Queen's University
CISC/CMPE 457
Test 1

October 5, 2018
Duration: 50 minutes

Closed book

Initial of Family Name: ___

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

There are 6 questions and 21 marks total.

Answer all questions.

This exam paper should have 8 pages,
including this cover page.

1 – Short Answers	/ 8
2 – Homogeneous Transformations	/ 3
3 – Histogram Equalization	/ 2
4 – Bilinear Interpolation	/ 3
5 – Convolution	/ 2
6 – Image Sharpening	/ 3
Total	/ 21

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 Short Answers — 8 points

Part A — 1 point What is the "quantum efficiency" of a photodiode?

THE PERCENTAGE OF ARRIVING PHOTONS THAT ARE CAPTURED/DETECTED

Part B — 1 point What happens at the electronic level at a photodiode when "blooming" occurs?

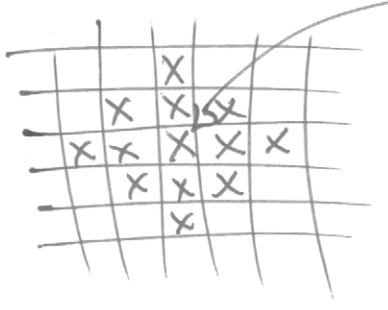
A PHOTODIODE'S ELECTRON WELL FILLS UP AND ELECTRONS SPILL OVER INTO ADJACENT WELLS, CAUSING THE CORRESPONDING PIXELS TO BE BRIGHTER.

Part C — 1 point Why should the weights of a smoothing filter sum to 1?

TO KEEP THE SAME OVERALL IMAGE BRIGHTNESS.

Part D — 1 point Write the equation of the distance, $d(a, b)$, between two pixels, $a = (a_x, a_y)$ and $b = (b_x, b_y)$, using the 1-norm. Draw the 2-neighbourhood of a pixel using the 1-norm.

$$d(a,b) = |a_x - b_x| + |a_y - b_y|$$



1-NORM 2-NEIGHBOURHOOD OF THE CENTRE PIXEL

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Part E — 1 point Briefly explain why averaging N images to reduce the noise is an inefficient process.

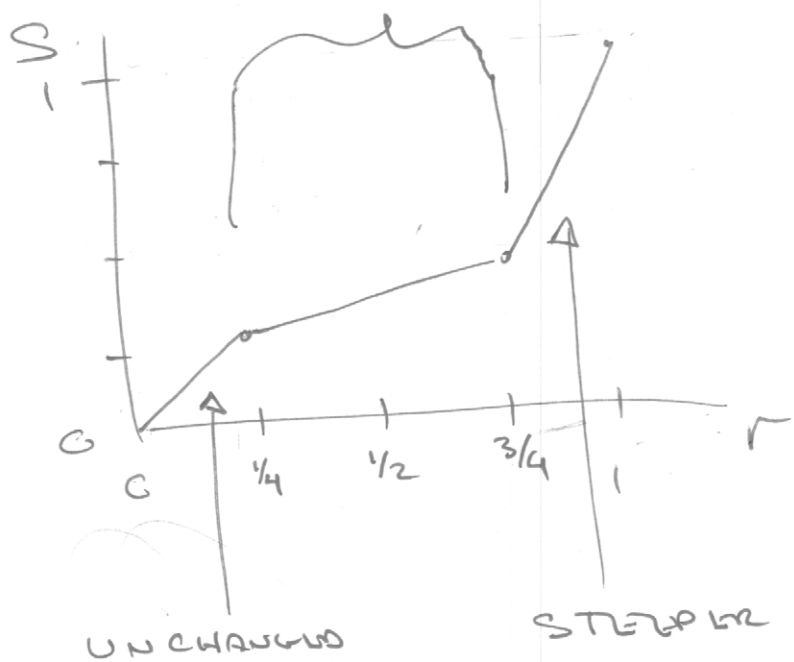
THE STANDARD DEVIATION OF THE NOISE IS REDUCED BY ONLY $\frac{1}{\sqrt{N}}$ FOR N SAMPLES, SO MANY IMAGES ARE REQUIRED TO REDUCE THE NOISE BY ONLY A SMALL AMOUNT.

Part F — 1 point A median filter is used to remove "salt and pepper" noise. Ignoring the processing time, is it better to have a 3×3 or 9×9 neighbourhood for a median filter? Explain.

3x3. A SMALLER FILTER WILL REPLACE A PIXEL BY SOMETHING FROM ITS IMMEDIATE NEIGHBOURHOOD, RESULTING IN LESS IMAGE DISTORTION

Part G — 2 points For pixel intensities in the range $[0, 1]$, draw an intensity transformation graph, $s = T(r)$, which increases contrast of high-intensity (≥ 0.75) pixels while leaving low-intensity pixels (≤ 0.25) unchanged.

CAN BE ANYTHING THAT IS MONOTONIC AND NON DECREASING



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2 Homogeneous Transformations — 3 points

Show a homogeneous (i.e. 3×3) transformation that scales 2D points around a centre position $(1, 2)$ by a factor of 5. Write only the product of transformation matrices; do not multiply them to get a single matrix.

