UNIVERSITY of York

BEng/BSc, MEng, MMath Examinations, 2017-2018

Introduction to Neural Computing and Applications (INCA)
Open Examination

Issued at:
Wednesday 28th February 2018

Submission due:
Wednesday 25th April 2018

Feedback and marks due:
Wednesday 23th May 2018

All students should submit their answers through the electronic submission system: http://www.cs.york.ac.uk/student/assessment/submit/ by 12 noon, **Wednesday 25th April 2018**. An assessment (or part of an assessment) submitted after this deadline will be marked initially as if it had been handed in on time, but the Board of Examiners will normally apply a lateness penalty to the whole assessment.

The feedback and marks date is guided by departmental policy but, in exceptional cases, there may be a delay. In these cases, all students expecting feedback will be emailed by the module owner with a revised feedback date. The date that students can expect to see their feedback is published on the module descriptor: http://www.cs.york.ac.uk/modules/

Your attention is drawn to the section about Academic Misconduct in the Departmental Statement on Assessment:
http://www.cs.york.ac.uk/student/assessment/policies/.

All queries on this assessment should be addressed to
Simon O'Keefe, simon.okeefe@york.ac.uk.

Your examination number must be written on the front of your submission.
You must not identify yourself in any other way.

Answers must not exceed 10 A4 pages in total, with a minimum 11pt font and minimum 2cm margins either side. This limit includes any title page, diagrams, references, and so on. Excess pages will not be marked.

Answer *all* questions.

Section A: Your answers to Section A must address all of the points in the questions to gain full marks. It is not necessary to submit code for the neural network, but you must evaluate thoroughly the performance of the network (in terms of accuracy). You must provide justification for the choices you make. If your network does not perform perfectly you will still get credit for attempting to explain the performance.

Section B: Credit will be given for reference to the appropriate literature. Your answer should show that you have understood the literature you have selected, are able to explain the material, and can critically compare material from different sources. You must comply with the Students' Handbook guidelines on referencing and plagiarism. You must also make it clear how the sources contribute to your answer: quotations or paraphrases from published sources will attract very few marks *unless* you show their context and relevance.

Section A - [70 marks]

This part of the assessment requires you to create a neural network. You may use any appropriate software to create the neural network, including but not limited to MATLAB and/or its toolboxes. A full justification for your choice of network and evaluation of its performance are more important than the ability of the network to produce "correct" results.

The data for this assessment are taken from the UCI Machine Learning Repository, and may be found on the Assessment page of the VLE site.

The problem is to guide a mobile robot in a wall-following navigation task. Your task is to construct a neural network to map from the sensor data that is given to movement instructions for the robot.

The data were collected as the robot navigates through a room moving approximately parallel to the wall in a clockwise direction, for 4 rounds. To navigate, the robot uses 24 ultrasound sensors arranged circularly around its "waist". The numbering of the ultrasound sensors starts at the front of the robot and increases in a clockwise direction.

For this assessment, you will use the data in the file `sensor_readings_24.data`, a CSV file that contains the raw values of the measurements of all 24 ultrasound sensors and the corresponding class label. Class labels indicate a movement direction - forward, slight right, sharp right, or slight left. Sensor readings are sampled at a rate of 9 samples per second.

The details of this file and all the measurements are given in the file:
`Wall-following.names`.

[This data was first used in:

Ananda L. Freire, Guilherme A. Barreto, Marcus Veloso and Antonio T. Varela (2009), "Short-Term Memory Mechanisms in Neural Network Learning of Robot Navigation Tasks: A Case Study". Proceedings of the 6th Latin American Robotics Symposium (LARS'2009), Valparaíso-Chile, pages 1-6.

DOI: `10.1109/LARS.2009.5418323`]

Your report for section A should be **no more than 7 A4 pages in length** and should contain the following sections:

1. [20 marks] Discussion of architectures.

   This should

   - identify the type of problem [2 marks]
   - identify which classes of architectures would be suitable [4 marks]
   - give a brief discussion of the technical features of the architectures, and the advantages and disadvantages of each [10 marks]

   You should then state which class of architecture you are going to use and justify your choice, relating the characteristics of the problem to the advantages/disadvantages of the architecture. [4 marks]

   To do this you might need to

   - do some preliminary experiments with simple versions of the architecture to get a feel for what will work
   - do some exploratory data analysis to see what the characteristics of the data are
   - consider the principles involved and relate them to the problem

2. [50 marks] Creation and application of a neural network with your chosen architecture.

   - Data [15 marks]

     Describe (briefly) the data you have, and how much there is of it.

     Describe the inputs to (and outputs from) the network. You need to describe how the data you started with have been preprocessed. Explain how you investigated the data, including any assumptions you have made. Again, this may include some testing of networks to see what the effects are of different preprocessing choices. [5 marks]

     Give a step by step process for transforming the data into the network inputs, with sufficient detail for someone else to process a new batch of data for use with the trained network. [10 marks]

   - Training [5 marks]

     State which training algorithm you selected for this problem. [1 mark]

Explain how you selected the best training algorithm for this problem. [2 marks]

For the training algorithm you used with the final version of the network, give sufficient detail for someone to implement the training algorithm. [2 marks]

This does NOT mean (for example) describe gradient descent in great detail. It DOES mean give any parameters, initialisation, etc, even if they are the toolbox defaults.

- Evaluations [10 marks]

  In selecting the final network you will have to make choices about, for example, the number of neurons or the number of layers to use.

  - Explain how you used the data in this selection process. For example, was it split into training, validation and test sets? How big were they? [2 marks]
  - Explain the metric or metrics you have used for comparison between networks. [3 marks]
  - Explain the process you went through in making the selection of the final architecture. If you evaluated a number of networks, give details of what their structures were and how they performed. You may summarise repeated tests of the same structure, but remember to give mean and variance of summary statistics. [5 marks]

- Network [10 marks]

  You should describe the network architecture that you have found to be the best for solving the problem.

  The description of the structure of the architecture should be sufficient for someone else to implement your network exactly, using different software, so you should include all the structural information and parameters necessary. Include a diagram.

  You should also indicate how you implemented it. This could be brief if you have used MATLAB defaults, for example.

- Results [10 marks]

  Give a synopsis of the results obtained from the final selected network. Relate these results back to the problem as stated – a MSE on its own is not helpful in judging how well something works. [6 marks]

Identify anything of interest in the results, such as areas of particularly good or poor performance, or variation between different training runs. [4 marks]

Section B - [30 marks]

Your report for section B should be **no more than 3 A4 pages in length**.

In the previous section you used a neural network to convert ultrasound sensor data into movement control for a robot.

Robots may also use many other sensors to collect data about their environment. In particualar, a robot may use a camera or cameras to examine its environment. However, applying neural networks to robot vision is non-trivial. Complex problems like vision require large networks, and training large neural networks requires a lot of training data. Collecting this data on robots is hard – the time and resource needed to collect a large body of data is significant, and robots may be subject to hardware failures. The resulting neural network is then robot specific and cannot be used on a different type of robot directly, therefore limiting the incentive to train such a network.

You should discuss *two* papers in the recent literature that present the use of different forms of neural networks in vision processing for robotics.

For *each* neural network, you should:

- Explain the main features of the architecture [5 marks]
- Explain how the network is trained, how much data is required, and how it is pre-processed [5 marks]
- Discuss the effectiveness of the architecture for a robot vision system [5 marks]