Queen's University
CISC/CMPE 457
Test 1

October 6, 2016
Duration: 50 minutes

Closed book

Initial of Family Name: ____

Student Number: SOLUTIONS
(Write this at the top of every page.)

There are 4 questions and 25 marks total.

Answer all questions.

This exam paper should have 6 pages,
including this cover page.

1 – Image Basics	/ 10
2 – Transformation and Interpolation	/ 5
3 – Shift Invariance of Convolution	/ 4
4 – Filters	/ 6
Total	/ 25

The candidate is urged to submit with the answer paper a clear statement of any assumptions made if doubt exists as to the interpretations of any question that requires a written answer.

1 Image Basics — 10 points

Part A — 4 points Define each of these terms as they are used in image processing:

sampling EVALUATION OF AN IMAGE (TYPICALLY A CONTINUOUS FIELD) AT DISCRETE POINTS

quantization DISCRETIZATION OF PIXEL VALUES

dyanamic range RATIO OF BRIGHTEST TO DIMMEST INTENSITIES A SENSOR CAN DETECT

contrast DIFFERENCE BETWEEN BRIGHTEST AND DIMMEST VALUES IN AN IMAGE

Part B — 2 points Name and describe two sources of sensor noise.

- QUANTUM INEFFICIENCY: NOT ALL PHOTONS THAT ARRIVE AT THE SENSOR ARE DETECTED
- CHARGE SHIFTING: ELECTRONS ARE LOST/GAINED AS THEY ARE SHIFTED OFF AN IMAGE ROW
- A/D: ANALOG-TO DIGITAL CONVERSION IS NOT ACCURATE
- THERMAL CURRENT: HEAT INDUCES ELECTRON FLOW

... *continued*

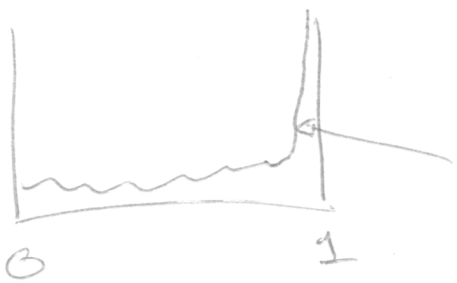
Part C — 2 points What is one value of gamma (γ) that will increase the contrast of dark pixels with the mapping $s = r^\gamma$ for original pixel luminance r and new pixel luminance s. Draw this graph and label the ranges of the axes.

ANY $\gamma \in [0,1]$

Part D — 1 point Sketch a histogram of a high-contrast image.

AN EVEN DISTRIBUTION WITH WIDE RANGE BETWEEN BRIGHT & DARK

Part E — 1 point Sketch a histogram of an image with many saturated pixels.



MANY PIXEL AT MAXIMUM POSSIBLE VALUE

... continued

2 Transformation and Interpolation — 5 points

Part A — 3 points Find a 3×3 homogeneous transform that first rotates by 45°, then translates by $(1, 2)$. Show all of your work. Note that $\sin 45° = \cos 45° = 0.707$.

$$p' = T\,R\,p = M\,p$$

$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} .707 & -.707 & 0 \\ .707 & .707 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} .707 & -.707 & 1 \\ .707 & .707 & 2 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} c & -s & 0 \\ s & c & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Part B — 2 points With bilinear interpolation at location (1.2,5.9), state the integer coordinates of the four pixels that are summed to produce an interpolated pixel and, for each pixel, state its weight in the sum.

CAN SUBSTITUTE ACTUAL VALUE, OR NOT.

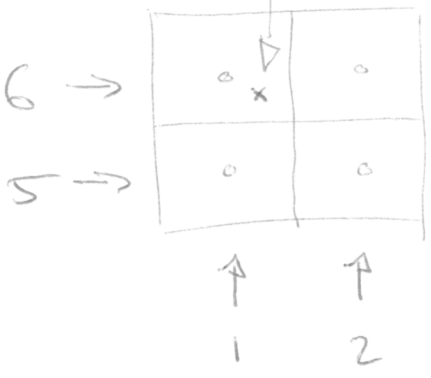
p[1.2, 5.9] =

$(1-\alpha)(1-\beta)$ × p[1 , 5]

+ $(1-\alpha)\beta$ × p[1 , 6]

+ $\alpha(1-\beta)$ × p[2 , 5]

+ $\alpha\beta$ × p[2 , 6]



$\alpha = 1.2 - \lfloor 1.2 \rfloor = 0.2$

$\beta = 5.9 - \lfloor 5.9 \rfloor = 0.9$

... *continued*

3 Shift Invariance of Convolution — 4 points

The shift invariant property of convolution states that

$$S_a(I) * H = S_a(I * H)$$

where $S_a(X)$ denotes a shift of X by a units to the right.

Part A — 1 point Show a convolution filter that performs a shift of 2 units to the right.

Part B — 3 points Let R_a be a convolution filter that performs a shift of a units to the right. Prove that $S_a(I) * H = S_a(I * H)$, using only the associative, commutative, and identity properties of convolution. Note that $S_a(X) = R_a * X$.

$$S_a(I) * H = (R_a * I) * H$$
$$= R_a * (I * H) \quad \text{(Assoc)}$$
$$= S_a(I * H)$$

... *continued*

4 Filters — 6 points

Part A — 1 point Given a box filter with weights that add up to 2, what effect (other than blurring) does the box filter have when convolved with an image?

IMAGE IS BRIGHTENED BY FACTOR OF 2

Part B — 3 points What is the minimum number of multiplications needed to apply a difference–of–Gaussians filter, $G_1 - G_2$, to an $M \times N$ image if G_1 is 7×7 and G_2 is 5×5? Explain and show your work.

SEPARATE EACH GAUSSIAN $G_1 = G_{1A} * G_{1B}$ (7×7 = 7×1 * 1×7)

$G_2 = G_{2A} * G_{2B}$ (5×5 = 5×1 * 1×5)

$G_{1A} * G_{2B} * I$ COSTS $MN \times (7+7)$

$G_{2A} * G_{2B} * I$ COSTS $MN \times (5+5)$

COST = 24 MN

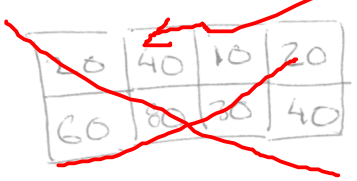
Part C — 2 points Convolve the following filter F and image I, and show the result. The origin of F is in its middle.

$$F = \begin{bmatrix} 1 & 0 & 2 \end{bmatrix} \qquad I = \begin{bmatrix} 10 & 20 \\ 30 & 40 \end{bmatrix}$$

10 20 20 40
30 40 60 80

This is gotten by reversing F (which is the correct thing to do)

This is gotten when F is NOT reversed (which is the wrong thing to do)



E.G.

1×0 + 0×10 + 2×20 = 20

→ COULD ALSO CLAMP PIXEL VALUES SO THAT PIXELS OUTSIDE ARE EQUAL TO CLOSEST PIXEL INSIDE

... End Of Test 1