SUBTRACT CENTRE, THEN SCALE, THEN ADD CENTRE!

$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 5 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & -2 \\ 0 & 0 & 1 \end{bmatrix}$$

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3 Histogram Equalization — 2 points

Given this set of pixels 9 with values in the range $[0, 3]$

$$\begin{matrix} 0 & 0 & 0 \\ 1 & 2 & 3 \\ 0 & 3 & 1 \end{matrix}$$

what is the value 2 mapped to by histogram equalization? Show your work. The value may be fractional.

HISTOGRAM

$h(0) = 4$
$h(1) = 2$
$h(2) = 1$
$h(3) = 2$

$$T(r) = \frac{4}{9} \sum_{i=0}^{r} h(r) - 1$$

4 = NUMBER OF POSSIBLE INTENSITIES

9 = NUMBER OF PIXELS IN HISTOGRAM

$$T(2) = \frac{4}{9}(4+2+1) - 1$$

$$= \frac{28}{9} - 1 = 19/9 = 2\,1/9$$

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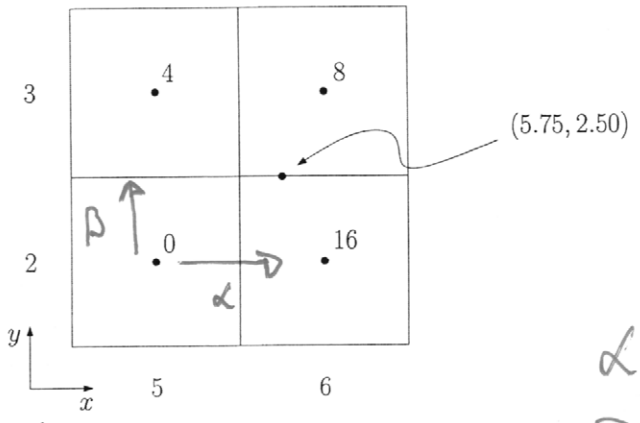
4 Bilinear Interpolation — 3 points

Calculate the intensity at position (5.75, 2.50) using bilinear interpolation of the intensities (= 0, 4, 8, and 16) below. Show your work.



$\alpha = 3/4$

$\beta = 1/2$

$$I(5\tfrac{3}{4}, 2\tfrac{1}{2}) = (1-\alpha)(1-\beta)\,I(5,2) + (1-\alpha)\,\beta\,I(5,3) + \alpha\,(1-\beta)\,I(6,2) + \alpha\,\beta\,I(6,3)$$

$$= 1/4 \cdot 1/2 \cdot 0 + 1/4 \cdot 1/2 \cdot 4 + 3/4 \cdot 1/2 \cdot 16 + 3/4 \cdot 1/2 \cdot 8$$

$$= 1/2\,(0 + 1 + 12 + 6)$$

$$= 19/2 = 9\tfrac{1}{2}$$

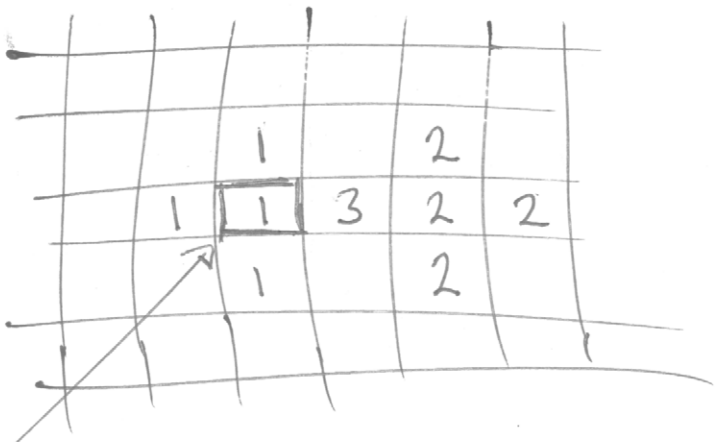
... continued

5 Convolution — 2 points

Convolve these two signals. The origin of each signal is in a box.

0	0	**1**	0	2

0	1	0
1	**1**	1
0	1	0



6 Image Sharpening — 3 points

Part A — 2 points The Laplacian filter D is used to sharpen an image I. Write an equation for the sharpened image as a function of D and I and explain how the amount of sharpening is controlled.

$I = I + kD * I$

INCREASING k ADDS MORE SHARPENING

Part B — 1 point Explain why a "difference of Gaussians" filter can be more efficient than a "Laplacian of Gaussian" filter.

DoG CAN BE SEPARATED INTO TWO 1D FILTERS, MAKING IT MORE EFFICIENT

N×N DoG BECOMES N×1 AND 1×N

$(G_1 - G_2)$

$(G_1^H * G_1^V - G_2^H * G_2^V)$

2N OPS 2N OPS

4N OPERATIONS

LoG IS N×N

N^2 OPERATIONS

... End Of Test 1