FINAL

IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2017-2018

MEng Honours Degree in Mathematics and Computer Science Part IV
MEng Honours Degrees in Computing Part IV
MSc in Advanced Computing
MSc in Computing Science (Specialist)
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the Associateship of the City and Guilds of London Institute

PAPER C407H

MEDICAL IMAGE COMPUTING

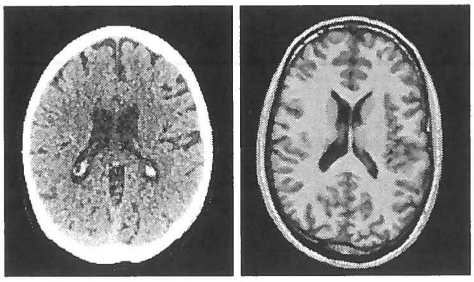
Thursday 14 December 2017, 11:40
Duration: 70 minutes

Answer TWO questions

Paper contains 3 questions
Calculators not required

1 Image analysis

a Imaging modalities



(a) (b)

i) What are the imaging modalities for the brain scans in (a) and (b) above? Desribe the key characteristic visible in each image regarding its modality.

ii) What are the high-level physical principles underlying each of the two modalities above?

b Image filtering

Given a 5×4 image and a 3×3 filter mask f which is applied in a sliding window fashion to the grey shaded pixels results in a 3×2 output.

1	2	3	4	5
1	2	3	2	1
5	4	3	2	1
5	4	3	4	5

$* f =$

i) Write down the horizontal and vertical 3×3 Sobel filters.

ii) Calculate the 3×2 outputs when applying the horizontal and vertical 3×3 Sobel filters at the positions of the grey shaded pixels.

c Window/level

i) Explain briefly the concept of window/level for medical image visualisation and say why it is required.

ii) Calculate the window/level corresponding to the range $[-200, 700]$.

The three parts carry, respectively, 20%, 60%, and 20% of the marks.

2 **Image segmentation**

a Image quality

i) Describe briefly what the 'partial volume effect' is.

ii) List three other challenges that might effect the accuracy of an image segmentation algorithm.

iii) Describe briefly what 'leakage' means in the context of image segmentation.

b Segmentation algorithms

i) Sketch in pseudo-code the region growing algorithm.

ii) Describe briefly how multi-atlas label propagation works.

c Evaluation

Given the following 6×6 binary segmentations, with pixels marked with a '1' belonging to the foreground object, and pixels marked with '0' are background.

0	0	0	0	0	0
0	0	0	0	1	0
0	0	1	1	1	0
0	1	1	1	1	0
0	1	1	1	1	1
0	0	1	1	1	0

(d) Ground truth

0	0	0	0	0	0
0	1	0	0	1	0
0	1	1	0	1	0
0	1	1	1	0	0
0	1	1	0	1	1
0	0	0	0	0	0

(e) Prediction

i) Calculate the number of true positives, false positives, true negatives and false negatives.

ii) Calculate the precision, recall, sensitivity and specificity.

iii) Calculate the Dice Similarity Coefficient.

iv) Discuss briefly whether specificity is a useful metric for evaluating segmentation algorithms.

The three parts carry, respectively, 25%, 40%, and 35% of the marks.

3 Machine learning

a Gaussian Mixtures

i) Give the mathematical definition of the univariate Gaussian Mixture.

ii) Describe what the 'latent variables' represent in the context of the Expectation-Maximization (EM) method.

iii) Describe in brief the two steps of the EM method.

iv) What is the main difference between EM and Variational Bayesian estimation of Gaussian Mixture Models?

b Learning curves

i) In which of the two cases is acquiring more training data likely to help? Explain why.

A) High training and high test error

B) Low training and high test error

ii) What other options are there to improve the test error in cases A and B?

c Logistic regression

After employing logistic regression for a three-class classification problem using a 'one-vs-all' strategy, we are getting the following predictions:

Class 1: $h_\Theta^{(1)}(\mathbf{x}) = 0.3$ Class 2: $h_\Theta^{(2)}(\mathbf{x}) = 0.4$ Class 3: $h_\Theta^{(3)}(\mathbf{x}) = 0.3$

i) What should be the final prediction for a test sample $\mathbf{x}$? Is there anything unusual about this? Explain your reasoning in a few sentences.

ii) How could a 'one-vs-one' strategy work? How many classifiers are needed for a K-class problem, and how to decide on the final prediction?

iii) In order to effectively use gradient descent for optimising the parameters of logistic regression, we had to rewrite the cost function from:

$$(h_\Theta(\mathbf{x}) - y)^2 \quad \text{to} \quad (-y\log(h_\Theta(\mathbf{x}) - (1-y)\log(1-h_\Theta(\mathbf{x})))$$

Explain in a few sentences why this is necessary.

The three parts carry, respectively, 35%, 25%, and 40% of the marks.