Queen's University
CISC/CMPE 457
Test 3

November 28, 2018
Duration: 50 minutes

Closed book

Initial of Family Name: ____

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

There are 4 questions and 18 marks total.

Answer all questions.

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

1 – Short Answers (including Hough)	/ 6
2 – CT Imaging	/ 6
3 – Compression	/ 4
4 – HDR Photography	/ 2
Total	/ 18

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 (including Hough) — 6 points

Part A — 1 point   What is the dimension of the Hough space used to accumulate votes when detecting an ellipse of arbitrary position, orientation, and size? Explain.

> 5D for 5 parameters: x position, y postion, orientation, minor axis length, major axis length.

Part B — 1 point   Is a Fourier Transform used by the filtered backprojection algorithm that reconstructs a CT image? Explain.

> No. The FBP algorithm uses a convolution in the spatial domain instead of a multiplication by $|\omega|$ in the frequency domain.

Part C — 1 point   Show an expression for the integral of the attenuation along a ray as it passes through a medium, using only the input radiance I_{in} and output radiance I_{out}.

$$\log I_{\text{in}} - \log I_{\text{out}}$$

Part D — 1 point   Name two parts of JPEG encoding in which information can be lost.

1. Optional subsampling of 8x8 blocks into 4x8 or 8x4 blocks.

2. Quantization of DCT coefficients.

Part E — 2 points   Why does the Hough Transform, when detecting lines, have trouble distinguishing lines that cross with almost the same slope? What technique can resolve this problem?

Such lines can map to the same bin in the Hough space.

Use a multiresolution technique: Subdivided bins with many votes and perform another iteration of the Hough voting with these finer bins.

2   CT Imaging — 6 points

Part A — 1 point   What is the *purpose* of the Radon Transform?

To convert the integral of attenuation along a ray into an integral of attenuation over the domain (i.e. over the subject being imaged)

Part B — 2 points   A point (x, y) in a CT slice appears as a curve in the sinogram's (ρ, θ) space. What is the equation of this curve? Explain (using words, not math) how the equation is derived.

At angle θ, the CT detector is aligned in direction $(\cos\theta, \sin\theta)$. Point (x, y) is perpendicularly projected onto the CT detector.

The perpendicular projection of (x, y) onto $(\cos\theta, \sin\theta)$ is $x\cos\theta + y\sin\theta$.

The distance of this projection from the origin is the parameter ρ.

So the equation is $\rho = x\cos\theta + y\sin\theta$.

Part C — 2 points   Why is there a term $|\omega|$ in the Inverse Fourier Transform

$$\int_\theta \int_\omega |\omega| \; G(\omega, \theta) \; e^{2\pi i \omega \rho} \; d\omega \; d\theta.$$

Explain, with reference to the (ω, θ) parameterization of the Fourier space.

$|\omega|$ comes from the size and shape of the infinitesimal element $|\omega| \; d\omega \; d\theta$. That infinitesimal element comes from the reparameterization of the Fourier space from (u, v) to (ω, θ).

Part D — 1 point   Name one advantage and one disadvantage of Algebraic Reconstruction over Filtered Backprojection in reconstructing CT images.

Advantage: AR can handle arbitrary scanner geometries without change, while FBP cannot.

Disadvantage: AR takes longer than FBP.

3   Compression — 4 points

Part A — 1 point   Explain, with reference to entropy, why predictive encoding permits better compression.

> The predictively-encoded values have a smaller variance, and hence a lower entropy, than the original values. A lower entropy signal is generally more compressible.

Part B — 1 point   Explain why MPEG encoding of multiple image frames takes much longer than MPEG decoding of the same frames.

> Encoding must search for the best-matching 8x8 block from the previous frame, while decoding is given the offset to that block and just looks it up.

Part C — 2 points   Blocks of 8×8 pixels are often apparent in highly compressed JPEG images. Explain, with reference to DCT coefficient quantization, why the boundaries between these 8×8 blocks are particularly perceptible.

> The higher frequency DCT coefficients are usually zeroed, resulting in a smoother image in the 8x8 block.
>
> This will cause two adjacent smoothed blocks to not be continuous at their common boundary, resulting in a perceptible boundary.

4   HDR Photography — 2 points

Part A — 1 point   For determining pixel radiance, explain why steep parts of the response curve are better than shallow parts.

A range of pixel values (e.g. $Z \pm 0.5$ for the 1-unit range around a pixel value Z) maps to a smaller range of exposures at steep parts than at shallow parts, so the pixel's exposure (or radiance) can be more accurately determined.

Part B — 1 point   What two properties of the Mean Threshold Bitmap makes it particularly good for aligning images? Explain.

Matching is robust against varying exposure because the same pixels will be below the median at all exposures, and the same pixels will be above the median at all exposures.