Aston University

School of Engineering and Applied Science

CS3330 Image and Video Processing

Final Year Examination

CLOSED BOOK

Date: TBC
Time: TBC
Duration: 2 hours

Instructions to Candidates

1. **Answer ALL questions from section A.**
2. **Answer any TWO questions from section B.**
3. **Section A contains six questions worth 40 marks in total.**
4. **Section B contains three questions, each worth 30 marks.**

Materials provided

1. **Answer booklets**
2. **Casio fx-85ms Calculator**

This exam paper cannot be removed from the exam room

Section A: Answer all questions

1. State ONE similarity and TWO differences between the uses of **rod cells** and **cone cells** in the **human visual system**.

(6 marks)

- *Similarity: Both are retinal cells used to detect light. (**2 marks**)*
- *Differences: Several to choose from. For example: Cone cells provide colour vision, rod cells only black and white. Rod cells are more sensitive to light than cone cells and so provide our night vision. (**2 marks each**)*

2. Name and briefly describe the three variables which specify a colour in the **HSV colour model**.

(6 marks)

- ***Hue**: The dominant colour. Essentially, what colour the light appears to be when lightness and darkness (covered by saturation and value) are ignored. (**2 marks**)*
- ***Saturation**: How close the colour is to white. As the saturation is decreased, the colour becomes closer to white. (**2 marks**)*
- ***Value**: Intensity, or brightness of the light. As the value is decreased, the colour becomes closer to black. (**2 marks**)*

3. State the difference between **subjective** and **objective evaluation** image quality. Give ONE advantage and ONE disadvantage of **objective evaluation**.

(6 marks)

- *Subjective: evaluation by users. (**1 mark**)*
- *Objective: evaluation based on some predefined mathematical criteria. (**1 mark**)*

Many advantages/disadvantages e.g:

- *Advantage: Directly measures the response of human. (**2 marks**)*
- *Disadvantage: Not consistent. More time-intensive to implement. (**2 marks**)*

4. Describe the types of redundancies addressed by the **MPEG** AND the **MJPEG video standards** and explain why any differences allow the MPEG standard to achieve a higher compression ratio than MJPEG.

(6 marks)

- *Both algorithms minimize spatial redundancies; redundancies in individual frames. (**2 marks**)*
- *However, only MPEG makes use of inter-frame coding to minimize temporal redundancies; redundancies between frames. (**2 marks**)*
- *Because videos frequently have a lot of repeated information in proximate frames, this can greatly increase the compression which MPEG can achieve. (**2 marks**)*

5. a) **High definition video** is, in its raw format, composed of 1920x1080 pixel images with a **colour depth** of 24 bits-per-pixel, displayed at a rate of 30 frames-per-second. Calculate the space, in gigabytes, required to store 1 minute of such video.

(4 marks)

- *1 frame = 1920 * 1080 * (24 / 8) Bytes / 1024^2 ~= 6 MB*
- *1 second of video = 6 MB * 30 frames ~= 180 MB*
- *1 minute of video = 180 MB * 60 seconds / 1024 ~= 10.4 GB*

b) Given that bandwidth and digital storage capacity are constantly increasing, justify with evidence why compressing image and video data is still important. You may make use of the fact that **Blu-ray disks** have a capacity of 25 GB and are used to store high definition video as described in part (a).

(4 marks)

- *While capacity is increasing, so are the demands on quality. (**1 mark**)*
- *Use of evidence, e.g. from the above, Blu-ray discs could only store 25/10.4 ~= 2.5 minutes of video – vastly insufficient for typical use cases. (**3 marks**)*

6. Describe and briefly discuss ONE practical application of an image processing technique. In your answer, you should name the technique, describe how it is used in the real world and explain how it solves a practical problem.

(8 marks)

- *Many valid examples.*
- *Answer should include:*
    - *Name of suitable technology (**2 marks**).*
    - *Description of the application (**4 marks**).*
    - *Illustration of real world relevance (**2 marks**).*

END OF SECTION A

Section B: Answer any TWO questions in this section

7. a) State the difference between a **line** and an **edge** in a digital image.

(4 marks)

- *A line is a line is a sequence of connected pixels which share similar properties. It is one pixel thick. (**2 marks**)*
- *An edge is a line a boundary between regions of pixels which share similar properties. (**2 marks**)*

b) Give TWO ways in which the presence of **noise** in an image can be problematic in **edge detection**.

