Project Title: Spiking Neural P Systems: An Unconventional Model of Computation

Supervisor: Matteo Calliviere

Student: Michael Stachowicz **Student ID**: 15068126

Course-Specific Learning Outcomes:

1. Use knowledge, abilities and skills for further study and for a range of employment in areas related to scientific and technical computing.
2. Analyse, design, and implement algorithms using a range of appropriate languages and/or methodologies.
3. Apply the principles and operation of object-oriented programming within their work.
4. Demonstrate that the student has capability to learn and implement new material independent of teachings within their respective Degree programme.
5. Demonstrate effective communication, decision making and creative problem-solving skills, and identify appropriate practices within a professional, legal and ethical framework.
6. Critically appraise and apply suitable artificial intelligence techniques for use within a specific system.
7. Study the fundamentals of Spiking Neural P Systems and related analyse discuss and compare existing work ~~with their own findings.~~
8. Integrate the learning obtained from other units within this project and utilise the skills gained through their degree.
9. Implement an object-oriented solution which will focus on attempting to create an SN-P system which evolves utilising ~~a genetic algorithm implementation.~~

Project Background:

Spiking Neural P systems are an unconventional model of computation inspired by the structure and functioning of neurons. This project shall focus on the implementation of the most studied model, in which a neuron fires after a condition expressed by a regular expression is satisfied. This system will then be adapted to add the functionality which will allow it to evolve and learn the structures that allow for the implementation of a certain functionality.

The challenge of encoding information in the intervals of time passed between events, specifically in regard to related topics in neural computing, have already been discussed in several works such as W. Gerstner and W. Kistler's *Spiking Neuron Models. Single Neurons, Populations, Plasticity* [1] or W. Maass' *Computing with Spikes* [2], and an attempt at simulating these systems has been made in 2015 at the University of Seville by Luis Ramos [3]. An implementation of these methods with the specific goal of an SN-P system evolving and attempting to learn structures required for the recreation of an SN-P system for the purposes of solving a specific problem or implementing a certain functionality, however, has not yet been made.

In tandem with the research done in the field of genetic algorithms, this implementation will attempt to "evolve our simulation", as described in the 9th chapter of Daniel Shiffman's *The Nature of Code* [4]. In order to achieve this evolution, mutation needs to be possible within these systems, which can be achieved with the tweaking of multiple variables within an SN-P system, such as the number of rules a neuron can possess, the total amount of spikes a system can contain and the number of neurons which are allowed to be created within a confined system.

~~With a general solution,~~ given an indeterminate amount of time, ~~a system such as described would have the potential at delivering a specific system which would provide a solution to the requested use case to a calculated degree of fitness.~~ Note that the more complex a scenario for this system to compute is, the longer a solution would take to be created, however the performance of these systems is not the key focus in this research but instead the actual implementation of such a system. The use of different hardware for such computation, as described in section 6.6 of [3], would be beneficial in regard to improving performance as the parallel architecture of a Graphical Processing Unit could be used to simulate such a network with a higher fidelity compared to a Central Processing Unit, which takes instructions in sequence. This implementation however shall not be further discussed within the project.

Aim:

To design, implement and validate a program which can be used to simulate Spiking Neural P Systems, with the additional ability to evolve and learn.

Objectives:

To achieve the aim outlined above, several steps are required and are listed below:

1. Find material covering SN-P Systems and Genetic Algorithm theory and implementation through journal articles (accessed via the internet and university online databases) and books (accessed through the MMU Library).
2. Find related works which can be used as a source for this project.
3. Compare and make assumptions concerning the techniques used to implement an SN-P system.
4. Design, implement and validate the code which will simulate an SN-P system which can evolve and learn.
5. Study technologies which can be implemented within the program that will create a reliable and accurate software, as well as techniques which can increase performance at runtime.
6. Compare multiple techniques in which a genetic algorithm could be applied to make the SN-P system learn and evolve to produce a specific result.
7. Produce and collect data for comparison with previous studies.

