UNIVERSITY OF TORONTO
Faculty of Arts and Science

APRIL / MAY 2008 EXAMINATIONS

CSC320H1S : Introduction to Visual Computing

Duration: 3 hours

No aids allowed

There are 14 pages total (including this page)

Given name(s): ________________________________

Family name: ________________________________

Student number: ________________________________

Question	Marks
1	__________/30
2	__________/25
3	__________/25
4	__________/30
5	__________/20
6	__________/25
7	__________/25
Total	__________/180

1 Masks and Template Matching (30 marks total)

(a) [7 marks] Give the definition of a *separable* $N \times N$ mask (or filter):

(b) [8 marks] Why is separability a useful property for a mask to have? Be as specific as possible.

(c) Suppose we want to perform template matching using the following image and template:

Image:

row/col #	1	2	3	4	5	6	7	8	9
1	1	6	1	20	13	4	20	20	20
2	6	7	6	21	21	1	21	20	21
3	0	6	1	22	3	4	20	22	20
4	1	6	1	1	3	1	0	20	0

Template:

18	21	18
1	20	2
2	21	4

Indicate the best-matching pixel when we use

(c1) [5 marks] cross-correlation:

(c2) [5 marks] normalized cross-correlation:

In each case, include an explanation. No marks will be given without it. *(Hint: You should be able to answer (c1) and (c2) without computing the similarity scores for every patch in the image.)*

(d) [5 marks] What is the geometrical interpretation of the normalized cross-correlation of two $N \times N$ patches P and Q?

2 Wavelet Transforms (25 marks total)

(a) [15 marks] Compute the 2D Haar wavelet transform of the following image:

18	12	11	3
12	14	19	15
10	8	22	12
0	14	16	6

(b) [6 marks] List three properties that are common to both the Haar wavelet transform and the Laplacian pyramid.

(c) [4 marks] Give one essential difference between these two representations.

3 Gaussian Pyramids & Pyramid Blending (25 marks total)

(a) [15 marks] State the three criteria that define the 5-element mask $\hat{w}$ used by the REDUCE() function. Be as specific as possible.

(b) [10 marks] Give the expression for blending the pyramids of two images A and B into the pyramid of the blended image S, using matte M and the pyramid blending algorithm. Use XL_l to denote level l of the Laplacian pyramid of an image X, and use XG_l to denote level l of the Gaussian pyramid of X.

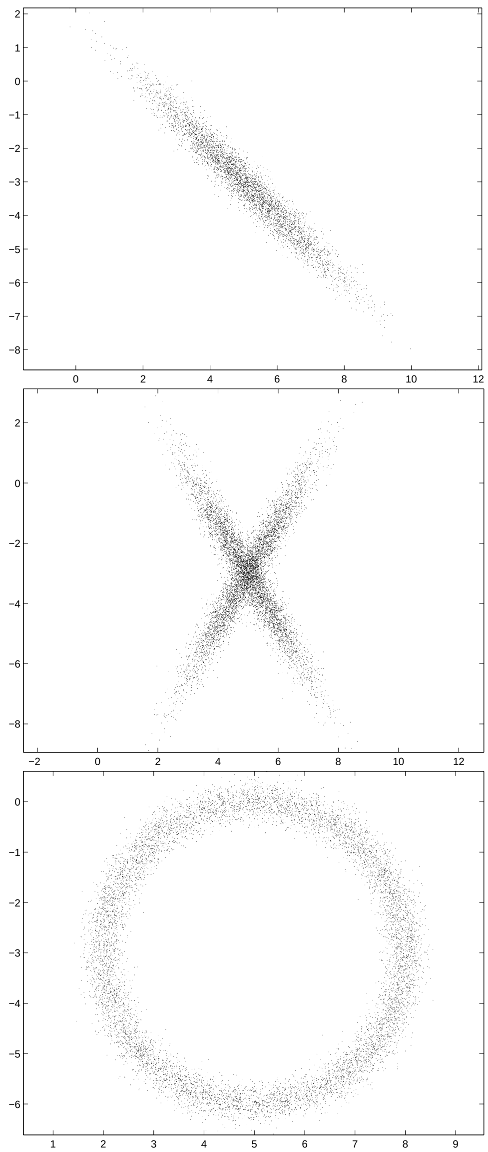
$$SL_l(i,j) =$$

4 PCA & Eigenfaces (30 marks total)

Let $I_1, \ldots, I_n$ be a set of face images, represented as M-dimensional column vectors.

(a) [15 marks] Give the main steps of the algorithm for computing the eigenfaces of $I_1, \ldots, I_n$. Be as specific as possible.

(c) [10 marks] Suppose that $M = 2$. In this case, we can represent the n 2-pixel images with a scatter plot, where each point in the scatter plot corresponds to one of the images. For each of the three scatter plots below, indicate the location of the mean image and draw the corresponding principal components.



(d) [5 marks] Are the principal components of a set of images always unique?

