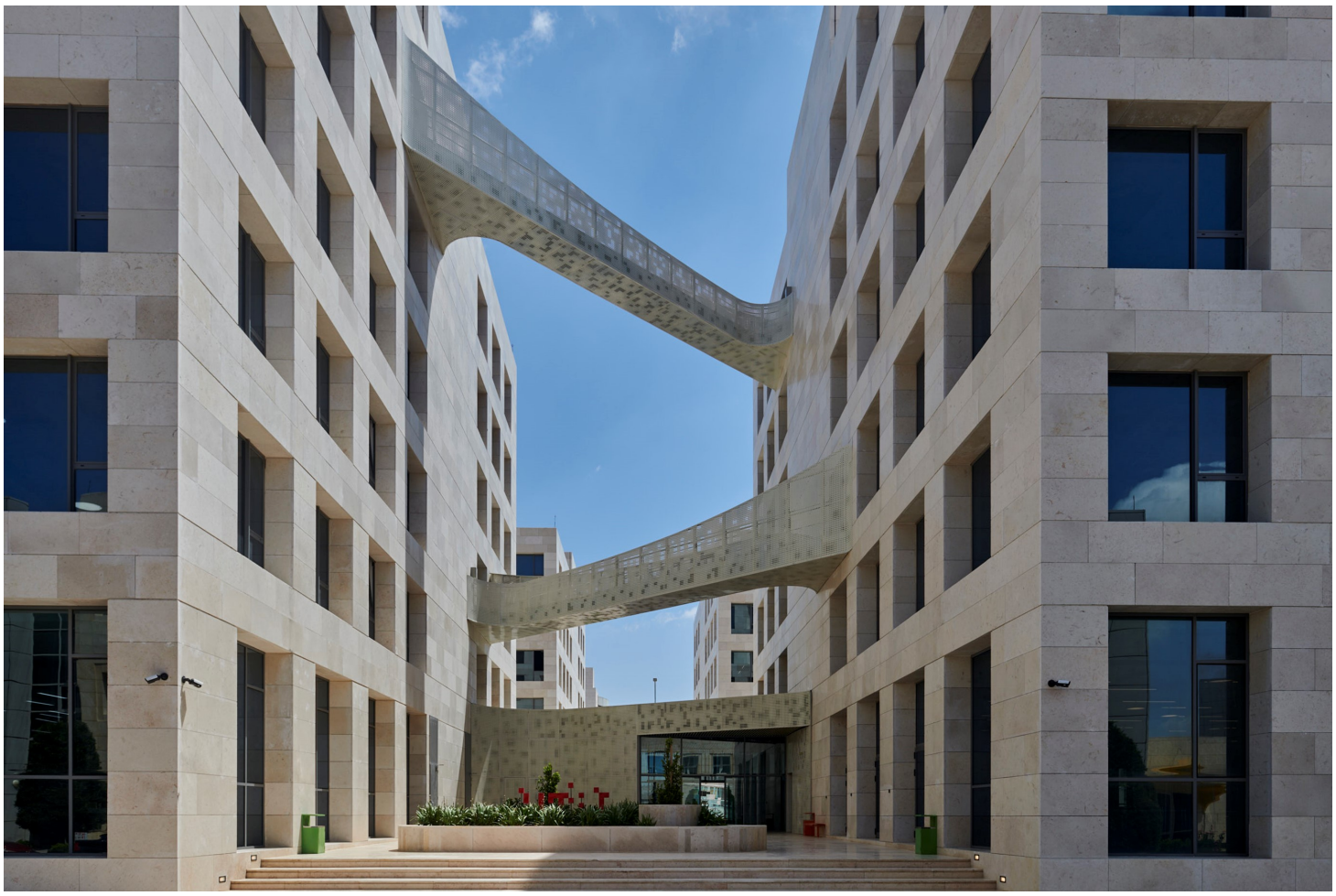
جامعة الحسين التقنية
Al Hussein Technical University

ASSIGNMENT BRIEF

HTU Course No: 10204330	**HTU Course Name:** Modeling and Simulation
BTEC Unit Code:	**BTEC UNIT Name:**

Version: 3



Student Name/ID Number/Section	
HTU Course Number and Title	10204330 Modeling and Simulation
BTEC Unit Code and Title	
Academic Year	2023-2024 Spring
Assignment Author	Murad Yaghi
Course Tutor	Murad Yaghi
Assignment Title	Application of Modeling and Simulation in Computational Neuroscience
Assignment Ref No	1
Issue Date	01/05/2024
Formative Assessment dates	From 01/05/2024 to 30/05/2024
Submission Date	15/06/2024
IV Name & Date	Rami Al-Ouran 30/04/2024

Submission Format

The assignment consists of 2 parts, take-home assignment, and in-class assignment.

