UNIVERSITY OF TORONTO
Faculty of Arts and Science

APRIL / MAY 2016 EXAMINATIONS

CSC320H1S : Introduction to Visual Computing

Duration: 2 hours

No aids allowed

There are 10 pages total (including this page)

Given name(s): ________________________________

Family name: ________________________________

Student number: ________________________________

Question	Marks
1	__________/30
2	__________/25
3	__________/30
4	__________/15
5	__________/20
Total	_________/120

1 Short-Answer Questions (30 marks total)

Give a short answer to each of the following questions (1-2 sentences or mathematical expressions).

(a) **[6 Marks]** Which of the following three operations will *not* affect the gradient of an image I: (1) multiplying every pixel by the same constant c; (2) adding to every pixel the same constant c; (3) rotating the image by 90 degrees.

(b) **[6 Marks]** Why does RANSAC-based polynomial fitting confer robustness to outliers?

(c) **[6 Marks]** Give the definition of a *separable* 2D filter $w(r, c)$.

(d) **[6 Marks]** What representation does the SIFT *keypoint detector* use for keypoints?

(e) **[6 Marks]** Give the expression for the homogeneous coordinates of the intersection $\mathbf{p}$ of two lines $\mathbf{l}_1$ and $\mathbf{l}_2$.

2 2D Curves (25 marks total)

(a) **[15 Marks]** Derive the tangent (**5 marks**), normal (**5 marks**) and curvature (**5 marks**) of a circle of radius r. Be sure to show all your calculations, including intermediate steps.

(b) **[10 Marks]** Suppose we have painstakingly measured the log-inverse camera response function of 100 different camera brands and models using Debevec *et al.*'s algorithm, and stored each as a 256-dimensional vector $\mathbf{g^i} = (g^i_0, g^i_1, \ldots, g^i_{255})$, where i denotes the i-th camera.

We would now like to somehow use this "database" of log-inverse response functions to help us estimate the log-inverse response of a new camera we haven't seen before without making too many measurements. In particular, suppose the new camera has index $i = 101$ and that we are given just four elements, $g^i_{10}, g^i_{55}, g^i_{151}, g^i_{250}$, of vector $\mathbf{g^i}$.

Suggest an algorithm to compute the vector's 252 unknown elements by taking advantage of the available database.

3 Multi-Scale Image Representations (30 marks total)

(a) The Laplacian pyramid representation depends on a one-dimensional, five-element filter $\hat{w}(n)$ that defines the representation's *EXPAND()* and *REDUCE()* functions.

(a1) **[5 Marks]** Explain why this filter must satisfy $\sum_{n=1}^{5} \hat{w}(n) = 1$. Be as specific as possible.

(a2) **[10 Marks]** Give the expression for the filter's *equal contribution criterion* and explain its purpose in the context of the *REDUCE()* function. Your explanation should include the relevant diagram(s).

(b) **[15 Marks]** Pictured below is a partially-completed 2D image and its partially-completed 2D (unnormalized) Haar wavelet transform. Complete both the image and its transform by filling the blank entries.

Image

	8	-8	-16
8	8	-8	-8
0	-32	16	16
-8	8	8	-8

2D Haar Transform

0	1	3	
0		-1	-1
0	2	2	2
0	-8	12	-4

4 Image Interpolation (15 marks total)

You are given a *three-dimensional* grayscale image I whose intensity at the discrete locations $(0, 0, 0), \ldots, (N, M, K)$ is known.

(a) **[10 Marks]** Using sum notation, give the mathematical expression for the intensity $I'(x, y, z)$ at a non-integer location (x, y, z) that is computed from I using a 3D Gaussian interpolation kernel of standard deviation σ. *Hint:* While we haven't covered interpolation of 3D images in class, you should be able to generalize the expression from the 1D case we did cover.

$I'(x, y, z) =$

(b) **[5 Marks]** The Gaussian and the linear interpolation kernels are both symmetric about zero. Why would *non*-symmetric kernels be a poor choice for image interpolation?

5 Image Noise (20 marks total)

In order to take a photo of a stationary object we mount our camera on a tripod, focus on the object, and expose the camera's sensor for T seconds. Suppose that during this exposure period, light fell onto sensor pixel $\mathbf{p}$ at a rate of Φ photons per second.

(a) **[6 Marks]** Give the expression for the *mean intensity* at that pixel, in units of Digital Numbers (DNs). Be sure to take into account all three sources of noise discussed in class and to define all terms and/or constants you introduce. You may assume that the sensor's quantum efficiency is equal to 1.

mean$\{ I(\mathbf{p}) \} =$

(b) **[8 Marks]** Give the expression for the *variance* of the pixel's intensity, again in units of Digital Numbers.

variance$\{ I(\mathbf{p}) \} =$

(c) **[6 Marks]** Suppose that the photo we took in (a) and (b) used a lens aperture with a circular shape of radius r. We now double the aperture radius to $2r$ and take a second photo I'. How would your answers to (a) and (b) change for the newly-captured photo?

mean$\{ \ I'(\mathbf{p}) \ \} \ =$

variance$\{ \ I'(\mathbf{p}) \ \} \ =$

END OF EXAM