(4 marks)

- *Several answers possible. I would expect answers related to good detection and good localization. (**2 marks each**)*

c) State ONE advantage and ONE disadvantage of using a high threshold in **edge detection**.

(4 marks)

- *We have high certainty that edge pixels classified with a high threshold represent true edges (few false positives). (**2 marks**)*
- *We may reject true edges incorrectly, leading to gaps in edges (false negatives). (**2 marks**)*

d) The following are a set of **greyscale intensities** from a region of a 2D image in which we wish to detect **horizontal lines**.

$$\begin{pmatrix} \mathbf{100} & \mathbf{0} & \mathbf{100} & \mathbf{100} & \mathbf{100} \\ \mathbf{0} & \mathbf{100} & \mathbf{100} & \mathbf{0} & \mathbf{0} \\ \mathbf{100} & \mathbf{0} & \mathbf{100} & \mathbf{100} & \mathbf{100} \\ \mathbf{0} & \mathbf{100} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{100} & \mathbf{100} & \mathbf{100} & \mathbf{100} \end{pmatrix}$$

i) State which ONE of the following **filter masks** would be suitable for detecting a horizontal line and justify your answer with reference to the type and direction of **derivative** it calculates.

$$\begin{pmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{pmatrix} \qquad \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \qquad \begin{pmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{pmatrix}$$

Mask A **Mask B** **Mask C**

(6 marks)

- ***2 marks** for choosing the correct mask (mask C).*
- ***2 marks** for explanation in terms of derivative type (2^{nd}).*
- ***2 marks** for explanation in terms of derivative direction (across the line).*

ii) Calculate the **response** (the value taken by the filtered image) at locations **X**, **Y** and **Z** indicated below if the above image was filtered using the mask chosen in your answer to part (d) (i).

$$\begin{pmatrix} \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \boldsymbol{X} & \cdots & \cdots \\ \cdots & \boldsymbol{Y} & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \boldsymbol{Z} & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \end{pmatrix}$$

(9 marks)

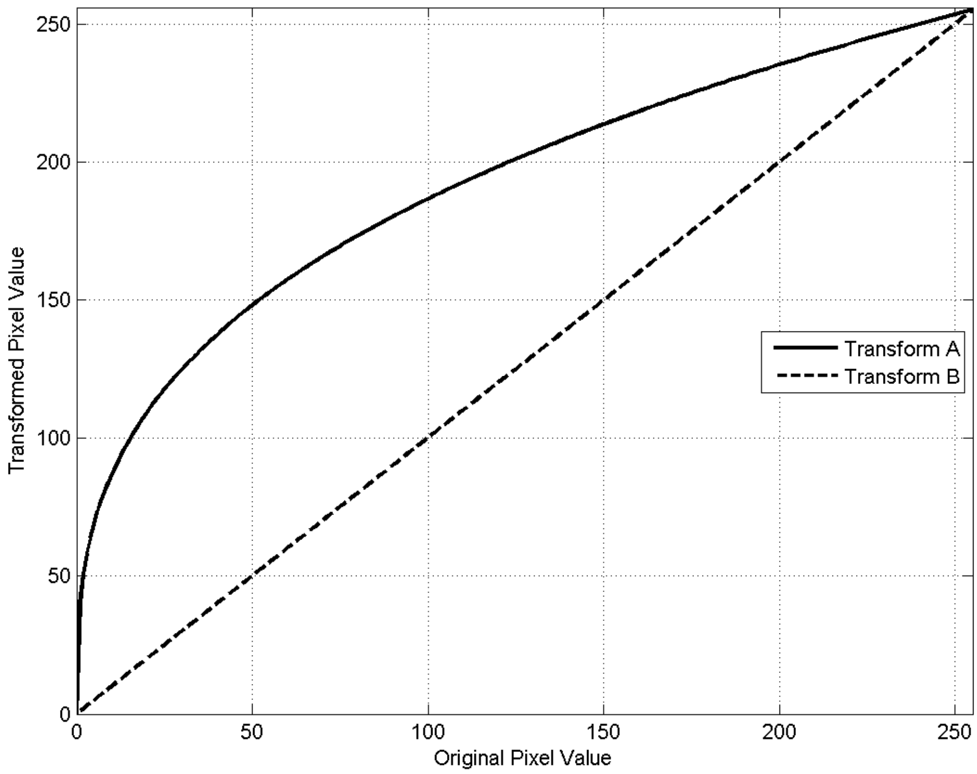
- *Values dependent on filter mask chosen.*
- ***1 mark each** for correct 3x3 neighbourhood selected.*
- ***1 mark each** for correct application of filter (element-wise multiplication).*
- ***1 mark each** for correct value.*

iii) Given your answer to part (d) (ii), state where lines would be detected at a threshold of 250.