Submission for part 1 of the assignment is expected to be as follows:

1. The submission of a report in the form of a **Docx** soft copy submitted to the university's eLearning system as well as ipynb for Python code.
2. Written in a formal business style using single spacing and font size 12, of times roman.
3. You are required to make effective use of headings, bullet points, and subsections as appropriate, and your work must be supported with real-world examples and research papers/books.
4. Your research should be referenced using the IEEE referencing system.
5. All the results and figures generated in Python (ipynb file) should be copied to the Docx report file with in-detail comments and analysis for the appropriate part.

Submission for part 2 of the assignment is expected to be as follows:

1. The submission of an in-class assignment that would be given at the specified date
2. Declaration Form

eLearning Submission Checklist:

o No compressed files or folders (no.zip or .tar extensions)

o Report file named as "FirstName LastName MS part 1 Spring 23-24.docx".

o Notebook named as "FirstName LastName MS part 1 notebook Spring 23-24.ipynb"

o Declaration form named as "FirstName LastName MS Declaration Form Spring 23-24.docx"

Unit Learning Outcomes

LO1 Introduction and Basic Principles of Modeling and Simulation.

LO2 Modeling and Simulation for Continuous First Order Systems.

LO3 Modeling and Simulation for Continuous Second Order Systems.

LO4 Advanced Data-Driven Techniques for Modeling and Simulation of Continuous Systems

Assignment Brief and Guidance

Scenario: You are working as a research assistant in a modeling and simulation lab. Your role includes simulating real models formulated mathematically using differential equations by another specialized team. You should provide a simulation and analyze the produced results for each given system. Your role also includes optimizing these differential equations and finding their parameters using empirical data, as well as solving some of these differential equations to provide more efficient simulation

Task I:

You are currently involved in simulating the neuronal behavior of the human brain. Another team has formulated a differential equation that mimics the behavior of a single neuron based on Nagumo model, and you have to simulate and optimize the dynamical behavior of this system using Python.

The Nagumo model was developed by Jinichi Nagumo, following the foundational work by Richard FitzHugh, to create a simplified model for describing action potentials in neurons. Action potentials are rapid electrical signals that travel along nerve cells, leading to communication between neurons.

the system of differential equations can be represented as:

$$\frac{dv}{dt} = v - \frac{v^3}{3} - w + I,$$

$$\frac{dw}{dt} = \varepsilon(v + a - b \cdot w),$$

- Describe and investigate the single-neuron modeling principles.
- Investigate the benefits of applying modeling and simulation for simulating the neuronal dynamics
- Simulate each equation using Python and plot the results for each equation.
- Explain the theoretical principles of each equation and the effect of varying the differential equation's parameters.
- Simulate the second-order system that consists booth equations together, where I(t) is the input, and V(t) is the output
- Explain the theoretical principles of the second-order system and the effect of varying the differential equation's parameters.
- Use empirical data to tune the parameters of a simulation model, the imperial data can be downloaded from: https://celltypes.brain-map.org/experiment/electrophysiology/474626527

    - This website contains many electrophysiological data of the neurons where the output V has been measured for many input values I.
    - It also contains the data for many many neurons in many brain cells and other species, you will be informed on specific ones to follow.
    - You can use a ready script in colab to download the data: https://allensdk.readthedocs.io/en/latest/_static/examples/nb/cell_types.html
- Apply different optimization techniques to tune simulation parameters.

Task II:

- Design a detailed workflow for solving a specific problem using modeling and simulation.
- Evaluate the performance of the second-order system in achieving desired behavior.
- Analyze the effectiveness of each optimization technique for tuning the parameters of the simulation using empirical data.

Task III:

- Investigate previous methods and work done in the field of neuronal modeling.
- Critically analyze and compare the performance of different models used for neuronal modeling and simulation.

Learning Outcomes and Assessment Criteria			
Learning Outcome	**Pass**	**Merit**	**Distinction**
LO1 Introduction and Basic Principles of Modeling and Simulation.	**P1** Describe a specific problem suitable for applying modeling and simulation. **P2** Investigate the benefits of applying modeling and simulation for specific problem	**M1** Design a detailed workflow for solving a specific problem using modeling and simulation	**D1** Investigate the previous methods and work done to solve specific problem
LO2 Modeling and Simulation for Continuous First Order Systems.	**P3** Simulate a first order system using appropriate programming language **P4** Explain the theoretical principle of a first-order system and the effect of varying the differential equation parameters	**M2** Solve basic separable first-order differential equations analytically using appropriate methods	**D2** Solve advanced first-order differential equations analytically using appropriate methods
LO3 Modeling and Simulation for Continuous Second Order Systems.	**P5** Simulate a second-order system using an appropriate programming language **P6** Explain the theoretical principle of a second-order system and the effect of varying the differential equation parameters	**M3** Evaluate the performance of a second-order system in achieving the desired behavior	**D3** Solve second-order differential equations analytically using appropriate methods
LO4 Advanced Data-Driven Techniques for Modeling and Simulation of Continuous Systems	**P7** Use empirical data to tune the parameters of the simulation model. **P8** Use different optimization techniques to tune the simulation parameters	**M4** Analyze the performance of each optimization technique to tune the parameters of the simulation with the empirical data	**D4** Critically analyze and compare the performance with different models