Exercises (Lectures 3 and 4)
Computer Vision 1, Master AI

Exercise 1. Image Filtering

Below are four types of filters.

3x3 uniform (box) filter:

$$T = \begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

7x7 uniform (box) filter:

$$U = \begin{array}{|c|c|c|c|c|c|c|}\hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline \end{array}$$

3x3 edge filter

$$V = \begin{array}{|c|c|c|}\hline -1 & 0 & 1 \\ \hline -1 & 0 & 1 \\ \hline -1 & 0 & 1 \\ \hline \end{array}$$

Laplacian using the following matrix values:

$$W = \begin{array}{|c|c|c|}\hline 1 & -2 & 1 \\ \hline -2 & 4 & -2 \\ \hline 1 & -2 & 1 \\ \hline \end{array}$$

- (a) Which of the following would make an image blurrier, a 3x3 or a 7x7 uniform filter? Why?
- (b) What edges are highlighted with the 3x3 edge filter?
- (c) You wish to transform an image by applying a 3x3 uniform filter followed by the 3x3 Laplacian filter. Show that this can be implemented in a single convolution using a 5x5 filter and calculate the elements of this filter.

$R =$

120	120	120
120	120	120
180	180	180

$G =$

70	80	70
70	70	80
80	230	70

$B =$

100	50	30
90	220	20
150	120	80

Table 1: The R, G and B channels of a small image.

Exercise 2. Color Constancy

Color constancy is an important issue when recognizing an object independent of the color of the light source. Two simple color constancy algorithms are based on the white patch assumption and the grey-world hypothesis. The R, G and B channels of a small image are given in Table 1.

- (a) Give an example of an image for which the white patch method will fail. Please explain.
- (b) Explain in words how these color constancy methods work.
- (c) Calculate the results of both algorithms for the image shown in Table 1.

Exercise 3. Edge Classification

Edge classification is used to detect and classify transitions based on their physical nature. One possible transition type is a shadow one. An example is shown in Table 2 where the R, G and B values of a small image are given.

- (a) Compute the derivative, of the image in Table 2, in the x-direction by the use of a simple differential filter [-1 1]. The origin is the left pixel.
- (b) Compute the normalized red (r) response of the image.
- (c) Calculate the derivative in the x-direction for r.
- (d) How can you classify the transition to be of a shadow type?
- (e) With the same procedure, could you distinguish shadow edges from geometry edges? Please explain.
- (f) With the same procedure, how can highlights be classified? Do you need more than two color features? Which ones?

$R = G = B =$

20	20	40	40
20	20	40	40
20	20	40	40
20	20	40	40

Table 2: The R, G and B values of a small image containing a shadow transition.

Exercise 4. Error propagation

Color invariants become unstable for certain imaging conditions. One way to handle instabilities is by error propagation. Consider a pixel having the following values $R = 20$, $G = 40$, $B = 60$ with $\lambda = 4$.

- (a) Show that intensity $I = R + G + B$ is a color feature which is stable.
- (b) Show that the color feature $1/R$ becomes unstable when the intensity is decreasing.
- (c) Under which circumstances do you think that normalized color and hue will become unstable?
- (d) How can error propagation be used for histogram construction for image retrieval? Please explain.

Exercise 5. Retrieval Effectiveness Measures

Given are two different image retrieval systems with the following characteristics. Firstly, the image database consists of 1000 images. The number of relevant images with respect to a given query is 10 composed of the following set $(A, B, C, D, E, F, G, H, I, J)$. The number of images shown to the user is 15 (Answer Set). Further, the order of the 15 highest ranked images of the two different image retrieval systems (for the same image query) is as follows:

S_1	S_2
1. A	1. K
2. L	2. A
3. B	3. M
4. N	4. N
5. O	5. O
6. P	6. B
7. Q	7. Q
8. C	8. R
9. S	9. S
10. T	10. T
11. D	11. C
12. V	12. V
13. W	13. W
14. X	14. X
15. Y	15. D

- (a) Calculate the precision and recall.
- (b) Compute the precision-recall graph for the two different image retrieval systems.
- (c) Compute the R-Precision.