(3 marks)

- *Answer depends on part (d) (ii) – any response with absolute value > 250. **1 mark for each correct classification**.*

8. a) The following graph shows two **intensity transformation functions** labelled as "**Transform A**" and "**Transform B**".



i. State the name of **Transform A** and describe how an image would change if the transform were applied to it.

(5 marks)

- *The gamma transform (**1 mark**)*
- *The image's brightness would be increased… (**3 marks**)*
- *…but colour depth would be maintained. (**1 marks**)*

ii. State the name of **Transform B** and describe how an image would change if the transform were applied to it.

(3 marks)

- *The identity transform (**1 mark**)*
- *The image would remain unchanged (**2 marks**)*

iii. State the effect that applying **histogram equalization** to an image would have on the image's appearance AND its histogram.

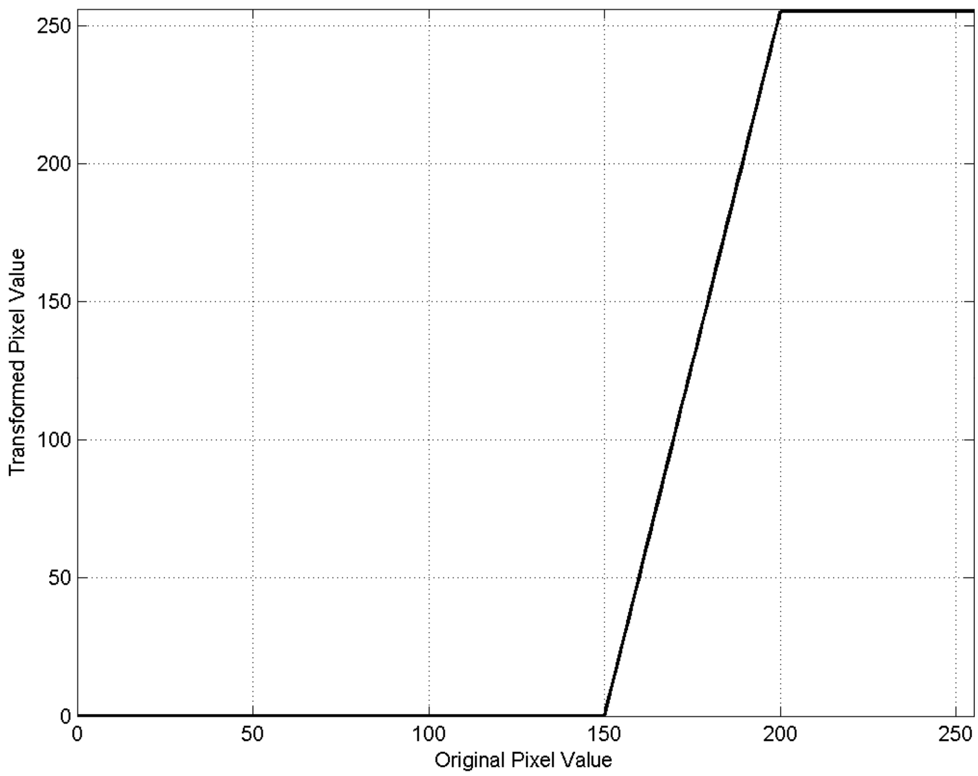
(4 marks)

- *The contrast of the image would be increased. (**2 marks**)*
- *The histogram of the image would be made approximately uniform across the range of pixel values. (**2 marks**).*

iv. An image has pixel values evenly distributed in the range 150 to 200. Sketch the approximate shape of the transform function which would be derived by histogram equalisation.

(6 marks)

Model Answer:



- *Correct general outline (**1 mark**)*
- *Values between 0-150 as above (**1 mark**)*
- *Values between 150-200 as above (**3 marks**)*
- *Values between 200-255 as above (**1 mark**)*

b) State the definition of **primary colours**.

(2 marks)

- *Set of colours which can be mixed in various proportions to create a large range of other colours. (**2 marks**)*

c) State the difference between **additive** and **subtractive colour models**. Give ONE example of a set of primary colours for each type of model.

