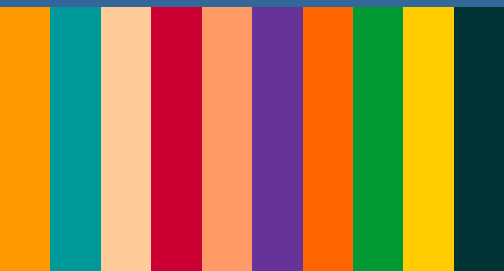
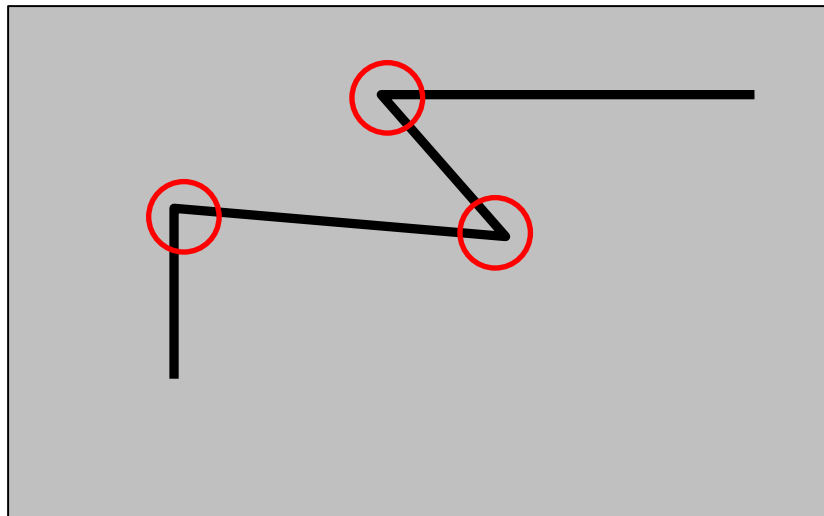


Harris Corner Detector

Slides taken from: “Matching with Invariant Features”, Darya Frolova, Denis Simakov, The Weizmann Institute of Science, March 2004



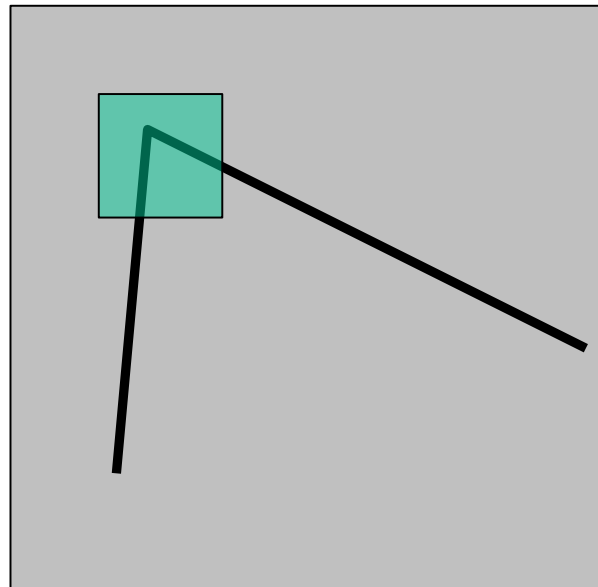
An introductory example:



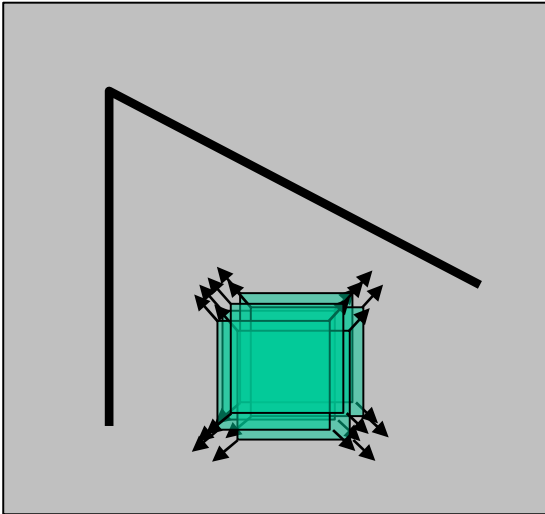
C.Harris, M.Stephens. "A Combined Corner and Edge Detector". 1988

