UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE : **MPHYGB06**

ASSESSMENT PATTERN : **MPHYGB06B**

MODULE NAME : **Information Processing in Medical Imaging**

DATE : **30-May-14**

TIME : **10:00**

TIME ALLOWED : **2 Hours 0 Minutes**

TURN OVER

EXAMINATION

MPHYGB06: Information Processing in Medical Imaging

Answer 3 questions out of 5 only.

Each question is worth 20 marks.

Answer each question in a separate answer booklet.

The marks given in square brackets at the right hand side are an indication of the marks carried by that part of the question.

Approved electronic calculators may be used.

Question 1

a) State the 3 main components of a registration algorithm. [3]

b) Given your answer to question 1.a), what is the difference between a parametric and a non-parametric registration scheme? [1]

c) Give two examples of parametric registration algorithms. [2]

d) Give two examples of non-parametric algorithms. [2]

e) A penalty on the determinant of the Jacobian of the transformation is often included within a registration algorithm. What is the motivation for using this term? Give two examples where the determinant of the Jacobian of the transformation is used in the context of medical image registration. [3]

f) The equation below describes the mutual information between two images A and B, where the probabilities p refer to the weighted number of voxels within a given intensity bin. State an expression that describes the joint entropy similarity measure. Why is mutual information preferred over joint entropy for image registration? [3]

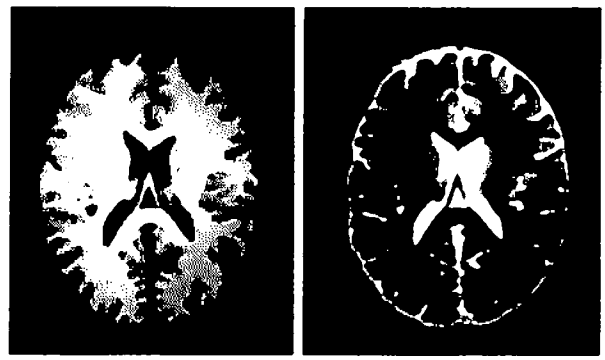
$$\mathrm{MI} = \sum_{i}^{\text{bins}} \sum_{j}^{\text{bins}} p_{ij}(A,B) \log \frac{p_{ij}(A,B)}{p_i(A)p_j(B)}$$

g) Describe three different ways to assess the quality of a registration result. [3]

h) Measures of similarity can be global or local. Give one example of each. For each type give one advantage and one disadvantage. [3]

Question 2

a) We want to perform an automatic segmentation of grey and white matter tissue types in 3D MRI. The figure below shows T1-weighted and T2-weighted images. The images are skull-stripped in order to simplify the segmentation procedure.



i) The k-means algorithm could be used to segment these images. Describe the steps used in this algorithm. [3]

ii) The T1-weighted image is corrupted by a bias field. Explain what "bias field" means and how it could be corrected. [3]

iii) Describe the Expectation-Maximisation procedure and what parameters are being optimised. What assumptions are being made regarding the image intensity model? [4]

iv) How could the algorithm be modified to include information from both modalities simultaneously? [3]

b) Tissue segmentations can also be generated by registration of a pre-existing segmentation to the new target space. With regards to brain image segmentation state two problems that might be encountered using this approach, how might these be mitigated? [3]

c) Label fusion is a strategy used to generate a consensus tissue parcellation from a number of candidates. Describe two methods of estimating a consensus. [4]

Question 3

a) Four requirements for a measure of image similarity between two images A and B to be regarded a metric are shown below:

$$d(A,B) > 0$$
$$d(A,B) = 0 \quad iff \quad A = B$$
$$d(A,B) = d(B,A)$$
$$d(A,B) \leq d(A,C) + d(C,B)$$

Show that the sum of squared difference similarity measure below meets these requirements and is therefore a metric. [5]

$$\sum_n (A_n - B_n)^2$$

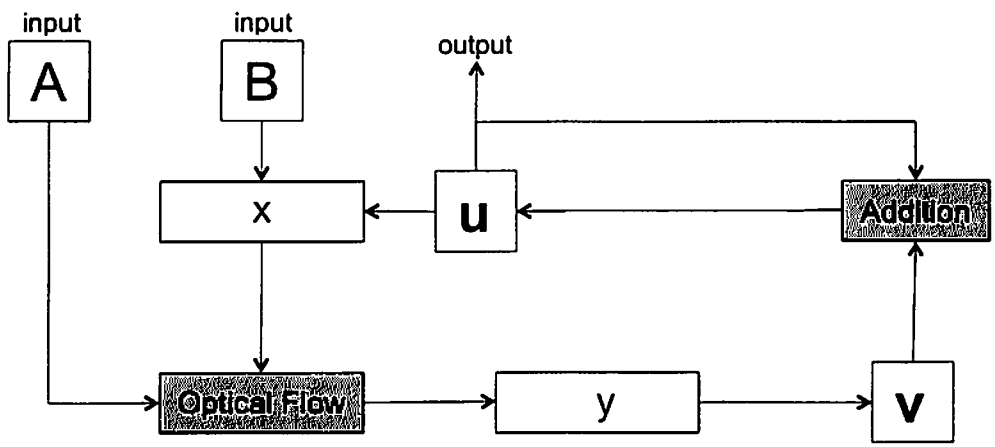
b) Describe two methods that can be used to fill a joint image histogram. [2]

