Harris Corner Detector

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Outline

- Introduction to corner detection
- The Harris corner detection algorithm
- Applications
- Summary
- MATLAB demonstration

Introduction

- Corners are common interest points in an image
- Corner detection is good for obtaining image features for object tracking and recognition
  - Especially for three-dimensional objects from two-dimensional images.
- Humans understand “a corner” easily, but for algorithm we need a more mathematical detection

Definitions

- A corner can be defined as the intersection of two edges
- An edge is a sharp change in image brightness
- A corner can also be defined as a point for which there are two dominant and different edge directions in a local neighborhood of the point.
- In simpler terms: Find the points where two edges meet.

Background

- The algorithm presented here is known as the Harris Corner Detector
  - aka Harris/Stephens detector
  - aka Plessey operator
- Published in 1988.
- Harris improved on the Moravec algorithm for detecting corners

Improvements upon the Moravec detector

- Harris and Stephens improved upon Moravec's corner detector by considering the differential of the corner score with respect to direction directly, instead of using shifted patches.
  - Moravec only considered shifts in discrete 45 degree angles, Harris considers all directions
  - Harris uses a circular Gaussian window, reducing noise
  - Harris detector distinguishes between edges and corners more accurately

Harris Corner Detector

- Harris corner detector is based on the local auto-correlation function of a signal
- the local auto-correlation function measures the local changes of the signal with patches shifted by a small amount in different directions.

The auto-correlation function

- Given a shift (x,y) and a point the auto-correlation function is defined as

$$c(x,y) = \sum_W [I(x_{i,}y_i) - I(x_i + \Delta x, y_i + \Delta y)]^2 \text{ (1)}$$

- Where $I(x_i,y_i)$ denotes the image function and (x_i,y_i) are the points in the window W centered on (x,y).

Taylor expansion and partial derivatives

- The shifted image is approximated by a Taylor expansion truncated to the first order terms

$$I(x_i + \Delta x, y_i + \Delta y) \approx \left[I(x_i, y_i) + \left[I_x(x_i, y_i) \;\; I_y(x_i, y_i) \right] \right] \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \quad (2)$$

- where $I_x(x_i, y_i)$ and $I_y(x_i, y_i)$ denote the partial derivatives in x and y respectively
- The partial derivates can be calculated from the image with a filter like [-1,0,1] and $[-1,0,1]^T$

Forming the equation

- Substituting (2) in (1) we get:

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

$$C(x,y) = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

- with C(x,y) the auto-correlation matrix which captures the intensity structure of the local neighborhood.

Interpreting the value

- Let α_1 and α_2 be the eigenvalues of C(x,y), then we have 3 cases to consider:
  - Both eigenvalues are high: Interest point (corner)
  - One eigenvalue is high: contour(edge)
  - Both eigenvalues are small: uniform region (constant intensity).

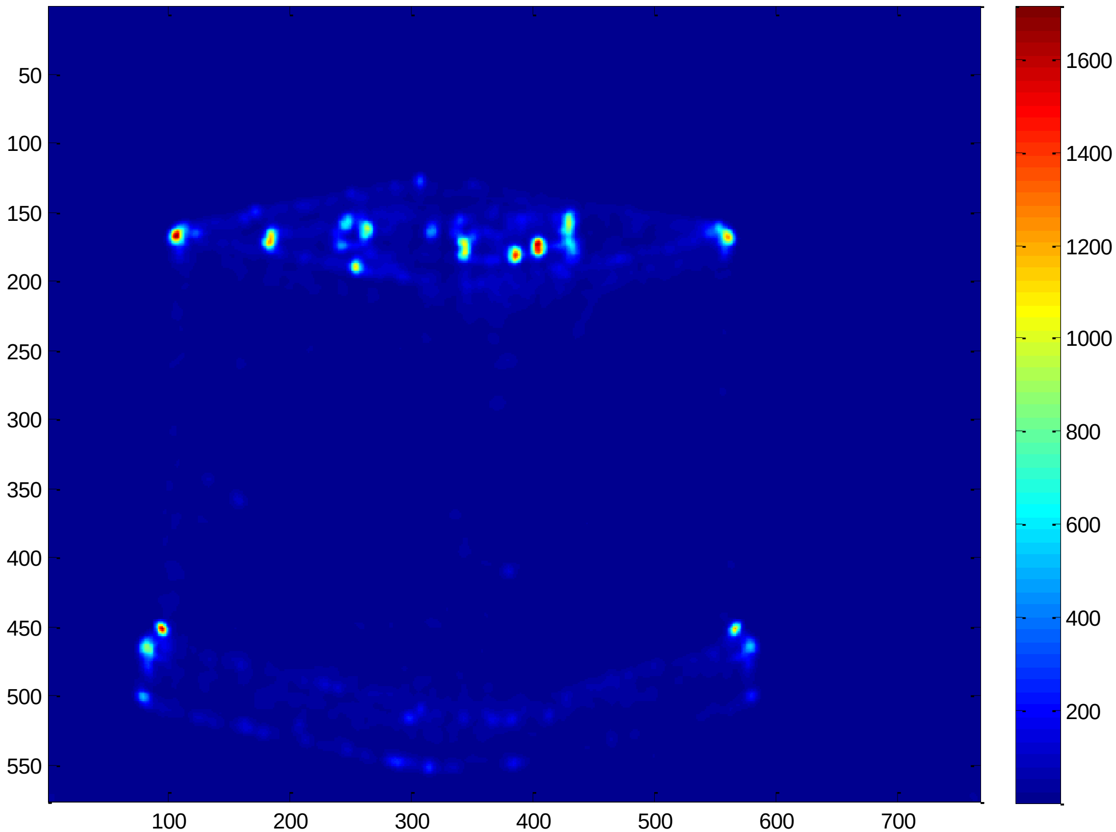
How to find the interest points?