Problems:

1. As an implementation of genetic algorithms utilising SN-P systems does not currently exist, there is a possibility that the solution may be very demanding on performance or simply inefficient to implement on current hardware.
2. As the designs for the simulation program are all made directly for this project, it is possible that a re-design might be necessary to fix issues which will arise during development.
3. Creating a non-deterministic system means that the randomisation algorithms which will be implemented might be difficult to debug, possibly preventing further development until a different approach is selected.
4. Due to time constraints a true general solution might not be possible, as this system will not be tested for use on other platforms.

Required Resources:

1. Personal PC
2. Microsoft Visual Studio 2015 Professional Edition for developing the C# code
3. LaTeX for compiling the final report
4. A range of Microsoft Office programs including Excel and Word for collecting and transcribing data, as well as any other draft work before a final compilation of the report.
5. GitHub account for storing of the source code in a private repository

Schedule: [To be added]

Deliverables:

1. A feasibility study
2. A final product which successfully satisfies the points described in aims
3. A final project report
4. A presentation

Ethics check form:

A1 Please confirm that you will abide by the University's Academic Ethical Framework in relation to this project.

- (•) Yes
- ( ) No

A2 Are you submitting this application as a learning experience, for a unit which already has ethical approval? (please confirm with your supervisor)

- ( ) Yes
- (•) No

A3 Student details

Title	First Name	Surname
	Michal	Stachowicz

Email: michal.stachowicz@stu.mmu.ac.uk

A4 Supervisor

Title	First Name	Surname
Dr	Matteo	Cavaliere

Faculty: Science and Engineering

Telephone: +44 (0)161 247 ----

Email: m.cavaliere@mmu.ac.uk

A5 Which Faculty is responsible for the project?

Science and Engineering

A6 Course title

6G6Z1101 Final Year Project

A7 Project title

Spiking Neural P Systems: An Unconventional Model of Computation

A8 What is the proposed start date of your project?

15/10/2018

A9 When do you expect to complete your project?

24/08/2019

A10 Please describe the overall aims of your project (3-4 sentences). Research questions should also be included here.

The project consists in implementing one of the most studied model of Spiking Neural P Systems and adapt the system to create a general solution which allows for the system to have the ability to evolve and learn the structure which allows for implementation of certain (provided at run-time) functionality.

A11 Please describe the research activity

Research mostly consists of investigating previous academic papers around the topic of Genetic Algorithms and SN-P systems, as well as investigating possible cryptographic solutions for a truly (or as close as possible) random algorithm, in order to implement a non-deterministic solution.

A12 Please provide details of the participants you intend to involve (please include information relating to the number involved and their demographics; the inclusion and exclusion criteria)

n/a

Project Activity

B1 Are there any Health and Safety risks to the researcher and/or participants?

- ○ Yes
- ◉ No

B2 Please select any of the following which apply to your project

- ☐ Aspects involving human participants (including, but not limited to interviews, questionnaires, images, artefacts and social media data)
- ☐ Aspects that the researcher or participants could find embarrassing or emotionally upsetting
- ☐ Aspects that include culturally sensitive issues (e.g. age, gender, ethnicity etc.)
- ☐ Aspects involving vulnerable groups (e.g. prisoners, pregnant women, children, elderly or disabled people, people experiencing mental health problems, victims of crime etc.), but does not require special approval from external bodies (NHS, security clearance, etc.)
- ☐ Project activity which will take place in a country outside of the UK
- ☑ None of the above

B2.4 Is this project being undertaken as part of a larger research study for which a Manchester Metropolitan application for ethical approval has already been granted or submitted?

- ○ Yes
- ◉ No

Data

F1 How and where will data and documentation be stored?

Online storage solutions include github.com for the open-source project code, as well as MMU servers for the documentation.
Offline storage is held on a personal hard-drive used for development of the code and writing of the documentation.
All of the data is digital.

