

Exercise 5 – Image saliency

Overview

In this exercise, we are going to work on different methods for image saliency, which refers to identifying important features in an image to compress its information. We will start by looking into different image filtering techniques. Subsequently, we will look at methods for edge and corner extraction before we will finally compare the properties of different point features.

Q1 Image filtering

During the lecture, you have been introduced to correlation and convolution for image filtering. We will have a look at their properties in this exercise.

1. 1D image filter

- (a) Consider the 1D image given below (Table 1). Correlate the image with the listed filters and state for each the effect it has on the resulting image. Use the first and last image values to fill the filter at the left and right image borders.

...	2	3	5	8	4	5	4	9	1	3	...
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Table 1: 1D image.

- i. $F_1 = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix}$
- ii. $F_2 = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}$
- iii. $F_3 = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix}$

- (b) What will be the effect on the image for filter F_2 given above if you use the convolution operation instead of the correlation operation?

2. Smoothing filters

- (a) A common choice for creating a smoothing image filter is to discretize a Gaussian filter. A (still continuous) filter for the 1D case is given below. Explain the influence of the parameter σ on the resulting image.

$$g(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \quad (1)$$

- (b) Consider now the 2D Gaussian filter below. Something is off here! Transform the filter into a proper image filter.

$$F = \begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}$$

- (c) (MATLAB) We will now apply a 2D smoothing filter to an image. Please refer to `ex_5_smoothing.m` for further instructions.

3. Separable filters

- (a) Consider the separable filter F given below. Which are the corresponding row and column factor that this filter can be separated into?

$$F = \frac{1}{256} \begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

- (b) Separable filters allow for computational speed-up through their decomposition. How many multiplications and additions need to be computed for a separable filter and non-separable filter of size $N \times N$. How could an additional speed-up be achieved for the separable filter?

4. True or False?

- (a) Let F , G and I be signals. Denoting the convolution operator as “*”, the expression “ $(F * G) * I = F * (G * I)$ ” holds.

Q2 Edge detection

After an introduction into basic image filtering in the first exercise, we will now have a look into how we can extract salient image regions from the image via edge detection.

1. Edge properties in images

- (a) How can you identify edges in images? Please describe two different options.
 (b) How can you achieve image sharpening? Please describe two different options.

2. 2D Edge detection

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	10	10	10	10	1	1
1	1	10	10	10	10	1	1
1	1	10	10	10	10	1	1
1	1	10	10	10	10	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

Table 2: 2D input image

- (a) Consider the 2D image given above (Table 2). Given the following filters for edge detection

$$F_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}, \quad F_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

filter the image to calculate the edge strength $|\nabla F| = \sqrt{F_x^2 + F_y^2}$. Then mark all pixels with an edge strength $|\nabla F| > 20$. You can use the matrices given below in Figure 1 and 2 to fill in your solution. Use the boundary values to fill the filter at the image borders.

- (b) We have used the boundary values to pad the image at the borders in the previous question. What would happen if we instead decided to use a black padding (pixel values of 0) at the image borders?

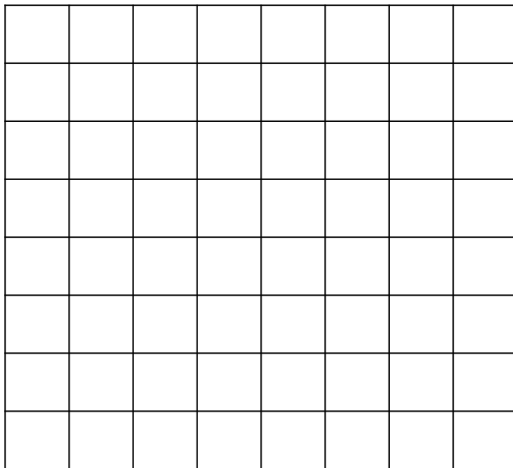
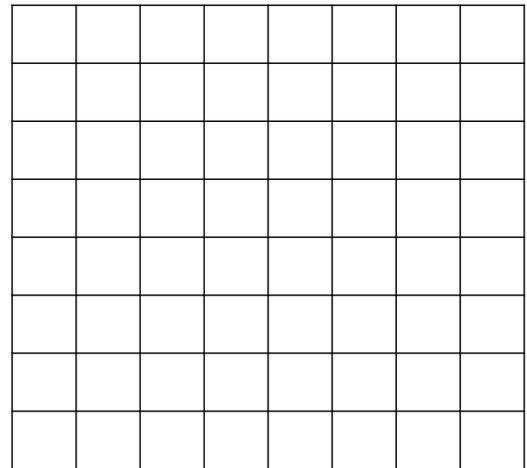
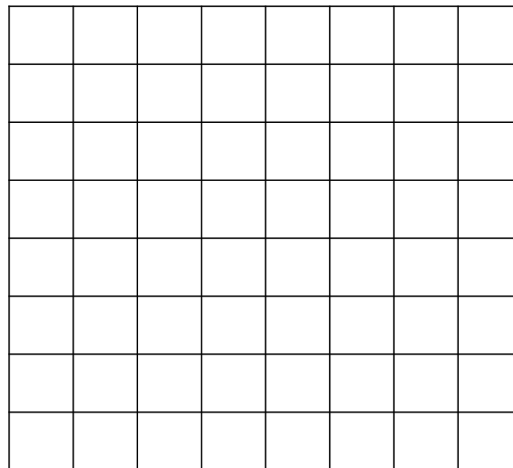
(a) Filtered image using F_x (b) Filtered image using F_y