The Basic Idea

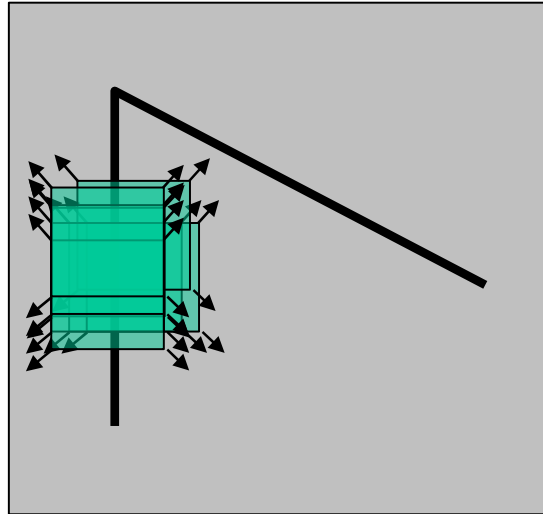
- We should easily recognize the point by looking through a small window
- Shifting a window in *any direction* should give *a large change* in intensity



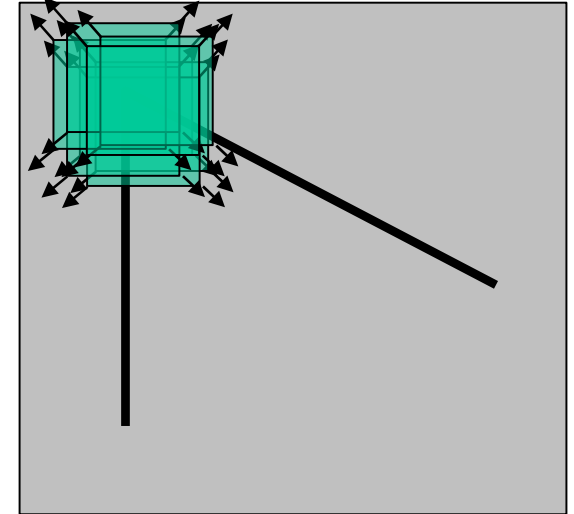
Basic Idea (2)



“flat” region:
no change in
all directions



“edge”:
no change along
the edge direction



“corner”:
significant change
in all directions

Mathematics

Change of intensity for the shift $[u, v]$:

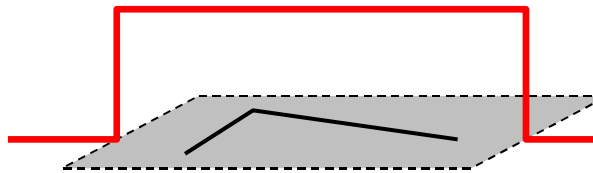
$$E(u, v) = \sum_{x, y} w(x, y) [I(x+u, y+v) - I(x, y)]^2$$

Window
function

Shifted
intensity

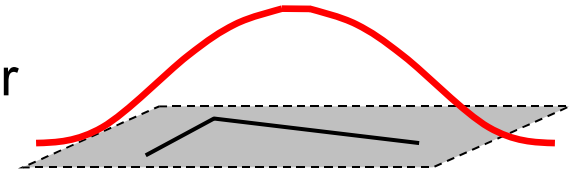
Intensity

Window function $w(x, y) =$



1 in window, 0 outside

or



Gaussian

Mathematics

For small shifts $[u, v]$ we have a *bilinear* approximation:

$$E(u, v) \simeq \begin{bmatrix} u & v \end{bmatrix} M \begin{bmatrix} u \\ v \end{bmatrix}$$

where M is a 2×2 matrix computed from image derivatives:

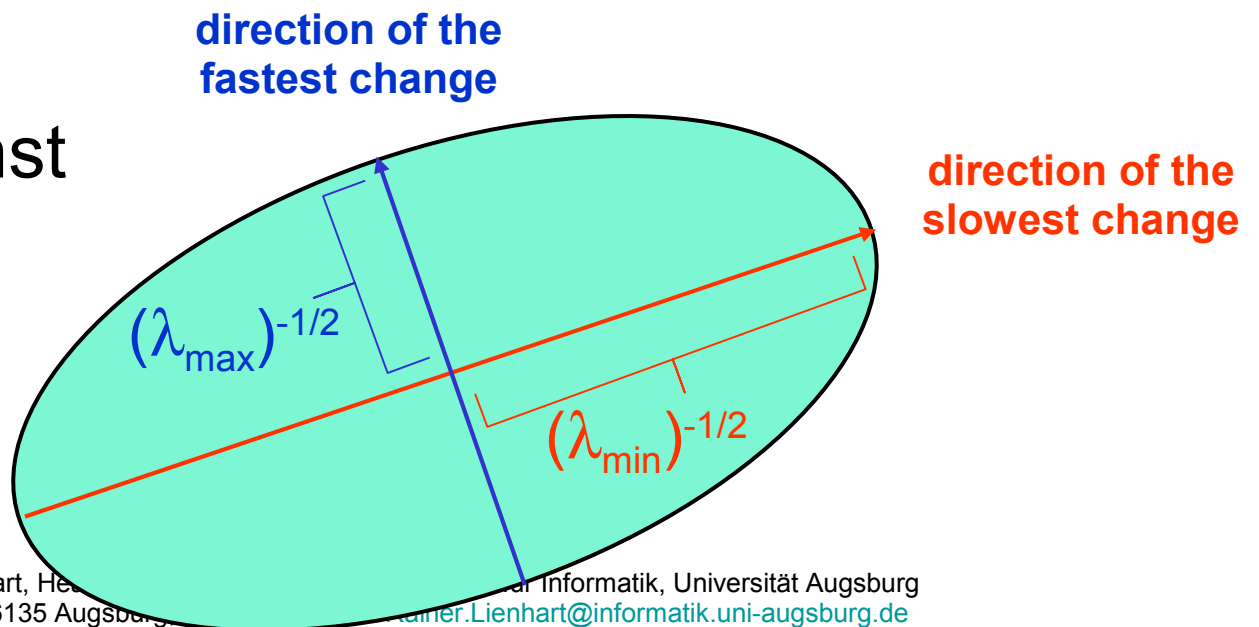
$$M = \sum_{x, y} w(x, y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$

