Final Assessment COMP5400

The module will be assessed by an online open book examination. The assessment will be available for a 50-hour period. You are expected to complete the assessment during the 50-hour period.
The assessment brief will be released at 0900 BST via Minerva on 28 May 2020. The deadline for submission is 1100 BST 30 May 2020.

During the assessment you will be required to research one of the topics specified in the topic list below and write an essay with a minimum length of 1000 words. Each topic contains a number of questions that will help you structure the essay: address them, even if you cannot answer them directly. Pick one topic only.

Prior to and during the assessment, support will be available to you via the module Yammer group. You will shortly be added to the module Yammer group. Please check the Yammer group to see if your question has already been asked. Please refrain from contacting module staff directly regarding the assessment. During the assessment, module staff will be monitoring the Yammer group during working hours (0900-1700 BST).

You are expected to submit your assessment submission via Minerva before the specified deadline. If you are unable to make the submission before the deadline then you should contact the SSO explaining which assessment you were unable to submit on time. It is your responsibility to ensure your submission has been submitted successfully. Your submission should be in a single PDF file, ***containing your student ID, but not your name****. You may hand write and scan your work, or you may complete your work using text processing software (Office, LaTex, etc.).*

You are encouraged to check the assessment specification as soon after the release is possible.
If you have any queries then please use the Yammer group to ask questions.

Assignment

You will write an essay about a recent topic related to bio-inspired computing. You will be given a range of topics and must pick one. Within each topic a number of questions will be raised that must be considered when writing your essay. The text of your essay should be at least 1000 words; there is no page limit. You are encouraged to include illustrations. You are allowed to use every resource at your disposal, **including online research.**

Plagiarism

Plagiarism rules apply, you must be familiar with them. You are allowed to use brief verbatim quotes, provided they are double-quoted and referenced by source. You are allowed to paraphrase or reword larger pieces of text if they fit your overall narrative, again referenced by source. Refrain from communicating with your colleagues during the research and writing of this essay. It is possible that some of you will pick a similar topic, but I expect a different treatment, style and composition in each essay. Where similarities are too striking to be attributed to chance, the essays containing them will be referred to the plagiarism officer.

Topics

You must address one of the topics below (swarm intelligence; genetic programming; genetic algorithms for neural networks without predetermined architecture; neural networks: the history of Convolutional Neural Networks (CNNs); neural networks: compositionality). Within each of the following topics, elements are listed that *must* be discussed in your essay. **Pick only one topic.**

Assessment

A good essay demonstrates curiosity and interest in the topic, and an ability to relate the topics of your essay to the content of COMP5400M. It also addresses all the required elements of your topic. Personal opinions are welcome if they are well argued. Clarity and good style help, but grammatical errors or minor mistakes in English are not important, as long as they don't distract from the content.

Topic List

1 Swarm Intelligence

Find a recent (post 2010) project in the area of swarm intelligence. You cannot discuss the *KILOBOTS* or the *COLLMOT* projects, as they were discussed in the lectures. Be judicious: there are a lot of uninteresting projects, which makes writing a good essay harder. Address the following points:

- What problem does the project intend to solve?
- Why use swarms for this problem?
- Is there biological inspiration? If so, what is it?
- Can you identify stygmergy in the approach?
- Is the technology currently in use?
- Is the technology made possible by recent developments in hardware; or is the study a simulation study that relies on future development of hardware?
- In the module, we have identified one of the central problems of swarm intelligence that one must program the behaviour of the swarm by programming the agents. Does this project make a contribution to understanding how one can control collective behaviour by controlling the agents?

2 Genetic Programming

Address the following points:

- What is genetic programming? Describe its history briefly.
- How is it related to the genetic algorithms that we discussed in the module?
- What kind of genotype representations are used in GP?
- GP has led to impressive applications. Discuss a recent (2000 or later) one. Give details about how it works, and how GP achieved the solution. Would the solution have been feasible without GP?

