Assignment

March 11, 2025

1 Deep Neural Network (DNN) Question

Consider a Deep Neural Network (DNN) with 4 layers:

- **Layer 1**: Input layer with 2 nodes.
- **Layer 2**: Hidden layer with 3 nodes.
- **Layer 3**: Hidden layer with 2 nodes.
- **Layer 4**: Output layer with 1 node.

There are no activation functions applied to any of the nodes. The weight of the connection between the i-th node in one layer and the j-th node in the next layer is denoted by w_{ij}. Each node has a bias term associated with it.

1.1 Weights and Biases

1. **Weights between Layer 1 and Layer 2** ($\mathbf{W}^{(1)}$):

$$\mathbf{W}^{(1)} = \begin{bmatrix} w_{11}^{(1)} & w_{12}^{(1)} & w_{13}^{(1)} \\ w_{21}^{(1)} & w_{22}^{(1)} & w_{23}^{(1)} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.2 & 0.3 \\ 0.4 & 0.1 & 0.6 \end{bmatrix}$$

2. **Biases for Layer 2** ($\mathbf{b}^{(1)}$):

$$\mathbf{b}^{(1)} = \begin{bmatrix} b_1^{(1)} & b_2^{(1)} & b_3^{(1)} \end{bmatrix} = \begin{bmatrix} 0.1 & 0.2 & 0.3 \end{bmatrix}$$

3. **Weights between Layer 2 and Layer 3** ($\mathbf{W}^{(2)}$):

$$\mathbf{W}^{(2)} = \begin{bmatrix} w_{11}^{(2)} & w_{12}^{(2)} \\ w_{21}^{(2)} & w_{22}^{(2)} \\ w_{31}^{(2)} & w_{32}^{(2)} \end{bmatrix} = \begin{bmatrix} 0.2 & 0.3 \\ 0.4 & 0.5 \\ 0.6 & 0.7 \end{bmatrix}$$

4. **Biases for Layer 3** ($\mathbf{b}^{(2)}$):

$$\mathbf{b}^{(2)} = \begin{bmatrix} b_1^{(2)} & b_2^{(2)} \end{bmatrix} = \begin{bmatrix} 0.4 & 0.5 \end{bmatrix}$$

5. **Weights between Layer 3 and Layer 4** ($\mathbf{W}^{(3)}$):

$$\mathbf{W}^{(3)} = \begin{bmatrix} w_{11}^{(3)} \\ w_{21}^{(3)} \end{bmatrix} = \begin{bmatrix} 0.8 \\ 0.9 \end{bmatrix}$$

6. **Bias for Layer 4** ($\mathbf{b}^{(3)}$):

$$\mathbf{b}^{(3)} = \begin{bmatrix} b_1^{(3)} \end{bmatrix} = \begin{bmatrix} 0.6 \end{bmatrix}$$

1.2 Input

The input to **Layer 1** is a row vector:

$$\mathbf{x} = \begin{bmatrix} x_1 & x_2 \end{bmatrix} = \begin{bmatrix} 1.0 & 2.0 \end{bmatrix}$$

1.3 Questions

1. Compute the output of **Layer 2**.
2. Compute the output of **Layer 3**.
3. Compute the output of **Layer 4**.
4. Write the final output of the network in matrix form.
5. What would be the answer to each of the above questions if sigmoid activation function is applied to each node?

   Hint: For the j^{th} node in layer 2, first calculate the output, $z_j^{(2)} = b_j + \sum w_{ij} \cdot x_i$, then apply the activation function to $z_j^{(1)}$. The result of the activation function will be the input for the next layer. Perform similar calculations for all the nodes in all other layers.

2 Supervised Machine Learning

In this assignment, we explore regression techniques to predict continuous outcomes using labeled data.

3 Natural Language Processing

Text: Renewable energy technologies like solar panels and wind turbines are revolutionizing power generation. Advances in battery storage enable efficient energy distribution even during low-production periods. Governments worldwide are investing in smart grids to optimize renewable resource allocation.

3.1 Text Processing

Tasks:

1. Perform byte-pair encoding tokenization.
2. Remove domain-specific stopwords (e.g., "energy", "power").
3. Apply BERT embeddings for semantic analysis.
4. Train a Word2Vec model and find similarities for: (a) solar, (b) grid, (c) storage.

3.2 Sentiment Analysis

Dataset: `nltk` product reviews corpus. **Test Sentences**:

1. "This eco-friendly appliance drastically reduced my electricity bills!"
2. "Poor durability – the solar charger failed within two months."
3. "Innovative battery design but complex installation process."
4. Calculate prediction accuracy across all test cases.

4 Prompt Engineering

4.1 Task 1 – Prompt Quality Assessment

Classify these as vague/good:

1. "Explain something about computers."
2. "Compare HTTP/1.1 vs HTTP/3 with latency benchmarks."
3. "Describe a scientific principle."
4. "List 3 IoT security risks for smart homes with mitigation strategies."

4.2 Task 2 – Prompt Crafting

Create prompts for:

1. Explaining transformer neural networks to high school students.
2. Generating a mystery plot involving AI ethics.
3. Summarizing a research paper on CRISPR gene editing.

4.3 Task 3 – n-Shot Prompts

Provide examples for:

1. Zero-shot: Explain quantum entanglement without examples.
2. Two-shot: Convert two imperial measurements to metric.
3. Chain-of-thought: Solve $\frac{d}{dx}(3x^2 + \ln x)$ step-by-step.

4.4 Bonus Task

Use iterative refinement to produce a 300-word technical essay on "Ethical Challenges in Generative AI". Include at least three revision cycles.