Mathematics

Intensity change in shifting window: eigenvalue analysis

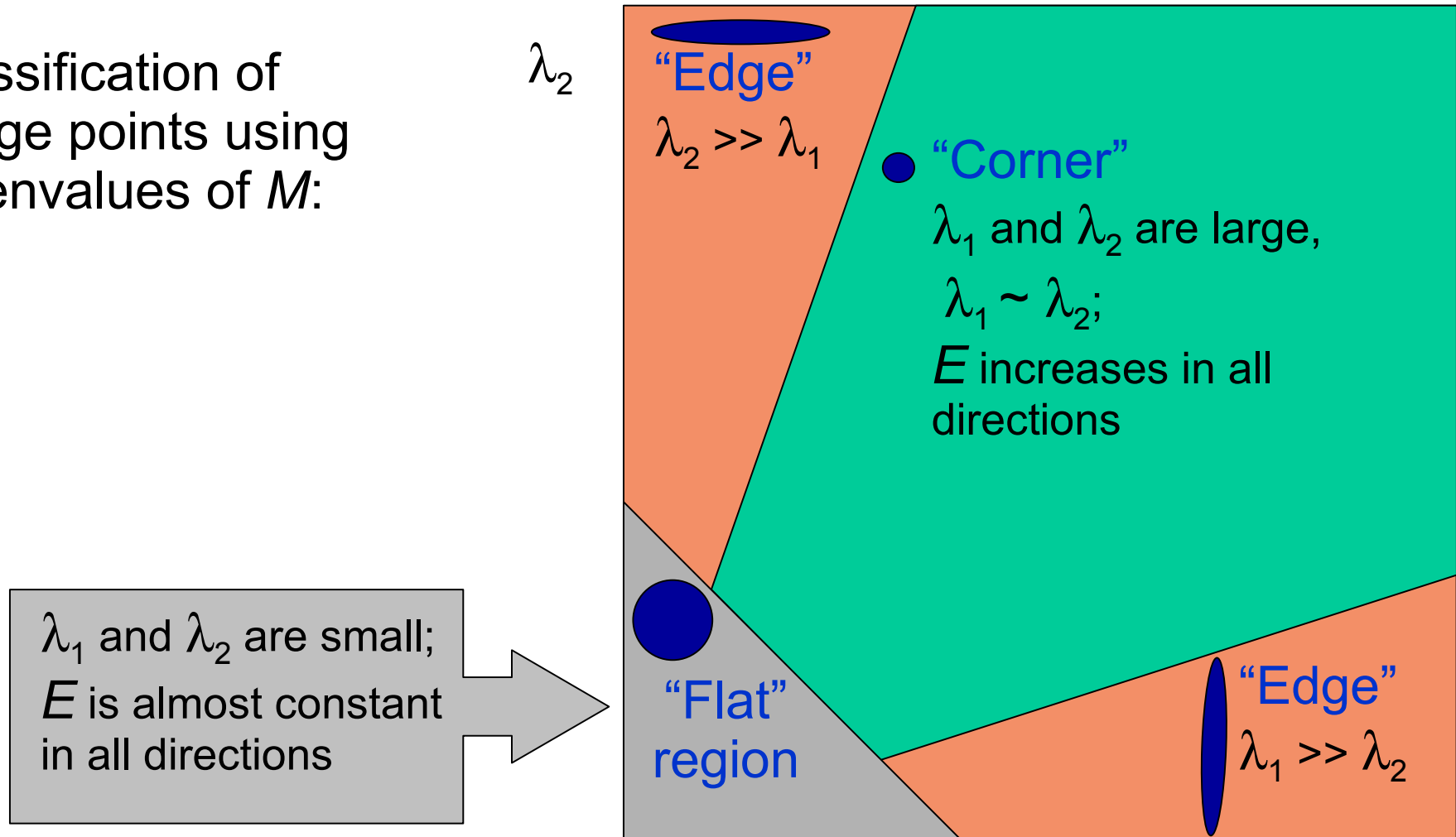
$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \quad \lambda_1, \lambda_2 - \text{eigenvalues of } M$$

Ellipse $E(u,v) = \text{const}$



Mathematics

Classification of
image points using
eigenvalues of M :



Mathematics

Measure of corner response:

$$R = \det M - k (\operatorname{trace} M)^2$$

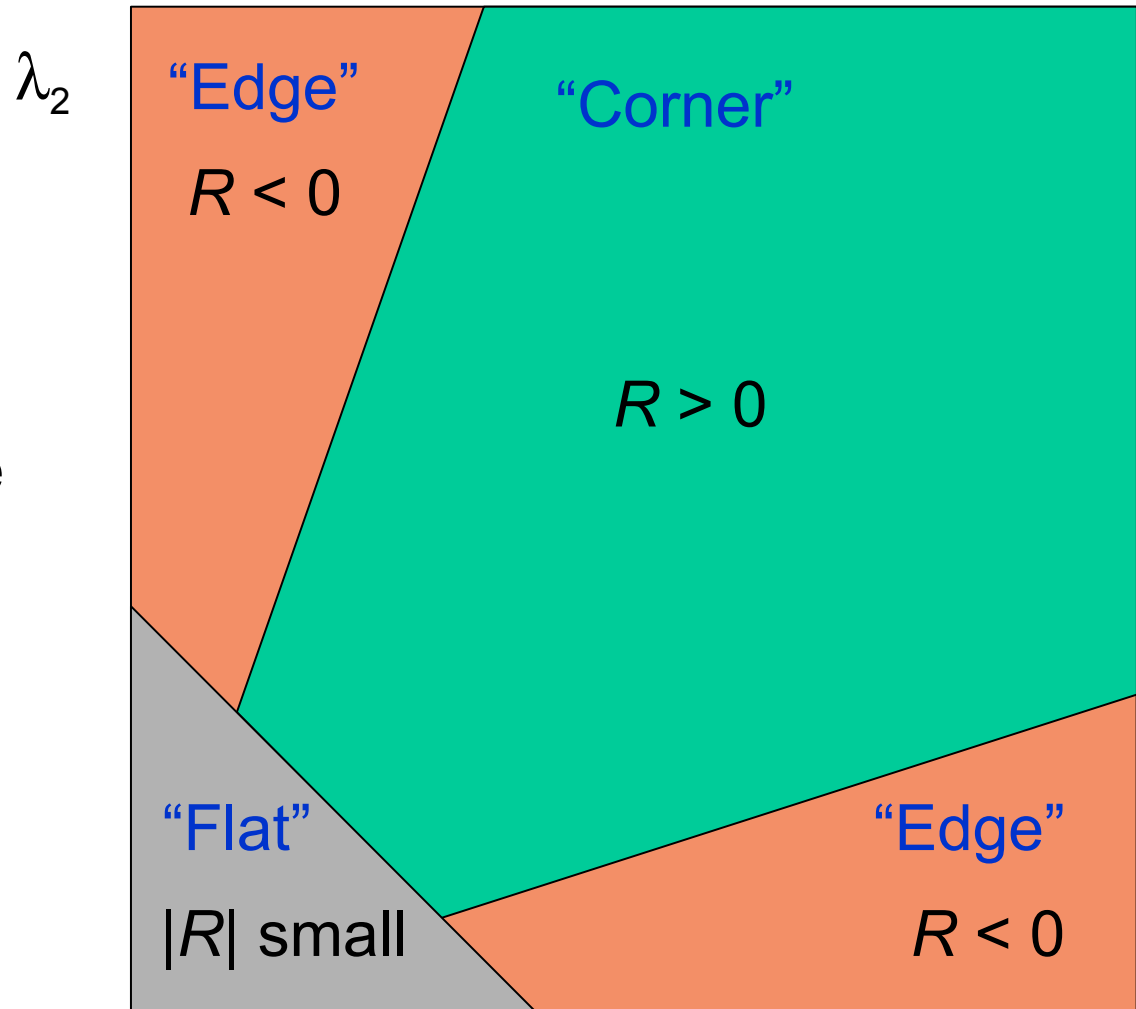
$$\det M = \lambda_1 \lambda_2$$

$$\operatorname{trace} M = \lambda_1 + \lambda_2$$

(k – empirical constant, $k = 0.04$ - 0.06)

Mathematics

- R depends only on eigenvalues of M
- R is large for a **corner**
- R is negative with large magnitude for an **edge**
- $|R|$ is small for a **flat** region



