COMP5400: Biological and Bio-Inspired Computation
Coursework 2:

Miniproject in Biocomputation, Biorobotics or Bioinspired Computation

Module Leader: Netta Cohen
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Marking

This coursework is summative and is worth 60% of the total grade for this module.

Assessment

There are two components to this assessment:

- A presentation in front of the class. Presentations are worth 50% of the marks. Presentations will take place in person on **Monday 12 May**.
- Written submission worth 50% of the marks: this will include at least **one** of the following:
  - Software submission + documentation
  - A report presenting your work.

  The written report will be due by: **Thursday, 6 May.**

Note: This coursework is worth 60% of the marks, and the time allotted to it should be commensurate.

Plagiarism

Projects are group projects for 2 students (on rare occasions, a larger group may be permitted on discussion with the module leader). You are encouraged to discuss your part of the project with others within your group and help each other with advice, integration and mock presentations. As appropriate, you are also encouraged to discuss material covered lectures, your related reading and ideas relevant to the coursework together with your group members. However, each student should have a separate task and must submit their own report/code. Any shared contribution (e.g. code that integrated different students' work) must be properly acknowledged. To do this, please include a **Statement of Contributions** at the start of your report or in the "readme" file if only submitting code.

Process: Finding a group and topic

A link to an online form will be circulated together with this coursework.

You may choose a topic, and then seek group members interested in the same topic, or else choose group members and then agree a topic amongst you. Once chosen, **please fill in requested information by 15 March at the latest.**

If you wish to be assigned to a group, please use fill in the online form with the requested information, including a maximum of 3 topics in order of preference. **Please fill in the form by 15 March at the latest.**

Overview

Part I: Picking a topic and objective
Each group should choose one of the topics we have covered in lectures, or any other related topic within the scope of the module. Define one specific task for your miniproject (or closely related tasks for different members of your group, working towards a coherent joint objective or addressing different aspects of a coherent common question). Possible tasks may fall into one or combine 2-3 of the following categories:

- Implementation and testing of a bio-inspired approach in a specific problem context
- Algorithm benchmarking or
- extension in a specific problem context

Notes:

- A list of potential topics and objectives are included at the end of this document.
- Multiple groups of students may choose the same topic.
- Avoid splitting projects into sequential sub-tasks (where one student waits for another student to deliver).
- Each student should contribute to both practical and theoretical aspects of the project. Collaboration is encouraged.

Part II: Presentations

- All group members must take part in the presentation.
- 8 minutes will be allotted per project for the presentation, including time for questions and answers.
- A characteristic template for presentations includes
    - A clear introduction of the topic and problem statement
    - Relevant Background
    - Methodology/Approach taken
    - Results/Outcomes
    - Discussion and Conclusions

  You may choose to follow this template or adapt it to better fit your specific topic or to fit the division of tasks among your group.

The following Mark Scheme will be used to guide the marking (out of 50 point):

Clarity and appropriateness of problem statement and introduction	10 pts
Coverage and evidence of understanding of the relevant background	10 pts
Quality of the work presented (including scope, achievement, methodology, results and conclusions)	20 pts
Quality and clarity of the presentation (including answers to questions)	5 pts
Appropriateness and effectiveness of the structure and style of the presentation (including sticking to the time)	5 pts

Part III: Written submission.

1) Practical component:
    - You must submit your code, documentation, a readme file with compilation/running instructions, a make file (if appropriate) and (if appropriate) sample inputs/outputs (e.g. inputs/outputs used in your presentation).
    - Your submission should consist of a single zip or tar file.

2) You are required to submit a single report per group. Report length should be no longer than 10 pages, using 11 point font, including figures but excluding references.
   Note: Only one student per group should make the submission, listing all group members.

Note: the expectation is that all group members contribute to the practical components as well as to the report.

Part IV: Suggested/Sample topics and objectives. The following topics are not exhaustive. Students are free to follow up on other suggestions made during lectures, or to suggest their own topics.

Note: Deep learning projects are outside the scope of this module.

Biological inspiration in artificial neural networks

1) Various topics can be considered, e.g. exploring bio-inspired architectures, bio-inspired training rules, etc.
2) Implement or explore an implementation of Hopfield Networks and evaluate their performance.
3) Implement or explore an implementation of Self Organising Maps and evaluate their performance.

Neurorobotics

4) Using the mouse demo in BEAST, replace the evolutionary learning with other neuro/bioinspired training algorithms. Can you outperform the evolutionary algorithm?
5) Using the mouse demo in BEAST, explore different neural architectures. Can you outperform the existing solution?
6) Implement or adapt an existing implementation of a simulated hexapod robot based on the original implementation by Gallagher et al. "Application of evolved locomotion controllers to a hexapod robot" Robotics and Autonomous Systems **19** (1)pp. 95-103 (1996): https://doi.org/10.1016/S0921-8890(96)00036-XGet
7) Implement or explore an implementation of subsubmption architectures.
8) Implement and train growing/pruning central-pattern-generating networks given a set task.

