Queen's University
CISC/CMPE 457
Test 1

October 3, 2019
Duration: 50 minutes

Closed book

Initial of Family Name: ____

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

There are 4 questions and 21 marks total.

Answer all questions.

This exam paper should have 7 pages,
including this cover page.

1 – Pixels and Pixel Operations	/ 7
2 – Geometric Transformations	/ 4
3 – Histograms	/ 3
4 – Filters and Convolution	/ 7
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 Pixels and Pixel Operations — 7 points

Part A — 1 point What happens at the electronic level at a photodiode when saturation occurs?

The electron well fills up and the electrons released from further photons cannot be stored. Or: The photodiode cannot report any higher value, even as more photons come in.

Part B — 1 point What statistical property of a sensor's measurements quantifies the measurement noise?

The variance or standard deviation.

Part C — 1 point How many separate images of the same scene must be averaged to reduce the image noise to $\frac{1}{10}$ of what it was before? Explain.

100 because the standard deviation of the noise is reduced to $\frac{1}{\sqrt{N}}$ for N samples.

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Part D — 1 point What is the effect of the transformation $T(x) = 1 - x$ on a greyscale image in which pixel intensities are in the range $[0, 1]$?

The black and white pixels are inverted, along with the greys between them.

Part E — 1 point What property of the HCL (hue, chroma, lightness) colourspace makes HCL more useful than RGB or YCbCr? Explain.

Linear interpolation between two colours in HCL corresponds to perceptual linear interpolation between those colours, so HCL is good for interpolating between colours.

Part F — 2 points If a computer monitor requires a gamma correction with $\gamma = 0.2$, for what range (low, middle, or high) of pixel intensities does the monitor *increase* contrast? Explain.

If the *correction* is 0.2, the monitor must be transforming intensity x to $x^{\frac{1}{0.2}}$, or x^5. This is a curve that is flat near 0 and steep near 1. So the high pixel intensities have their contrast increased.

2 Geometric Transformations — 4 points

Part A — 2 points Show a 3×3 homogeneous transformation that takes a 2D homogeneous point $(x, y, 1)$, translates it by $(2, 3)$, then scales it by 4.

$$\begin{bmatrix} 4 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} 4 & 0 & 8 \\ 0 & 4 & 12 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Part B — 2 points When does backward projection using bilinear interpolation *not* produce a noticably better image when zooming out (i.e. making the image smaller)? Explain.

When the zoom out is far enough that *many* pixels from the original image map to a single pixel in the new image, since bilinear interpolation only averages *four* pixels.

3 Histograms — 3 points

Part A — 1 point Draw a histogram of a low-contrast image.

Any histogram with pixel values that occupy a small range.

Part B — 2 points Find the mapping $s = T(r)$ from old pixel intensities r to new pixel intensities s that equalizes the histogram, h, shown below. All pixels intensities must be *integers* in the range $[0, 3]$. Show your work.

$$h(0) = 1 \qquad h(1) = 9 \qquad h(2) = 12 \qquad h(3) = 2$$

sum to 0 = 1
sum to 1 = 10
sum to 2 = 22
sum to 3 = 24

There are 24 pixels in the image.

T(0) = 4/24* 1-1 = -5/6 (clamp to 0)
T(1) = 4/24*10-1 = 4/6 (round to 1)
T(2) = 4/24*22-1 = 16/6 (round to 3)
T(3) = 4/24*24-1 = 3

4 Filters and Convolution — 7 points

Part A — 1 point What is a separable filter? What advantage does a separable filter have over a non-separable filter?

A separable filter is one that can be written as the convolution of two lower-dimensional filters. It is usually faster to convolve the image with the two lower-dimensional filters (one at a time) than it is with the original filter.

Part B — 2 points Consider a 5×5 "order statistic" filter that replaces each pixel with the neighbourhood pixel of maximum intensity. What will be the effect of this filter on an image with "salt and pepper" noise. Explain what happens to "salt" noise and explain what happens to "pepper" noise.

The black "pepper" pixels will disappear while the white "salt" pixels will each be spread out into a 5×5 neighbourhood around the original "salt" pixel.

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Part C — 2 points Name two properties of the convolution operation that the correlation operation does not have. Explain why these properties make convolution more useful than correlation.

Any two of: associativity, commutivity, shift invariance. Linearity and identity are *not* answers as correlation has the same properties.

The properties mean that filters can be combined to make more efficient computations.

Part D — 2 points Let F be a 2D filter that computes the first derivative in the x direction. Convolving F with an image I results in $(F * I)(x, y) = I(x + 1, y) - I(x, y)$.

Suppose F is applied to an image by computing $I' = I - 0.2\ F * I$, resulting in a new image, I'.

Where is I' darker than I? Explain.

In the positive x direction, an increase in pixel intensity results in a positive $I * F$ at the pixel *before* the increase. That positive value gets subtracted from the image, resulting in a darker pixel before the increase.

Similarly, a decrease in pixel intensity in the positive x direction results in a brighter pixel just before the decrease.

So I' is darker just left of intensity increases in the x direction.