Figure 1: Filtered images

Figure 2: Edge strength $|\nabla F|$

- (c) The filters given above detect edges in horizontal (F_x) and vertical (F_y) direction. How could you construct a filter that detects edges at 45° of rotation?

3. True or False?

- (a) Smoothing masks always sum to 0.
- (b) Smoothing masks may have negative values.
- (c) Low pass filters can be used for image sharpening.
- (d) Edges occur at the zero-crossings of the 1st order derivatives of an image.
- (e) Let the x -axis be aligned with the horizontal axis. Assuming that image I is noise free, the partial derivative $\partial I / \partial x$ will highlight the horizontal edges in image I .

Q3 Point features

Robots typically perceive their environment through sensors with a limited field of view and from different viewpoints. For the robot to build a consistent map of the environment, these different views have to be correlated. Point features allow us to relate different views (represented through images in our case) relative to each other by extracting distinctive structures from the image and matching these across the images.

1. Keypoint properties

- (a) Define what is understood under a feature detector and a feature descriptor and their relation to each other.
- (b) Based on what you learned in the lecture: What are important requirements for feature descriptors? Shortly describe for each requirement what happens if it isn't fulfilled.

2. Harris corner detector

- (a) To detect corners, the Harris corner detector looks at the eigenvalues of the moment matrix M .

$$M = \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} = R^{-1} \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix} R$$

Please mark the regions of eigenvalues for edges, corners and flat regions in Figure 3 and state which properties hold in these regions.

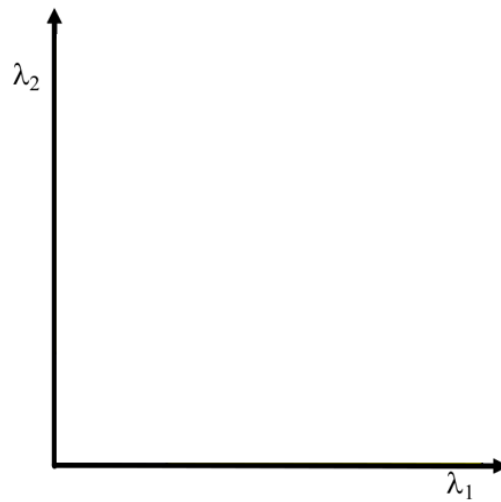


Figure 3: Eigenvalue properties for Harris corner detection

3. SIFT features

- (a) Which are the main processing stages when using a SIFT feature detector and descriptor?

4. Feature matching for panorama creation

(MATLAB) After learning about feature detectors and descriptors in the previous questions, we are now finally able to apply the concepts to stitch together images to create a panorama. Please refer to `ex_5_pointFeatures.m` for further instructions.

5. True or False?

- (a) The SIFT detection and description method is one of the most computationally efficient approaches to extracting image features.
- (b) When analyzing the 2x2 Second Moment Matrix M of an image area during Harris Corner detection, the criterion for this area to be named a Harris Corner is that both eigenvalues of M must be small.
- (c) Harris corners are invariant to scale.
- (d) SIFT feature detector uses LoG kernel to detect keypoints because of its efficiency.
- (e) SIFT feature descriptors can not be combined with the Harris corner detector.