MASTERS IN ARTIFICIAL INTELLIGENCE
Advanced Topics in Cognitive Science, SEMESTER 2, block 4
Written Exam, June 21, 2019 09:00-11:00

Read these instructions carefully!

This exam contains 6 open questions. You will be graded on your answers for all questions. Each question is stated on a separate sheet of paper. You can use the rest of the paper to formulate your answer. There should be enough room (you can also write on the back side of the paper), but if you need extra paper you can ask one of the examiners.

Remember to write your name and student identification number on every sheet of paper that you hand in, because we will break the papers apart during grading. When you are finished, please check this on each page, and deliver your paper to the examiner. One of the examiners will sign off your exam.

You are allowed to have a pen, the exam, and your student identification on your desk. Please put everything else in your bag under the table (and turn off your mobile phone and any other connected device). Smart watches must also be placed in your bag.

Every question yields a maximum of 10 points. Your grade for this exam will be the average of your score on each of the 6 questions. This exam makes up 40% of your final grade.

Name:.....

Student ID number: .....

Name: **Student ID number:**

Question 1

a. Give two general properties of tasks in which deep learning approaches are often effective, but other AI approaches are not. (1 point)

b. Give a specific example of a data source to which artificial DCNNs are applied, which has:
   i) 1 dimension
   ii) 2 dimensions
   iii) 3 dimensions (3 points)

c. i) Describe the ReLU thresholding operation commonly used in artificial DCNNs, in terms of its inputs and outputs (1 point)
   ii) What is the main theoretical motivation for including a thresholding operation (1 point)

d. i) Describe the (max) pooling operation commonly used in artificial DCNNs (1 point)
   ii) What is the main theoretical motivation for including a pooling operation (1 point)

e. i) Describe the normalisation operation commonly used in artificial DCNNs (1 point)
   ii) What is the main theoretical motivation for including a normalisation operation (1 point)

ANSWERS

a. Difficult to describe using formal mathematical rules

   Easy/intuitive/automatic for humans (0.5 points each)

b. I) Language processing / time series processing
   ii) Image processing
   iii) Medical image processing (1 each)

c. I) Set negative outputs to zero (0.5) and make positive outputs proportional/equal to inputs (0.5)
   ii) Introduces a nonlinearity (1)

d. I) Downsample the input (0.5) by taking the maximum activation over small groups of inputs (0.5)
   ii) Reduces computational load introduced by increasing numbers of feature maps (1)

e. I) Subtract the mean activation of a group of units (0.5) then divide by the standard deviation (0.5)
   ii) Forces independent and identically distributions in different groups of units (or feature maps (1)
   OR Avoids response level drifting up from repeated thresholding
   OR Forces even split between active and inactive units
   OR Weights different feature maps similarly

Name: **Student ID number:**

Question 2

a. How are different inputs to a biological neuron integrated to determine the neuron's firing rate? (3 points)

b. i) How does the sharing of connection weights differ between biological neural networks and most artificial DCNNs? (1 point)

ii) Give three reasons why this difference occurs, considering the properties of both biological and artificial networks. (3 points)

c. i) Describe one spatial analysis of visual position information (i.e. a spatial filter) in the retina.

ii)Describe one non-spatial analysis of visual feature information in the retina. (3 points total for both parts)

a Synaptic inputs lead to excitatory **and inhibitory** post-synaptic potentials (1)
A single EPSP is too small to activate voltage gated sodium channels (1)
When several EPSPs arrive in a short time, they add together (1)
Only when this summed PSP reaches the threshold for sodium channel activation does the neuron fire (1)

b I) Weights are shared in artificial networks, not in biological networks (1)
ii) Biological filters use distinct, independent synapses (1)
Orientation pinwheel organisation emerges when weights are independent (1)
Artificial networks use a matrix multiplication (1)
A large matrix multiplication is fast (1)
Fewer weights need to be learned/better constrained network (1)

c I) Description of surround suppression (1) by nearby photoreceptors (1)
ii) Description of colour opponency (1) comparing the activity of different cone types (1) to determine ratio of activity (1). Specific example of comparison operations also get 1 point.
(Max 3 for both parts)

Name: **Student ID number:**

Question 3

a. In Huth and colleagues' paper "A continuous semantic space describes the representation of thousands of object and action categories across the human brain", they determine the object selectivity of individual fMRI recording sites (or voxels) from responses to viewing natural movies. Describe the essential steps in this experiment that allow the researchers to determine this object selectivity. (3 points)

b. In Yamins and colleagues' paper "Performance-optimized hierarchical models predict neural responses in higher visual cortex", they test the performance of various models, biological neurons, and human observers on object recognition tasks of increasing complexity.
   i) How did they change task complexity? (1 point)
   ii) How did the object recognition performance of different models, different biological neurons and human observers change with task complexity? (4 points)

c. Why does a network that includes recurrent lateral or feedback connections require models to run over several time points/cycles? (2 points)

Answers:

a. Tag natural movie time points with objects shown (1) and actions performed (1)
For each voxel, determine the weight of each category (1)
From linear regression to fMRI responses (1)
Cross validation (1)
PCA to semantic space (1) (Max 3)

b. I) Changed the amount of view variation
ii) All performed well in low variation tasks (1)
Humans, deep models and IT neurons stayed strong as variation increased (2)
V4 neurons (1) and simple models dropped performance with increasing variation (1)
(Max 4)

c. Feedback and lateral connections come from units that are not initially responsive (1)
Information from the current level must feed into other levels (1)
Then feed back to influence the current level (1)