(6 marks)

- *Additive based on adding together wavelengths of light - emission. (**2 marks**)*
- *Subtractive based on combining light absorbing materials (pigments) – absorption. (**2 marks**)*
- *Many examples. Would expect RGB (additive) CMY (subtractive). (**1 mark for each**)*

d) What colour will we obtain if we mix the same amount of Magenta paint and Cyan paint together?

(4 marks)

- *CMY = (1,1,0) (**1 mark**)*
- *RGB = (1,1,1)-CMY = (1,1,1)-(1,1,0) = (0,0,1) (**2 marks**)*
- *Blue (**1 mark**)*

9. a) Explain what is meant by **psychovisually redundant** data and state how **lossy compression** algorithms can reduce file size by taking advantage of redundancies of this type.

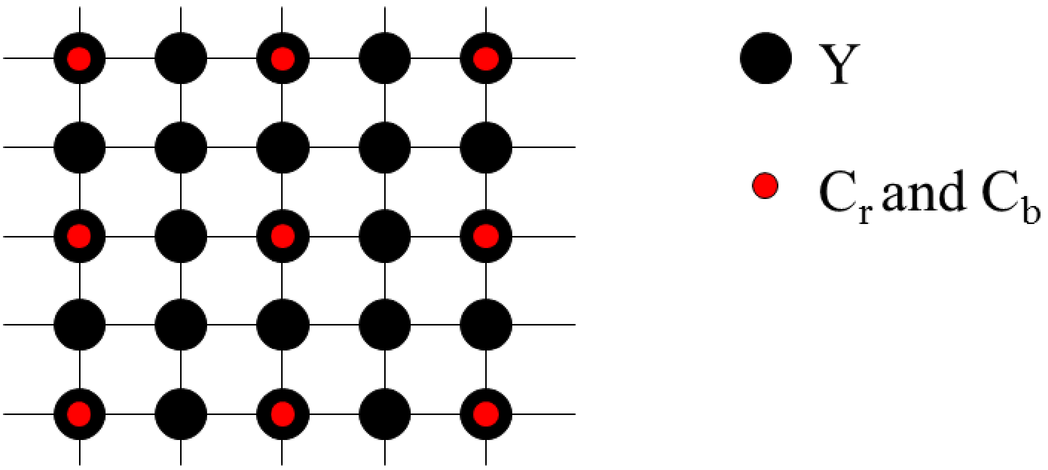
(4 marks)

- *The human visual system does not treat all information as equally important – some aspects of images have more effect on our perceptions than others. (**2 marks**)*
- *Removing data which is less perceptually important (psychovisually redundant) allows us to decrease file size without greatly decreasing perceived image quality. (**2 marks**)*

b) In the **JPEG compression algorithm** an RGB image is converted to **YCbCr** and then selectively **downsampled** at a ratio of 4:2:0. Draw a diagram to illustrate which pixels would be retained from each of the three channels: **Y**, **Cb** and **Cr**.

(6 marks)

- ***4 marks** for correct diagram of 4:2:0 downsampling.*
- ***2 marks** for correctly identifying which channels are downsampled.*



c) Assume that an 8x8 block of a 2D image has **DCT coefficients** given by the following matrix:

$$\begin{pmatrix} 8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Describe, with reasoning, the original image block.

(6 marks)

- *All pixels in the original image block have the same intensity (**2 marks**)*
- *DCT coefficients correspond to patterns within the original image block (**1 mark**)*
- *The top-left entry (8) corresponds to the overall strength of the signal (**1 marks**)*
- *The remaining entries correspond to fluctuations of intensity within the image block. As these are all zero-valued there is no change of intensity within the image block – all pixels have the same intensity. (**2 marks**)*

d) Create a **Huffman coding table** for the below string.

DBADCCBBDE

Use the following steps:

i) Write down the **frequency table**.

(3 marks)

Symbol	***A***	***B***	***C***	***D***	***E***
Frequency	*1*	*3*	*2*	*3*	*1*

- ***0.5 marks each** for correct symbol/frequency pairs*
- ***0.5 marks** if all frequencies are correct.*

ii) Design a **Huffman code tree** for the string.

(6 marks)

- *Several valid trees.*
- ***1 mark** for joining symbols in order of increasing frequency*
- ***5 marks** available for a correct tree. **1 mark** deducted for each mistake. In an incorrectly structured tree, the number of marks available is limited above by the number of nodes of the tree (e.g. a tree with only one node could only receive 1 mark).*

iii) Give the associated **coding table** for the string.

(5 marks)

- *The coding table is tree dependent.*
- ***1 mark each** for correct codes*

END OF EXAMINATION PAPER