AAE4011 Assignment 1: Artificial Intelligence in Unmanned Autonomous Systems

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March 4, 2025

Instructions

- Answer all questions in this assignment.
- Show all your work for calculation problems.
- You may use references but must properly cite them.
- The use of ChatGPT or similar tools is permitted for coding examples, but must be acknowledged.
- **All answers must be handwritten.** Typed solutions will not be accepted.

Questions

Q1: AI, Machine Learning, and Deep Learning (10 points)

What is the difference between AI, machine learning, and deep learning? Which is more explainable and why?

Q2: Spam Email Filtering (10 points)

Please explain the principle of machine learning for spam email filtering. Is this an example of supervised learning or unsupervised learning? Justify your answer and describe the process in detail.

Q3: Linear Regression for Classification (25 points)

Consider the following two categories of data points:

Category A (10 points):

$$(1,3),(2,7),(3,5),(4,8),(5,7),(6,9),(7,10),(8,11),(9,13),(10,14)$$

Category B (10 points):

$$(1,1),(2,2),(3,1),(4,2),(5,3),(6,3),(7,4),(8,5),(9,5),(10,6)$$

(a) Plot all the points on a coordinate system, using different symbols or colors for each category. *(6 points)*

(b) Use linear regression to find a straight line that best separates the two categories. Express your answer in the form $y = mx + b$, where m is the slope and b is the y-intercept. *(7 points)*

(c) For each point, determine whether it is correctly classified by your linear separator. Calculate the overall classification accuracy. *(6 points)*

(d) Suggest how the approach might be improved for better classification results. *(6 points)*

Q4: Logistic Regression for Classification (25 points)

Consider the following two categories of data points:

Category A (10 points):

$$(2,1),(3,2),(2,3),(4,3),(5,4),(6,5),(7,4),(7,6),(8,6),(8,7)$$

Category B (10 points):

$$(1,7),(2,6),(3,8),(4,7),(5,9),(6,8),(4,10),(7,9),(5,10),(6,11)$$

In logistic regression for binary classification, we use the sigmoid function $\sigma(z)$ to map the output to a probability value between 0 and 1:

$$\sigma(z) = \frac{1}{1+e^{-z}}$$

where $z = w_1 x + w_2 y + b$ is a linear combination of the input features, with w_1, w_2 as weights and b as the bias term.

(a) Plot all the points on a coordinate system, using different symbols or colors for each category. Label Category A as class 0 and Category B as class 1. *(5 points)*

(b) Implement logistic regression to find the optimal parameters w_1, w_2, and b that best separate these two categories. You may use gradient descent or any appropriate optimization method. Clearly state your approach and show your work. *(7 points)*

(c) Express the decision boundary in the form of an equation $w_1x + w_2y + b = 0$. This boundary corresponds to the line where $\sigma(w_1x + w_2y + b) = 0.5$. Plot this boundary on your graph from part (a). *(5 points)*

(d) For each data point, calculate the predicted probability using your logistic regression model: $\hat{y} = \sigma(w_1x + w_2y + b)$. Classify each point as class 0 if $\hat{y} < 0.5$ and class 1 if $\hat{y} \geq 0.5$. Calculate the overall classification accuracy. *(4 points)*

(e) Explain why logistic regression is often preferred over linear regression for binary classification tasks. Include in your explanation the limitations of linear regression in classification scenarios. *(4 points)*

Q5: Gradient Descent for Univariate Quadratic Function (15 points)

Consider the quadratic function $f(x) = ax^2 + bx + c$ where $a > 0$.

(a) Derive the gradient of this function. *(4 points)*

(b) Write the update rule for the gradient descent algorithm to find the minimum of this function. *(5 points)*

(c) If $a = 2$, $b = -4$, and $c = 5$, use gradient descent with a learning rate $\alpha = 0.1$ to find the minimum value of the function. Show your work for 5 iterations, starting from $x_0 = 0$. *(6 points)*

Q6: Gradient Descent for Multivariate Quadratic Function (15 points)

Consider the quadratic function $f(x, y, z) = 2x^2 + 3y^2 + 4z^2 + 2xy - 4xz + 2yz - 6x - 8y - 10z + 5$.

(a) Compute the gradient $\nabla f(x, y, z)$. *(5 points)*

(b) Write the update rules for gradient descent for each variable. *(5 points)*

(c) Starting from the point $(x_0, y_0, z_0) = (0, 0, 0)$ and using a learning rate $\alpha = 0.1$, perform 3 iterations of gradient descent. Show your calculations at each step. *(5 points)*

Grading Criteria

- Correct understanding of concepts: 40%
- Mathematical accuracy: 30%
- Clarity of explanations: 20%
- Problem-solving approach: 10%

Handwriting Requirement

- All solutions must be written by hand on blank paper.
- Your handwriting must be clear and legible.
- Mathematical notations, equations, and graphs must be drawn by hand.
- Make sure your name and student ID are clearly written on each page.
- Typed solutions will receive a grade of zero.

Due Date

Submit your completed assignment by March 21, 2025.