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Artificial Intelligence and Machine Learning (6CS012)

Question And Answers

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1. Long Question

You are a machine Learning Engineer at a growing e-commerce company preparing to implement and scale machine learning systems.

- List and explain at least three real-world challenges you expect during ML model development, deployment, or maintenance (e.g., data drift, imbalanced data, system latency).
- For each challenge:
  - Discuss potential consequences if not properly addressed.
  - Propose technical or organizational solutions you would implement (e.g., retraining pipelines, feature monitoring, distributed serving, MLOPs practices

As an ML Engineer in an e-commerce company, three real-world challenges expected during ML model development, deployment or maintenance that can impact system performance and business outcomes if not properly addressed are:

- Data Drift: It refers to the statistical attributes of input data which change over time and its common in e-commerce where customer preferences buying behaviors and product trends evolve rapidly, if it is not addressed then it leads model degradation, poor user experience and inaccurate predictions. Therefore, it is essential to set up automated performance and data tracking, periodic model retraining with new data, as well as drift detection using Population Stability Index (PSI) to mitigate this data drift.
- Imbalanced Data: It is mostly in use cases like fraud detection, predicting return, or forecasting rare events. The model in such settings tends to learn from skewed class distribution and if the focus is only on the majority class, the model fails to learn critical, capture rare, patterns which impact customer service and associated decision-making processes significantly. Possible solutions that can be adopted are oversampling the minority class such as SMOTE, cost-sensitive learning, and improved ensemble models which can handle class imbalance better.
- System Latency: System latency is a critical challenge when deploying real-time models for recommendation systems, setting dynamic pricing and optimizing search rank. Users may turn to competing applications when they experience high latency which impacts

revenue generation and service delivery simultaneously. For this to optimize model pipeline to enhance performance by using model quantization, pruning for latency critical tasks.

To ensure sustainable deployment and operation, integrating MLOps practices such as version control, CI/CD for models, feature tracking, and alerting systems is critical. These practices enhance reproducibility, scalability, and long-term reliability of ML solutions in production (Emma Yasenchak, 2024).

2. Short Question

2.1. Overfitting

- Define and differentiate between overfitting and underfitting.
- Explain why both are problematic for model performance.
- Illustrate your explanation with simple examples (e.g., overfitting a training dataset, underfitting a complex pattern).

Overfitting occurs when a model tries to learn well on training data including noise and outliers. which leads to high accuracy on training data but low performance in unseen data. Overfitted models typically have low bias and high variance.

Underfitting occurs when a model is too simple to learn underlying patterns in the data. As a result, it performs poorly on both the training and test data. It has high bias and low variance.

Aspect	Overfitting	Underfitting
Definition	Learns training data too well, including noise	Fails to learn underlying patterns in the data
Bias	Low	High
Variance	High	Low
Performance on Training and Test Data	High accuracy and Poor generalization	Poor accuracy and generalization
Model Complexity	Too complex	Too simple

Example	Student memorizes textbook but fails on reworded questions	Students only read summaries and lack detailed understanding

(GeeksforGeeks, 2023)

Both are problematic because they reduce the ability of the model to generalize new and unseen data. Overfitting ruins this by learning too much detail including noise and outliers which leads to high training accuracy but poor performance on test data, while underfitting fails by learning too little data resulting in poor performance of both training and test data.

For example, in overfitting a student memorizes every word in textbook but struggles to answer during exams, if the questions are slightly twisted. In underfitting students only read summaries of each chapter without details and fail to answer specific questions.

2.2. Neural Network Architecture

Difference between CNN and RNN:

- Explain the fundamental differences between a Convolutional Neural Network (CNN) and a Recurrent Neural Network (RNN).
- Provide examples of scenarios where one would be more suitable than the other (e.g., image recognition vs. time-series prediction).
- Briefly discuss common challenges faced during the training of deep learning models (e.g., vanishing gradients, overfitting).
- Provide possible solutions or techniques to address these challenges (e.g., batch normalization, early stopping).

The difference between CNN and RNN are as follows:

Aspects	Convolutional Neural Network (CNN)	Recurrent Neural Network (RNN)
Task	Image recognition	Sequence modeling
Input	Fixed size (e.g. images)	Variable length (e.g. text and speech)
Structure of data	Hierarchical features extraction	Sequential memory via recurrence

Use Case	Image classification	Sentiment analysis, speech-to-text

(tutorialspoint, 2025)

Fundamental Difference between CNN and RNN:
Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) both are the categories of machine learning models. CNN deals with tasks like image processing by using convolutional layers to extract features like edges, textures, and shapes. RNN is used for tasks like modeling languages, translation and speech recognition. It retains information from previous inputs, making them effective for language modeling, translation, and speech recognition.

Challenges faced while training deep learning models:

- Overfitting: Models may perform well on training data but fail to generalize for unseen data.
- Vanishing/Exploding Gradients: During backpropagation gradients become too small or too large which makes training difficult.
- High Computational Cost: In Deep Learning models large amounts of data and resources are required for training.
- Hyperparameter Tuning: Choosing the right set of hyperparameters can significantly impact model performance (Found, 2023).

Solutions for addressing these challenges

- Models like Dropout and L2 regularization to prevent overfitting.
- Limit the size of gradients to manage exploding gradients in RNNs.
- Batch normalization to stabilize training.
- Early stopping to improve generalization.
- Transfer learning can also reduce the need for large datasets and training time.

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