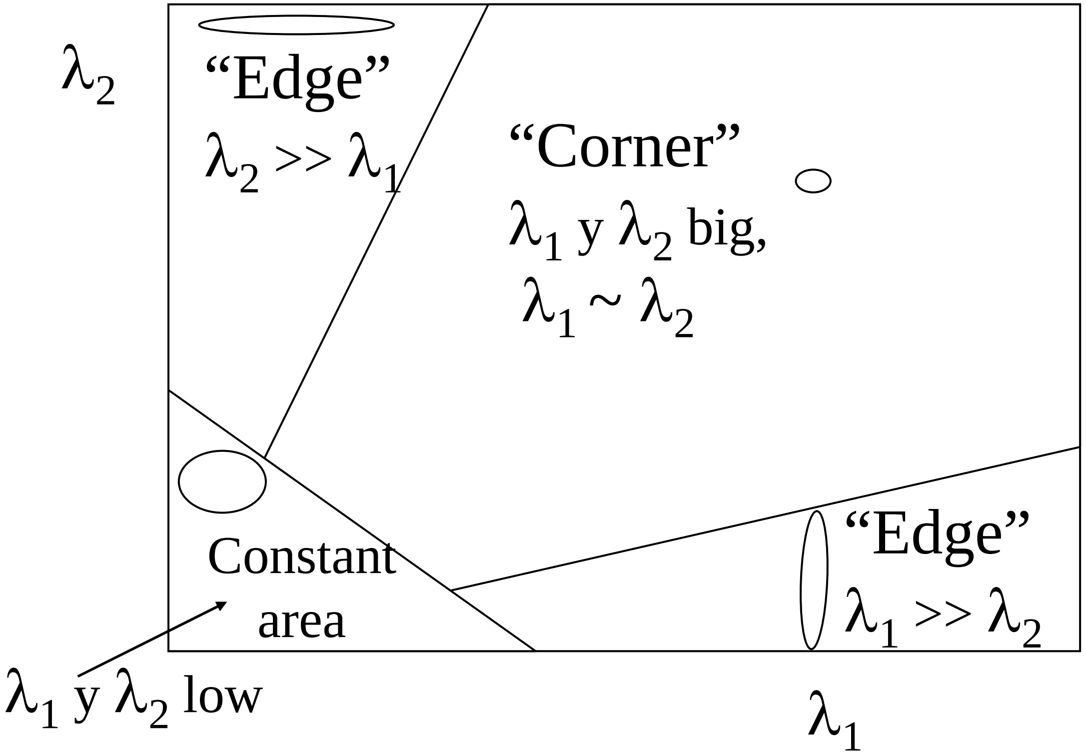
- We can find a diagonal matrix M:

$$M = \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix}$$

- The values of λ_1 y λ_2 give us the magnitude of variation over the direction of the eigenvectors



- On a corner… What can we say about λ_1 y λ_2?



$$R = \det(M) - k \cdot tr(M)^2$$

$$\det(M) = \lambda_1 \lambda_2$$

$$tr(M) = \lambda_1 + \lambda_2$$

- Harris: Calculate R. If R > T → corner (k=0.04-0.06, experimentally).