Harris Detector

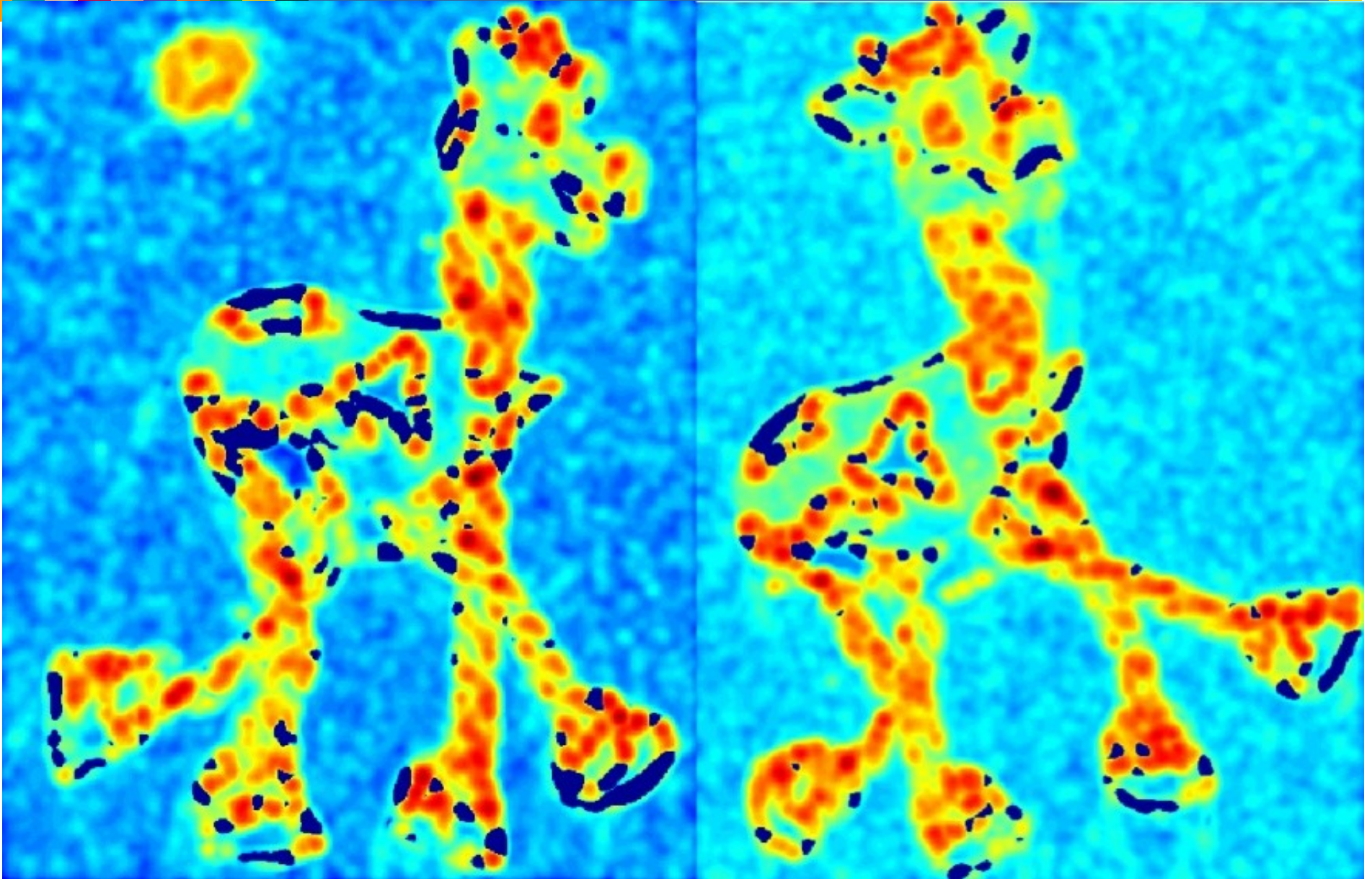
- The Algorithm:
 - Find points with large corner response function R ($R > \text{threshold}$)
 - Take the points of local maxima of R