F2 Will you be collecting personal data or sensitive personal data as part of this project?

- ○ Yes
- ◉ No

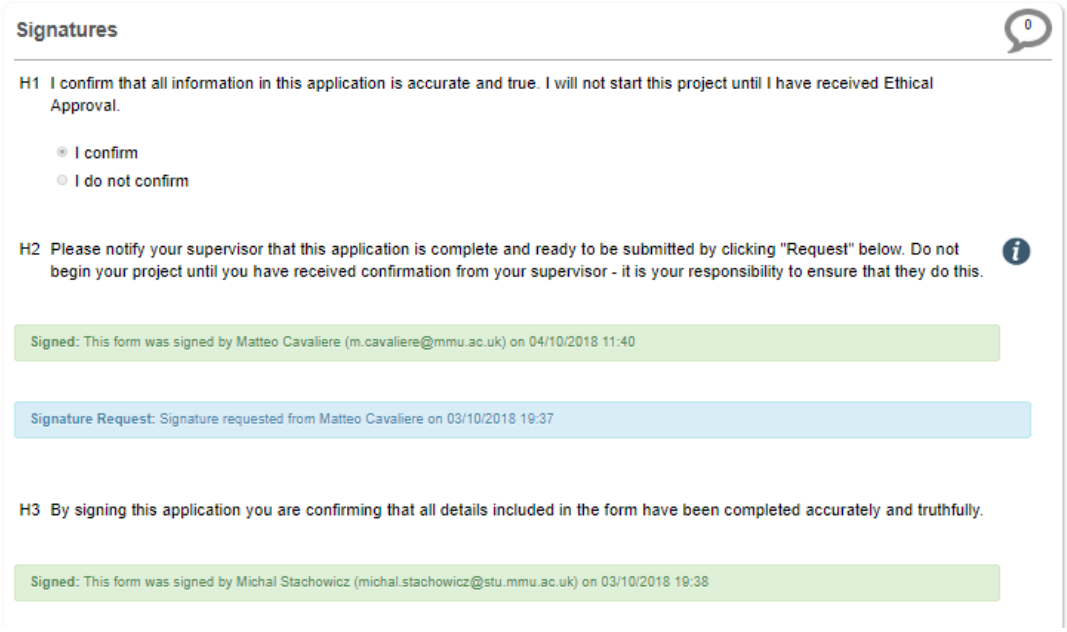
Additional Information

G1 Do you have any additional information or comments which have not been covered in this form?

- ○ Yes
- ◉ No

G2 Do you have any additional documentation which you want to upload?

- ○ Yes
- ◉ No



Signatures

H1 I confirm that all information in this application is accurate and true. I will not start this project until I have received Ethical Approval.

- I confirm
- I do not confirm

H2 Please notify your supervisor that this application is complete and ready to be submitted by clicking "Request" below. Do not begin your project until you have received confirmation from your supervisor - it is your responsibility to ensure that they do this.

Signed: This form was signed by Matteo Cavaliere (m.cavaliere@mmu.ac.uk) on 04/10/2018 11:40

Signature Request: Signature requested from Matteo Cavaliere on 03/10/2018 19:37

H3 By signing this application you are confirming that all details included in the form have been completed accurately and truthfully.

Signed: This form was signed by Michal Stachowicz (michal.stachowicz@stu.mmu.ac.uk) on 03/10/2018 19:38

References:

[1] W. Gerstner, W Kistler: Spiking Neuron Models. Single Neurons, Populations, Plasticity. Cambridge Univ. Press, 2002.

[2] W. Maass: Computing with spikes. Special Issue on Foundations of Information Processing of TELEMATIK, 8, 1 (2002), 32–36.

[3] L. F. M. Ramos, Developing efficient simulators for cell machines. University of Seville Dpt. of Computer Science and Artificial Intelligence, 2015.

[4] D. Shiffman, The Nature of Code: Simulating Neural Systems with Processing. Daniel Shiffman, 2012.