5 SIFT (20 marks total)

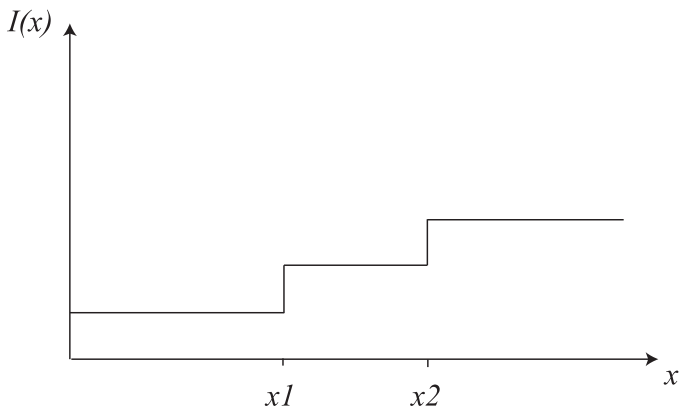
Give the main steps that the SIFT algorithm uses to compute the *descriptor* associated with each keypoint. Be as specific as possible, without providing any equations, and focus only on the SIFT descriptor—do not discuss keypoint localization, or how SIFT descriptors are matched between images. Feel free to use figures as part of your answer.

6 Gaussians & Zero Crossings (25 marks total)

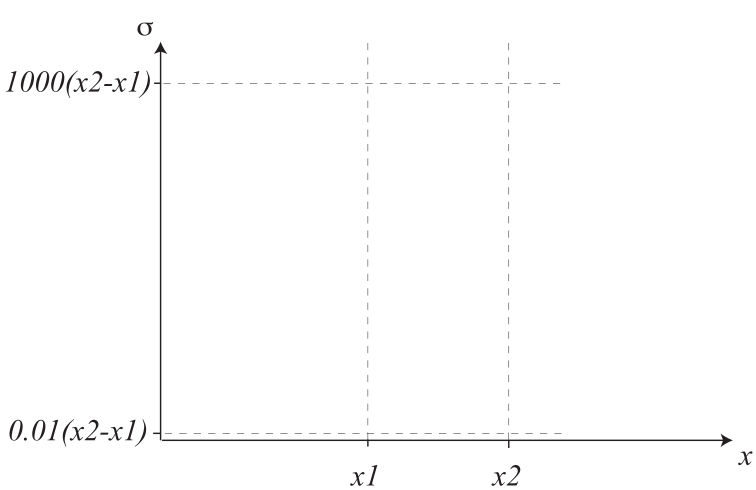
(a) [5 marks] Give the expression for the 1D Gaussian with mean 0 and standard deviation σ:

$$G_\sigma(x) =$$

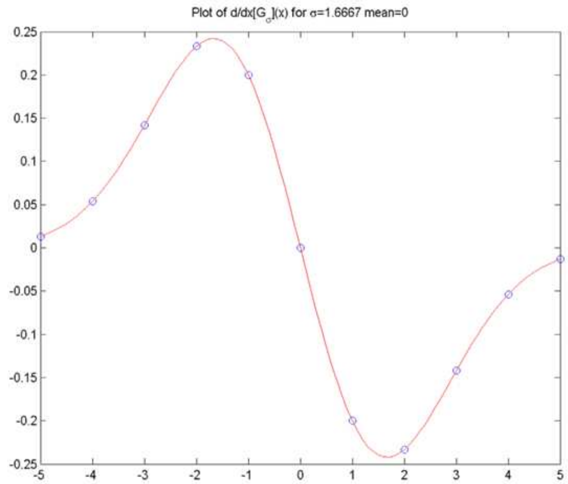
(b) [10 marks] Consider the following 1D image I:

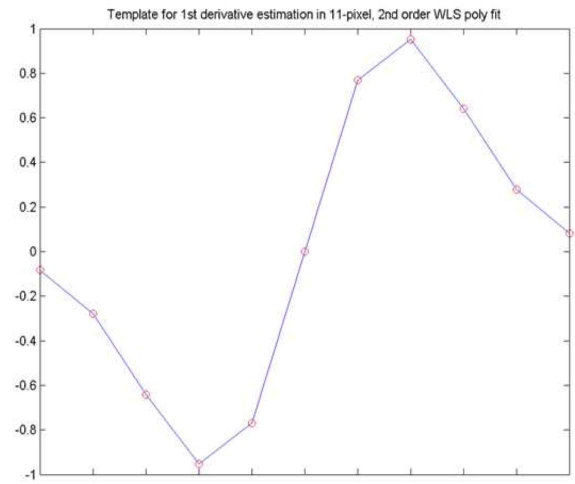


Draw on the graph below the location of the zero crossing(s) of $\frac{d^2 G_\sigma}{dx^2} * I$, if any, for different values for the standard deviation σ. You should consider values of σ in the range indicated on the graph. *(Hint: consider what happens to the zero crossing(s) as you increase σ from a value near zero to a really large value.)*



(c) [10 marks] Consider the two plots below; the left is a plot of $\frac{dG_\sigma(x)}{dx}$ while the right is a plot of the template used for estimating derivatives by 2^{nd}-order, weighted least squares polynomial fitting:





Why are they approximately a reflection of each other?

7 Image Understanding (25 marks total)

Describe how you would solve the following problems using the tools and techniques covered in class. In each case, be sure to specify any assumptions you must make for your algorithm to work. Try to be brief—three to five sentences per problem should be enough.

(a) A stop sign detector [5 marks]: Determine whether or not a stop sign is present in an image.

(b) A motion detector [5 marks]: Given a video camera that outputs a new "live" image every 1/30th of a second, issue an alert whenever something moves within the camera's field of view.

(c) A hand tracker [10 marks]: Given a video of someone waving a hand in front of the camera, compute a 2D curve that represents the hand's trajectory across the camera's field of view. You may assume that (1) the video is broken down into a sequence of successive images $I_1, \ldots, I_n$, and (2) the user placed a box around the hand in the first image.

(d) A hand velocity estimator [5 marks]: From the curve computed in (c), compute the instantaneous velocity of the hand as it moves across the camera's field of view.

END OF EXAM