National University of Computer and Emerging Sciences

Lahore Campus

ML for Robotics (CS 4090) Final

Date: December 23, 2025

Course Instructor(s)

Dr. Mirza Mubasher Baig

Total Time (Hrs): 3

Total Marks: 65

Total Questions: 4

Roll No _____ Section _____ Student Signature _____

Instructions: Attempt all questions

In Case of any missing values state your assumptions clearly

You are allowed to use on handwritten cheat-sheet during this exam

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Question No 1: [Machine Learning Shorts]

Give a precise answer for each of the following short question

a) Compute the number of parameters of an RNN that has 20 hidden units, 4 output units and 10 inputs. **[2 Points]**

b) A famous convolutional neural network is used to classify an image into one of the 36 categories. The network consists of a convolution layer with 6 filters of size 5 x 5 followed by a 2 x 2 average pooling layer another convolutional layer with 16 filters of size 5 x 5 followed by another 2 x 2 average pooling layer another convolutional layer with 120 filters of size 5 x 5 followed by a fully connected network with 84 hidden neurons in a single hidden layer and finally the output layer. Assume that all convolutional layers work without padding and hence output volume size decreases. Also assume that an input of size 32 x 32 is provided. Compute the total memory size of this network assuming that each weight is stored as a 4 byte floating point number. **[5 Points]**

c) Find the equation of the decision boundary for the linear classifier with weights W= [2 3] and bias -6. **[2 Points]**

d) A linear decision boundary has equation $x_1 - x_2 - 1 = 0$.
Determine the category of the point (2, 2) using this decision boundary. **[2 Points]**

e) You are predicting the target value for a query point using weighted KNN regression with k=4. The four nearest neighbors have the following distances and target values:

- **Neighbor 1:** distance = 0.5, target = 12
- **Neighbor 2:** distance = 1.0, target = 9
- **Neighbor 3:** distance = 1.5, target = 15
- **Neighbor 4:** distance = 2.0, target = 8

Compute the predicted value using **Inverse-distance weights i.e.** $w_i = 1 / d_i$ **[3 Points]**

f) Classify the query point (2, 3) using the following 2D **training dataset** using KNN for classification with k = 3. Use Manhattan distance for ease of calculations **[2 Points]**

Point (x,y)	Label
(1, 2)	A
(2, 1)	A
(4, 4)	B
(5, 5)	B
(3, 3)	B

g) You are solving a binary classification problem (spam vs. not spam). Two models with similar validation accuracy have been trained:

- **Model A:** A simple logistic regression classifier with 5 features.
- **Model B:** A deep neural network with 10 hidden layers, hundreds of parameters, and complex feature interactions.

Which model will be preferred if the principle of Occam's razor is used? Give a brief justification using the main idea of the principle **[2 Points]**

h) Create computation graph of a neuron with two inputs and a bias term that uses sigmoid activation to form the final output. Use your graph to compute the gradient of the loss w.r.t. learnable parameters and update the weights given that the input example is (Input:[1 -1] , Target:1) and initial weights and bias are [0.1, -0.1] and 0 respectively. Assume that cross entropy loss is used if needed **[6 Points]**

i) For each of the following scenarios, state whether it is a regression problem or a classification problem. Justify your answer in one sentence. **[4 Points]**

I. Predicting the selling price of a house based on its size, location, and number of rooms.
II. Predicting whether an email is spam or not spam based on its content.
III. Predicting the temperature for the next day based on historical weather data.
IV. Predicting the digit (0–9) in a handwritten image using pixel values.

j) Define a linear classifier in terms of how output is computed using inputs. Below are descriptions of several famous machine learning models discussed in class. For each model, state whether it is a linear classifier or not. Justify your answer using your definition in one sentence. **[5 Points]**

I. Perceptron used to separate two classes in a 2-D feature space.
II. Support Vector Machine (SVM) with a linear kernel.
III. Decision Tree that splits data based on feature thresholds.
IV. Logistic Regression applied to binary classification.
V. k-Nearest Neighbors (k-NN) classifier with k = 3.

Question No 2: [Reinforcement Learning] **[4 + 4 + 3 + 4 Points]**

A self-exploring robot is trying to learn a policy to reach the nearest charging port available in a grid world. Assume that it operates in a **4 × 4 grid world** with each cell in the grid is identified by coordinates (x, y), where (x, y take values in {0,1,2,3}) and that there are two charging ports available at positions (0, 0) and position (3, 3) respectively.

At each time step, the robot can execute one of the deterministic actions i) Up (U), ii) Down (D) iii) Left (L) or iv) Right (R) with actions that would move the robot outside the grid leave it in the same cell.

a) Formulate this problem as a **reinforcement learning task** by clearly specifying:
   I. State space
   II. Action space
   III. Terminal states
   IV. Reward function

b) The robot is trained using **Q-learning** and experiences the episode {(2,2) **U** (2,1) **L** (1,1) **L** (0,1) **U** (0,0)} i.e the robot was initially at position (2, 2) and it moved UP, Left, Left and finally Up to reach a terminal state.

   Using the **Q-learning update rule**, compute the **Q-value updates** for the given episode, starting from the terminal transition and proceeding backwards i.e. in each episode we modify the Q-value of entire sequence. Assume that the learning parameters used during the Q-value updates are

   - Learning rate $\alpha = 0.5$
   - Discount factor $\gamma = 0.9$
   - The reward is +10 for reaching the charging port and -1 for any other move
   - Initial Q-values ($Q(s,a) = 0$) for all state–action pairs

c) How does the values of various learning parameters, **α, γ and ε** effect the balance between future reward and immediate reward while learning Q-table values?

d) Explain how an ε-greedy policy affects the trade-off between exploration and exploitation in reinforcement learning.

Question No 3: [Histogram Filtering] **[2 + 5 + 3 Points]**

A mobile robot operates in a **1-D grid world** consisting of **5 discrete cells** labeled ({0,1,2,3,4}). The robot can face **two possible orientations: East (E)** or **West (W)**. The robot maintains its state as x = (p, θ) where robot position p is in {0, 1, 2, 3, 4}) and robot orientation θ is in {E, W}

The following motion model is used to update the robot belief when it executes the action **Move Forward** command.

- If the robot faces **East (right)**, it moves one cell to the right with probability **0.8**, and stays in the same cell with probability **0.2**.
- If the robot faces **West**, it moves one cell to the left with probability **0.8**, stays in the same cell with probability **0.1** and move two positions to left with probability **0.1**
- If the robot is at the boundary and attempts to move outside the grid, it remains in the same cell.

Initially the robot is in cell 2 and has perfect knowledge about its position on the grid but has **no knowledge of its orientation**, and hence its belief about the orientation is **uniformly distributed** over all possibilities.

a) How do we represent the **belief of robot** to implement histogram filter for this problem.

b) Compute the updated belief of the robot from its initial belief after a single move forward command is executed.

c) Update the belief of robot after it performs a second move-forward command.

Question No 4: [Project] [3 + 2 + 2 Points]

a) Describe in detail the problem your group addressed in your Kaggle competition project. In your answer, clearly specify: i) The input data used ii) The desired outputs or predictions and iii) The performance metric(s) used to evaluate your solution.

b) Describe the main steps (Maximum -5 steps) your group used to solve the Kaggle challenge in your project.

c) Describe the state representation of your reinforcement based assignment done at the end of the course