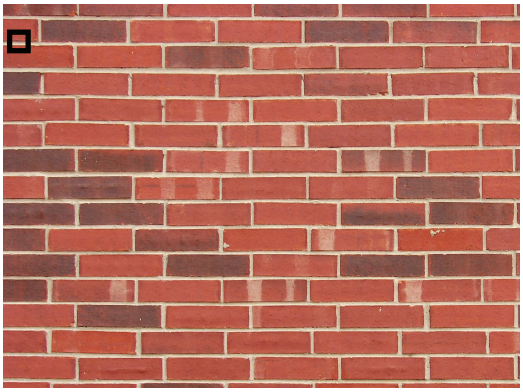
1 Estimation by 2D Polynomial Fitting (25 marks total)

(a) **[5 Marks]** Give the first-order Taylor series expansion of the image $I(x, y)$ in the neighborhood of pixel $(0, 0)$:

$I(x, y) \;=$

(b) **[10 Marks]** Consider the photo below. We want to use polynomial fitting to estimate the intensity, I, and its first derivative(s) at the center of the highlighted 21×21-pixel patch. To do this, we will use least squares to fit a *single* first-degree polynomial in x *and* y to the patch intensities.



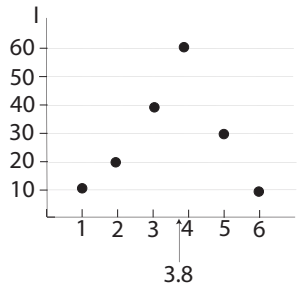
Using matrix notation, show the linear system that must be solved to compute the fit for the patch center. Be sure to indicate the dimensions and contents of each matrix. You should assume that the photo has been converted to grayscale before processing.

(c) **[5 Marks]** Now suppose that we slide the 21×21-pixel window over the entire image, solving the system in (b) for every possible window center (x, y) in order to estimate $I(x, y)$. Ignoring the pixels near the image border, what differences do you expect to see between the estimated image I and the original photo? Explain briefly.

(d) **[5 Marks]** Finally, suppose that we use RANSAC fitting, rather than standard least squares, to estimate $I(x, y)$. Ignoring the pixels near the image border, what differences do you expect to see between the estimated image I and the original photo in this case? Explain briefly.

2 Image Interpolation (15 marks total)

You are given a 6-pixel image I and are asked to interpolate the known pixels to compute an intensity for fractional pixel 3.8.



(a) **[10 Marks]** Give the expression for $I(3.8)$ in terms of I and an interpolation kernel (or mask) M. Assume that $M(t) = 0$ for $t > 3$ and that $M(-t) = M(t)$.

$I(3.8) =$

(b) **[5 Marks]** Compute the interpolation result when M is the *linear interpolation kernel*.

$I(3.8) =$

3 1D Wavelet Representation (20 marks total)

(a) **[10 Marks]** Compute the (unnormalized) Haar wavelet transform of the following 1D image:

23	25	20	24	29	21	16	10	18	26	28	24	17	1	13	-3

(b) **[10 Marks]** Now suppose we add 30 to all pixels in the image in (a) to get the image below. What is the Haar wavelet transform of this new image? Either show your calculations or explain your reasoning.

53	55	50	54	59	51	46	40	48	56	58	54	47	31	43	27

4 SIFT (15 marks total)

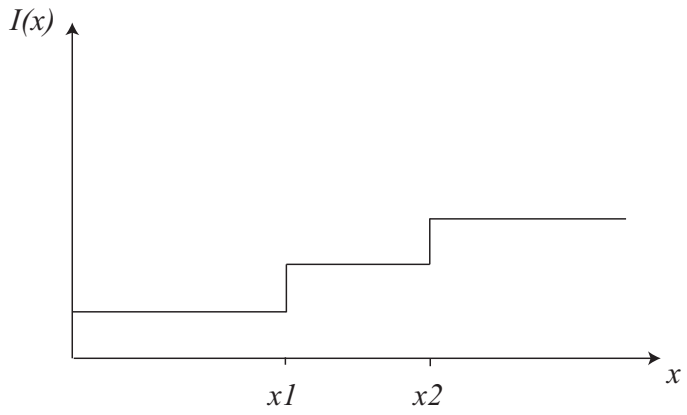
Describe the algorithm used to assign a *2D orientation* to a SIFT keypoint. Be as specific as possible—describe each step of the computation, give relevant formulas, and draw diagrams/plots as needed. Be sure to focus only on keypoint orientation assignment (*i.e.,* assume that the keypoint's 2D position is known and do not discuss the definition and creation of keypoint descriptors, or how the descriptors are matched between images).