Harris Detector: Workflow



Harris Detector: Workflow

Compute corner response R



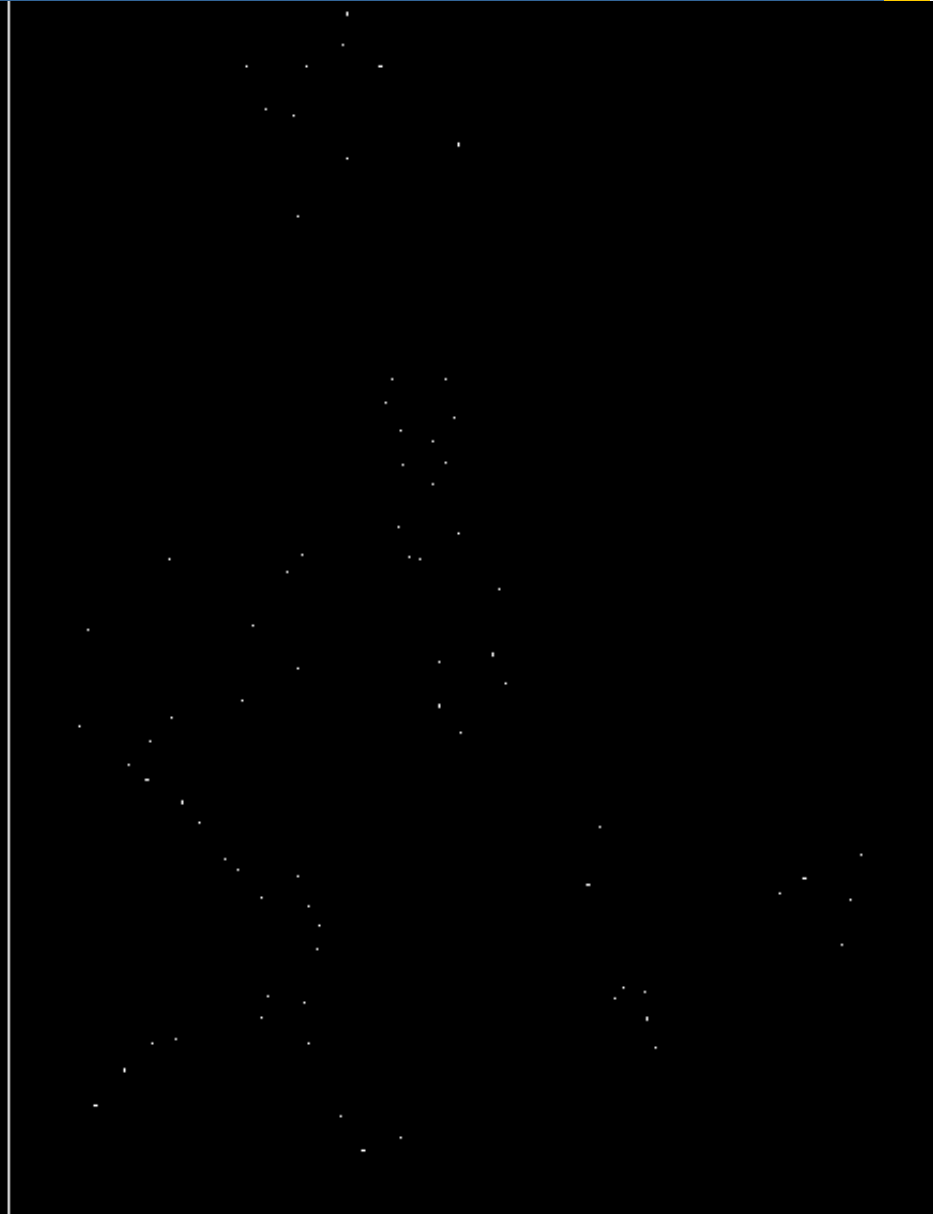
Harris Detector: Workflow

Find points with large corner response: $R > \text{threshold}$



Harris Detector: Workflow

Take only the points of local maxima of R



Harris Detector: Workflow



Harris Detector: Summary

- Average intensity change in direction $[u, v]$ can be expressed as a bilinear form:

$$E(u, v) \simeq \begin{bmatrix} u & v \end{bmatrix} M \begin{bmatrix} u \\ v \end{bmatrix}$$

- Describe a point in terms of eigenvalues of M :
measure of corner response

$$R = \det M - k (\text{trace } M)^2$$

- A good (corner) point should have a *large intensity change in all directions*, i.e. R should be large positive