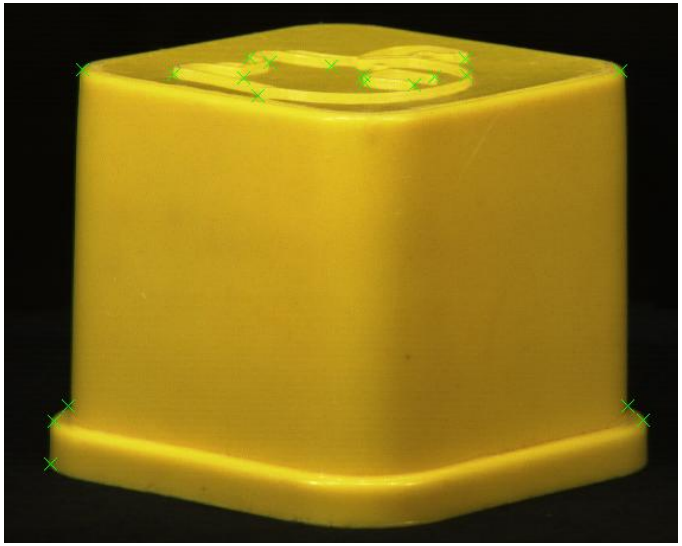
- Characterize corner response H(x,y) by eigenvalues of C(x,y),
  - C(x,y) is symmetric and positive definite that is α_1 and α_2 are >0
  - $\alpha_1\alpha_2 = \det(C(x,y)) = AC - B^2$
    - $\alpha_1+\alpha_2 = \text{trace}(C(x,y)) = A + C$
  - Harris suggested: $H_{cornerResponse} = \alpha_1\alpha_2 - 0.04(\alpha_1+\alpha_2)^2$
- Find corner points as local maxima of the corner response

Algorithm

1. Compute partial derivatives from intensity image
2. Compute A,B and C from the image
3. Compute corner response
4. Find local maxima in the corner response

Corner response





Properties and limitations of the Harris Corner detector

- Rotationally invariant
- Partially invariant to affine intensity change
- Non-invariant to image scale
  - However, there is multi-scale harris detector
- Computationally demanding
- Still sensitive to noise
- Good localization only occurs at L-junctions

Harris corner detection applications

- Corners can be used in applications that require some image/object feature
- Many applications require relating two or more images in order to extract information from them.
- Some applications of corners are presented here

Application examples

- stereo matching
- image registration (of particular importance in medical imaging)
- stitching of panoramic photographs
- object detection/recognition
- motion tracking
- robot navigation

Comparison to other corner detectors

- In all applications corner detection is used for feature extraction
- Harris corner detector in other algorithms
  - Harris
  - Moravec
  - Trajkovic

There are so many others: Wang and Brady, SUSAN,…

Comparison continued

- In a manner similar to SUSAN, Trajkovic detector directly tests whether a patch under a pixel is self-similar by examining nearby pixels.
- The Wang and Brady detector considers the image to be a surface
  - It looks for places where there is large curvature along an image edge.

MATLAB demo

- Short MATLAB presentation about how Harris corner detection works in practice.

References

- Harris, C., Stephens, M., 1988, A Combined Corner and Edge Detector, Proceedings of 4th Alvey Vision Conference
- http://en.wikipedia.org/wiki/Corner_detection
- http://vims.cis.udel.edu/~chandra/689/Spring06/Corners+Ransac.ppt
- Parks D., Gravel J., Corner Detectors, http://www.cim.mcgill.ca/~dparks/CornerDetector/harris.htm
- Werner T., 2008, Harris corner detector (slides)
- Konstantinos G. Derpanis, 2004, The Harris Corner Detector
- Kostas Daniilidis, 2003,Harris corner detector (slides)
- Kovesi P., Matlab functions, http://www.csse.uwa.edu.au/~pk/research/matlabfns/