5 Gaussians & Zero Crossings (25 marks total)

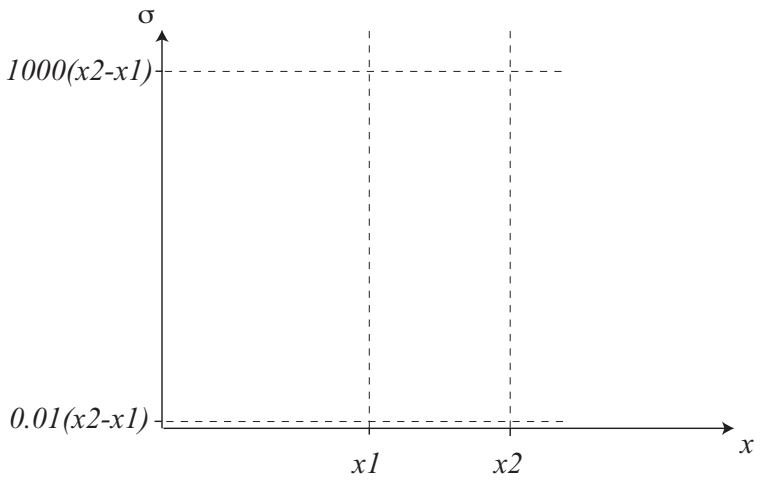
(a) **[5 Marks]** Give the expression for the 1D Gaussian with mean 0 and standard deviation σ:

$G_\sigma(x) \;=$

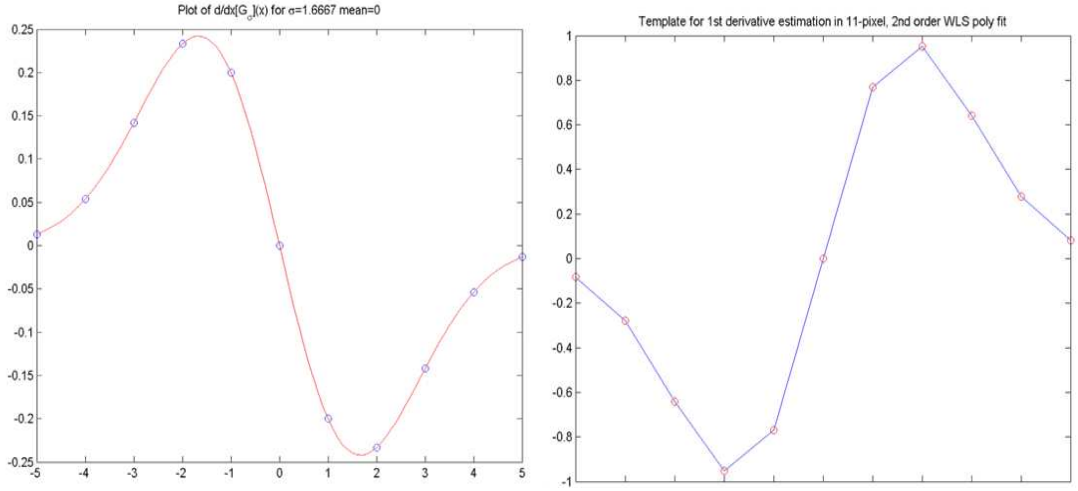
(b) **[10 Marks]** Consider the following 1D image I:



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 below. *(Hint: consider what happens to the image as you smooth it with a Gaussian of increasing values of σ, from 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 the first derivative by 2^{nd}-order, weighted least squares polynomial fitting with a Gaussian weight function:



Why are they approximately a reflection of each other?

6 Image Understanding (20 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) **[5 Marks]** *A stop sign detector:* Determine whether or not a stop sign is present in an image.

(b) **[5 Marks]** *A motion detector:* 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) **[10 Marks]** *A hand tracker:* 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.

END OF EXAM

UNIVERSITY OF TORONTO
Faculty of Arts and Science

APRIL / MAY 2013 EXAMINATIONS

CSC320H1S : Introduction to Visual Computing

Duration: 2 hours

No aids allowed

There are 11 pages total (including this page)

Given name(s): _____

Family name: _____

Student number: _____

Question	Marks
1	_____/25
2	_____/15
3	_____/20
4	_____/15
5	_____/25
6	_____/20
Total	_____/120