Molecular and cellular computation, cellular automata, etc.

9) Artificial Life, a critical exploration of Conway's Game of Life (For the first popular description of the game, see Scientific American **223**(4) (October 1970), pp. 120-123. https://www.jstor.org/stable/24927642
10) Implement or explore existing implementations of Lindenmayer systems.
11) Implement or explore a kinetic proofreading algorithm in an engineering or robotic context.

Evolutionary and/or co-evolutionary algorithms

12) Implement evolutionary and co-evolutionary algorithms, replicating or adapting the algorithm presented by Hillis (1990) for list sorting. Aim to demonstrate successful list sorting.
13) Implement an evolutionary or coevolutionary algorithm to study optimality of random walk or other foraging strategies.
14) Implement an evolutionary or coevolutionary algorithm to evolve more complex brains/brain architectures
15) Systematically study an aspect of evolutionary (or co-evolutionary algorithms) within the context of one of the demos in BEAST.
16) Extend the scope of evolution in BEAST to include other features of the agent (not only its brain).

17) Develop a new demo in BEAST (or another platform). If using BEAST, you may extend/modify (e.g. add features/micro-rules) to an existing demo, or start a new one. Examples might be:
    a. A demo to probe the evolution of cooperation
    b. A demo to probe the benefits of agent-agent interactions/communication in a group task.
    c. A demo to evolve specialisation among agents
    d. A demo to evolve novel structures (e.g. novel grippers, synthetic molecules, etc).
    e. A demo to probe the aesthetics of collective art.

Swarm Intelligence/Collective behaviour/Self organization and self-assembly

18) Implement a flocking algorithm in BOIDS or in a software framework of your choice. Analyze the contribution of the different rules.
19) Implement a flocking algorithm in BEAST.
20) Implement the Game of Life in BEAST, or unity, or other platform.
21) Implement or experiment with an existing implementation of Conway's Game of Life (if using an existing framework).
22) Implement an ant-inspired graph partitioning algorithm.
23) Implement and explore a swarm algorithm for construction or shape-forming.
24) Bacterial colonies can form fractal patterns on a dish. What is the underlying algorithm and how does it work? (A demo simulating such pattern formation is available in BEAST.)
25) Implement and study models of collective pedestrian motion and behaviour.

Part V: Suggested references (this list is in addition to references given out throughout the semester. It is not an exhaustive list and may/may not be relevant to your topic for the project):

26) Brooks, "Intelligence without reason" (1991), https://people.csail.mit.edu/brooks/papers/AIM-1293.pdf
27) Brooks, "Intelligence without representation" Artificial Intelligence **47**(1–3), pp. 139-159 (1991), https://doi.org/10.1016/0004-3702(91)90053-M.
28) Book by Daniel Amit (1989): "Modeling Brain Function: The World of Attractor Neural Networks"
29) Dennett "Why not the whole Iguana" Behavioral and Brain Sciences **1**, pp. 103-4 (1978), https://doi.org/10.1017/S0140525X00059859
30) Ijspeert et al., (2007) "From swimming to walking with a salamander robot driven by a spinal cord model", Science **315**(5817), pp. 1416-20. doi: 10.1126/science.1138353.
31) Boyle et al., "Adaptive Undulatory Locomotion of a *C. elegans* Inspired Robot" IEEE/ASME Trans. Mechatronics **18**(2), 439-448 (2013).
32) Lechner, Hasani and Grosu, "Neuronal Circuit Policies" (2018), https://arxiv.org/pdf/1803.08554.pdf
33) Marom and Shahaf (2002) "Development, learning and memory in large random networks of cortical neurons: lessons beyond anatomy" Quarterly Reviews of Biophysics, 35(1), 63-87. https://doi.org/10.1017/S0033583501003742
34) Li et al. "A Novel Robot System Integrating Biological and Mechanical Intelligence Based on Dissociated Neural Network-Controlled Closed-Loop Environment." PLoS ONE 11(11): e0165600. https://doi.org/10.1371/journal.pone.0165600
35) Artificial Immune Systems: any number of articles would be accepted. A recent review of the area is given by: R. Pump, V. Ahlers and A. Koschel, "State of the Art in Artificial Immune-Based Intrusion Detection Systems for Smart Grids," 2018 Second World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4), 2018, pp. 119-126, https://doi.org/10.1109/WorldS4.2018.8611584

36) Network Motifs for information processing. An example of a review paper is: Alon, U. Network motifs: theory and experimental approaches. *Nat Rev Genet* **8**, 450–461 (2007). https://doi.org/10.1038/nrg2102