c) Plot the first four pixels of table 1 where [x, y, I] denotes the current pixel's position in x,y and I its intensity value. The fifth point is a point from a different source that will be match to the coordinate [0.43;0.46]. Report which bins of the joint histogram H will be updated and by what partial volume weights. [3]

x	y	I
0.4	0.4	4
0.4	0.5	3
0.5	0.4	6
0.5	0.5	2
0.43	*0.46*	*5*

Table 1

d) The figure below shows a schematic of a registration pipeline. What steps might be carried out in boxes x and y? The deformation update step is carried out by addition. What problem might this pose? How could the transformation update step by modified to avoid this problem? [4]



e) This question is about registration using non-parametric scheme:

i) Starting with the optical flow equation below, show that in more than one dimension the optical flow registration problem is ill-posed. [2]

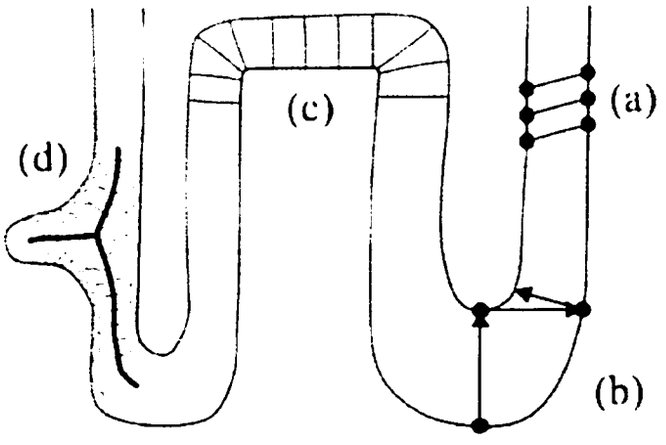
$$\frac{dA}{dt} = 0$$

ii) In the daemons registration algorithm, what regularisation method is used to help resolve a solution to the optical flow equation? [2]

iii) Non-parametric registration schemes such as diffusion or fluid registration can be regularised by solving a PDE. Describe two ways to efficiently solve this type of PDE. [2]

Question 4

a) Segmentations of the brain generated by label fusion, Gaussian mixture models, or surface based models can be used to measure the thickness of the cerebral cortex. Several thickness estimation methods are depicted in the figure below.



i) Identify and describe the four methods below (a-d). [8]

ii) What kind of segmentation algorithms provides the inputs necessary for methods (a-b) and for methods (c-d). [2]

iii) What are the advantages of each cortical thickness estimation methodology? [4]

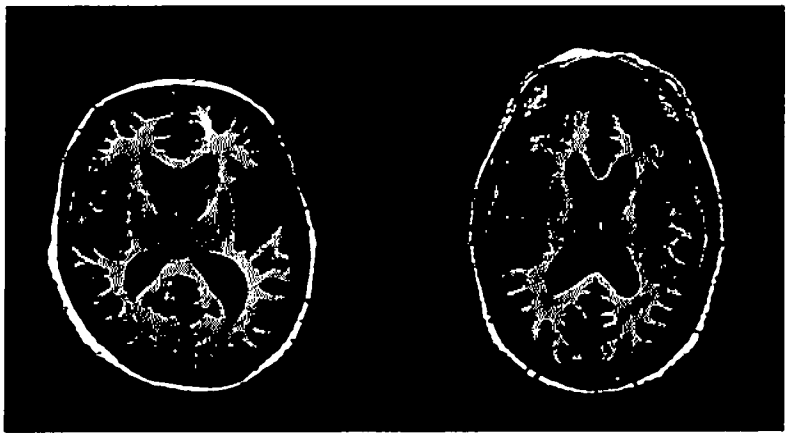
b) The Boundary Shift Integral (BSI) is a method to estimate volume change of the cerebral cortex and is widely used to investigate the differences between healthy ageing and dementias.

i) Briefly describe the technique, its requirements and its advantages. [3]

ii) Describe 3 problems that can arise while estimating the BSI and how would you solve each one of them. [3]

Question 5

a) Two different individuals have structural T1-weighted MR brain scans (see below). Comment on the suitability of using a registration algorithm to align these images for a study of local cortical volume change. If registration were required, what type of registration algorithm could be used? [3]



b) What is meant by the term 'groupwise registration'? Describe one possible application of this type of technique. [3]

c) Described the steps that are required to build a Statistical Shape Model (SSM) for medical imaging data [5]

d) State two examples of methods that are used within the SSM framework to model shape variability in the data. [2]

e) SSMs are often used in left ventricle segmentation of cardiac imaging data. Explain why this method is preferred over Gaussian Mixture model methods. [2]

f) Describe two further example applications of a SSM that are not cardiac related. What problems might you encounter in each case? [2]

g) What is an Active Shape Model and how does it differ from an Active Appearance Model? [3]

END OF PAPER