



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF APPLIED SCIENCES
DEPARTMENT OF COMPUTER SCIENCE
COMPUTATIONAL MODELLING
SCS2209

May 2024

Final Examination Paper

This examination paper consists of five (5) pages

Time Allowed : 3 hours

Total Marks : 100

Scientific Calculators are permitted

Examiner's Name : Mr. T. Taapatsa

INSTRUCTIONS

1. Answer Question 1 and then answer 3 other questions of your choice

MARK ALLOCATION

QUESTION	MARKS
1	25
2	25
3	25
4	25
5	25
TOTAL	100

Question One

- a) Explain the following terms as they are used in Computational Modelling
- i. Model Validation *The overall purpose of the model according to functions* [2]
 - ii. Model Verification *Does the model do what its suppose to do given a set of conditions and parameters* [2]
- b) Explain the difference between a deterministic and a stochastic model [4]
- c) With the aid of an example, explain the steps of the modelling process [10]
- d) A model is represented by the following system of linear equations

$$4x + 3y - 5z = 2$$

$$-2x - 4y + 5z = 5$$

$$8x + 8y = -3$$

Write a Python program to solve the system of linear equations and print the values of x, y, and z [7]

Question Two

- a) Explain the following terms as they are used in Markov Chains
- i. Random Walk [2]
 - ii. Absorbing State [2]
- b) With the aid of a suitable diagram, explain overfitting and underfitting [4]
- c) A Markov chain has three states namely Sunny (S), Cloudy (C), and Rainy (R).
The transition between the states is given as:
- From state S (Sunny), there's a 70% chance of staying in S, a 30% chance of moving to C (Cloudy), and a 0% chance of moving to R (Rainy).
 - From state C (Cloudy), there's a 40% chance of moving to S, a 60% chance of staying in C, and a 0% chance of moving to R.
 - From state R (Rainy), there's a 20% chance of moving to S, a 30% chance of moving to C, and a 50% chance of staying in R.
- i. Find the transition probability matrix. [2]
 - ii. Find the steady-state distribution of the Markov chain. [5]
 - iii. Give the interpretation of steady-state distribution [2]
 - iv. Write a Python program to print the steady-state distribution [8]

Question Three

- a) Explain any three characteristics of a good model [6]
- b) Explain the purpose of Sympy and PuLP Python Libraries [4]
- c) Explain the law of large numbers as it is used in Monte Carlo Modelling [2]
- d) Write a Python program to evaluate the following integral [5]

$$\int_0^1 4x - 6\sqrt[3]{x^2} dx$$

- e) Using Monte Carlo integration with a sample size of $n = 10,000$ points, write a Python program to estimate the integral of the following equation [8]

$$\int_0^{\pi} e^{-x} \sin(x) dx$$

Question Four

- a) Explain the following terms used in optimisation modelling [2]
 - i. Objective functions [2]
 - ii. Constraints
- a) Explain the logistic population growth model. Address the following points in your answer: [2]
 - i. Assumptions of the model [2]
 - ii. An illustration using a suitable diagram [2]
 - iii. Mathematical equations of the model [2]
 - iv. Explanation of the terms and parameters used in the equations [2]
 - v. Explanation of a real-world application of the model [2]
 - vi. Limitations and critiques of the model [2]
- b) A certain model is represented by the following linear model

$$\text{Maximise } Z = 12x_1 + 3x_2 + x_3$$

Subject to:

$$10x_1 + 2x_2 + x_3 \leq 100$$

$$7x_1 + 3x_2 + 2x_3 \leq 77$$

$$2x_1 + 4x_2 + x_3 \leq 80$$

$$x_1, x_2, x_3 \geq 0$$

Write a Python program to compute the values of x_1 , x_2 , and x_3 that give an optimal solution [9]

$P_0 \times e^{r \left(\frac{P_0 - K}{P_0} \right)}$
Logistic model
↓
Carrying Capacity

Question Five

- a) "On 20 January 2024, Africa CDC sensitised Heads of State and Government from the Southern Africa Development Community (SADC) regarding the increase of cholera-related cases and deaths in the region. Heads of State and Government then decided to organise an extraordinary summit hosted by the SADC Secretariat and led by President Lourenco from Angola as the Chair of SADC. This meeting was held virtually on 2 February 2024 to receive and consider a report on the status of the cholera outbreak in the SADC region. They expressed concern on the progress made in curbing the situation and the challenges that continue to hamper the effective fight against the recurrent outbreaks.

What We Know

The cholera situation in Africa is aggressive and more protracted in multiple countries. From January 2023 to January 24, 2024 (13 months), a total of 252,934 cases and 4,187 deaths (CFR 1.6%) have been reported from 19 African Union Member States. Over 72.5% of the total cases are reported from the SADC region."

Source Communications@africacdc.org

As a Computational Modelling Consultant, you have been asked to advise the Africa Centre for Disease Control (Africa CDC) to recommend a suitable model that can be used to understand and predict the spread of the disease. Write a report, which addresses the following points:

- i. The name of the recommended disease model [1]
- i. The assumptions of the model [2]
- ii. Mathematical equations of the model [2]
- iii. Explanation of the variables and parameters used in the equations [2]
- iv. Limitations and critiques of the model [4]
- v. List any 2 alternative models [2]
- vi. List any 2 software tools that can be used to implement the model [2]
- vii. List any two interventions to curb the spread the spread of the disease [2]

b) The table below shows that annual sales data for company XYZ

Month	1	2	3	4	5	6	7	8	9	10	11	12
Sales	500	520	520	510	530	580	610	620	580	550	510	480

Write a Python program to plot a chart to visualise the Sales data, fit a polynomial curve of degree 2 to the data and plot a curve on the same chart. Properly label the chart, with a chart title: "XYZ Annual Sales Report"; an x-axis label: "Month"; a y-axis label: "Sales" and legend labels for the data points and the polynomial curve [8]

END OF QUESTION PAPER