Computer Vision Assignment 2: Feature Detection

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1 Harris Corner Detection

The Harris Corner Detector is based on the earlier work by Moravec [2] which defined corners as being points with low self-similarity. The similarity is taken as the sum of squared differences to larger overlapping patches around a point. This method is quite computationally expensive as it requires separate computation for each pixel in an image.

The Harris corner detection [1] algorithm builds upon this by taking the gradients within a window as seen in figure 1.

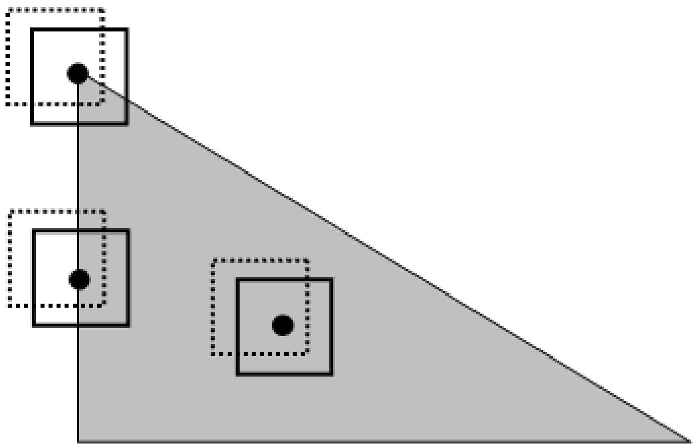

Figure 1: A shifting window for a flat patch, an edge and a corner (Image taken from MathWorks)

If there is no edge or a corner within the window, the intensity values within the window will not change a lot. If the window contains an edge, moving the window along the edge will not result in any difference, but any movement along the perpendicular axis will result in a shift in intensity. For a corner, it does not matter which direction the window is shifted, as every window will be different.

By shifting the window in the $[u, v]$ direction we can compute the window-averaged change in intensity as follows:

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

where $W(x,y)$ represents the window function which can be $W(x,y) = 1$ for all x and y within the window, or it can be a Gaussian function. $I(x+u,y+v)$ represents the shift in intensity and $I(x,y)$ represents the original intensity. For small values of u and v we can approximate this with a Taylor-series expansion and change the equation in:

$$E(u,v) \cong [u,v] M \begin{bmatrix} u \\ v \end{bmatrix}$$

where M is the structure tensor matrix, or second moment matrix defined as:

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

The structure tensor matrix M can be used to determine the direction of the largest change by finding the eigenvalues λ_1 and λ_2 of M where λ_1 represents the direction of the fastest change[1], whilst λ_2 represents the direction of the slowest change. As can be seen in figure 2.

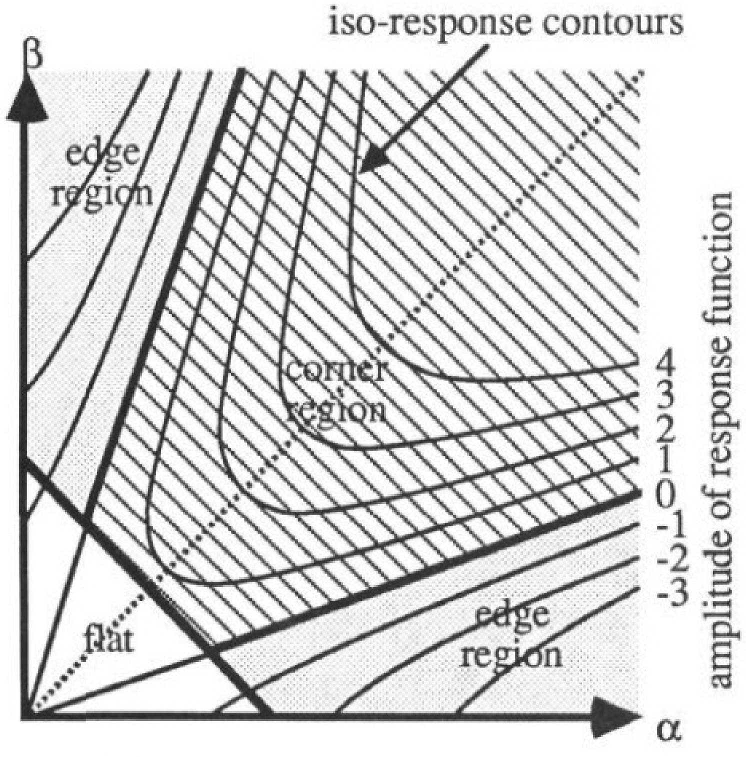

Figure 2: The iso-response surface for eigenvalues α and β [1]

[1]Note that we assume the eigenvalues to be ordered from largest to smallest

If both eigenvalues are low, than the change in intensity is small in all directions and thus the window is on a flat region. If one of the eigenvalues is larger than the other, the window is on an edge and when both eigenvalues are large then the change in intensity for every direction is large and the window is on a corner.

To circumvent the calculation of the eigenvalues of M, it is possible to represent the cornerness R by the determinant and the trace of M as follows:

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

where k is a small constant. It is possible to circumvent this empirical constant k by using Noble's measure (CITE) of cornerness:

$$M_c' = 2\frac{\det(M)}{\mathrm{trace}(M) + \epsilon}$$

2 SIFT

After finding corners with the Multi-scale Harris Corner Detection, SIFT descriptors are created for each of these corners. 1

3 Mosaic

4 DoG vs. Laplace

References

[1] Chris Harris and Mike Stephens. A combined corner and edge detector. In *In Proc. of Fourth Alvey Vision Conference*, pages 147–151, 1988.

[2] Hans Moravec. Obstacle avoidance and navigation in the real world by a seeing robot rover. In *tech. report CMU-RI-TR-80-03, Robotics Institute, Carnegie Mellon University & doctoral dissertation, Stanford University*, number CMU-RI-TR-80-03. September 1980.