The origin of this work can be found in: Koza, J. R., & Koza, J. R. (1992). *Genetic programming: on the programming of computers by means of natural selection* (Vol. 1). MIT press. There is a large series of books following on from this one. Consider travelling down its citation tree.

3 Genetic Algorithms for neural networks without predetermined architecture.

Address, among others, the following points:

- In the module, we have seen the use of genetic algorithms in neural networks, for example in: Beer, R. D., & Gallagher, J. C. (1992). Evolving dynamical neural networks for adaptive behavior. *Adaptive behavior*, *1*(1), 91-122.
- Use of GAs usually assumes a fixed neural network architecture, so that the weights can easily be encoded in a genome. What methods are available if the neural network architecture is not fixed? For an example, see: Gruau, F., Whitley, D., & Pyeatt, L. (1996, July). A comparison between cellular encoding and direct encoding for genetic neural networks. In *Proceedings of the 1st annual conference on genetic programming* (pp. 81-89).
- Give examples for the encoding of the genotype.
- What kind of applications require non-fixed neural architectures? What are the benefits of a neural network that can adapt its architecture?
- Can you find recent (2000 and later) examples of the use of this approach in technological applications?

4 Neural Networks: the history of Convolutional Neural Networks (CNNs)

Convolutional neural networks are biologically inspired. Often cited in this context are the work of Hubel and Wiesel, e.g. Hubel, D. H., & Wiesel, T. N. (1968). Receptive fields and functional architecture of monkey striate cortex. *The Journal of physiology*, *195*(1), 215-243. In your essay address the following points:

- In the literature, what is the essence of the work of Hubel and Wiesel. Why is it considered relevant for the development of neural networks?
- In general, what is the biological inspiration for CNNs?
- Who are the pioneers of CNNs? What are their contributions?
- In the 1980s, neural networks gained large popularity as part of a movement called Connectionism. What are the basic ideas behind Connectionism?
- In the 1990s, neural networks were replaced by so-called kernel-based methods and had fallen out of fashion. Why? Why did neural networks make such a strong comeback during the 2000s?

5 Neural Networks: Compositionality

Neural networks can be trained to do sophisticated image recognition tasks, among others. Once a neural network has been trained, it is difficult if not impossible to add novel information. Biological creatures have no such problems: they are capable of lifelong learning. There is general agreement that a neural network architecture that supports this capability must develop compositional representations, see e.g. de Kamps, M., & van der Velde, F. (2006). Neural blackboard architectures: the realization of compositionality and systematicity in neural networks. *Journal of neural engineering*, *3*(1), R1. This paper discusses the so-called **binding problem.** This problem is considered to be unsolved and

there is considerable controversy regarding its proposed solutions. In your essay, address the following points:

- What is the binding problem according to several authors?
- What are the various proposals for its resolution? Discuss at least 'binding by synchrony'; 'neural blackboard architecture'; 'tensor product representations'.
- Is this discussion related to symbol grounding?
- Is this discussion purely centred around human intelligence, or are there implications for a technology that can solve the binding problem?

Pointers can be found in van der Velde, F., & de Kamps, M. (2015). The necessity of connection structures in neural models of variable binding. *Cognitive neurodynamics*, *9*(4), 359-370, as well as Feldman, J. (2013). The neural binding problem (s). *Cognitive neurodynamics*, *7*(1), 1-11, and the references cited in these papers.

6 Hopfield Networks: The Travelling Salesman Problem

Discuss: Hopfield, J. J., & Tank, D. W. (1985). "Neural" computation of decisions in optimization problems. *Biological cybernetics*, *52*(3), 141-152.
You should address the following points:

- How does the network work?
- What is the role of energy in this paper?
- What are commonalities and differences between the Hopfield network presented in this paper, and discussed in the lecture?
- The Hopfield network is a constraint satisfaction network. What does this mean?
- The paper mentions a hardware implementation. Is the technology discussed still relevant?