

## **Student 22 – Answer Sheet**

### **Question 1:**

**Explain the differences between supervised, unsupervised, and reinforcement learning in machine learning. Provide examples of applications for each approach.**

#### **Answer:**

Supervised learning is a machine learning approach where algorithms are trained on datasets that include both input data and the correct output labels. The goal is for the model to learn the mapping from inputs to outputs, enabling it to predict outcomes for new, unseen data. This method is commonly used for classification tasks, such as detecting spam emails or diagnosing diseases from medical scans, and for regression tasks, like predicting house prices or stock market trends. Supervised learning is most effective when there is a wealth of historical data with known results.

Unsupervised learning, in contrast, involves working with datasets that do not have explicit output labels. The algorithm must independently uncover patterns, groupings, or structures within the data. Typical techniques include clustering (e.g., grouping customers based on purchasing behavior) and dimensionality reduction (e.g., simplifying high-dimensional data for visualization). Applications include customer segmentation in marketing, anomaly detection in cybersecurity, and topic modeling in large text datasets.

Reinforcement learning is a different paradigm where an agent learns by interacting with an environment. The agent receives feedback in the form of rewards or penalties based on its actions and aims to maximize cumulative rewards over time. This approach is particularly effective in sequential decision-making scenarios, such as training AI to play board games like Go, enabling autonomous vehicles to navigate complex environments, or optimizing resource management in logistics and robotics.

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### **Question 2:**

**Describe the architecture and functioning of Convolutional Neural Networks (CNNs) and explain why they are particularly effective for image recognition tasks.**

#### **Answer:**

Convolutional Neural Networks (CNNs) are specialized deep learning models designed for processing grid-like data, such as images. Their architecture consists of several key components: convolutional layers that use learnable filters to scan the input and extract local features, activation functions (such as ReLU) to introduce non-linearity, pooling layers that downsample

feature maps to reduce dimensionality, and fully connected layers at the end for final classification.

CNNs excel at image recognition because their structure is well-suited to capturing spatial hierarchies in visual data. Early layers detect simple features like edges and textures, while deeper layers combine these features to recognize more complex patterns and objects. Parameter sharing in convolutional layers reduces the number of learnable weights, making the network more efficient and less prone to overfitting. Pooling layers add translation invariance, allowing the network to recognize objects regardless of their position in the image. These properties have made CNNs the dominant architecture for tasks such as image classification, object detection, and facial recognition.

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### **Question 3:**

**Discuss the ethical considerations and potential societal impacts of implementing artificial intelligence systems in critical decision-making processes.**

#### **Answer:**

The adoption of AI in critical decision-making brings forth significant ethical and societal challenges. One of the foremost concerns is algorithmic bias, where AI systems trained on historical data may perpetuate or even amplify existing social prejudices, potentially leading to unfair outcomes in areas like hiring, lending, or criminal justice. For example, facial recognition systems have been shown to have higher error rates for certain demographic groups, raising concerns about discrimination and equity.

Transparency is another crucial issue. Many advanced AI models, especially deep neural networks, operate as "black boxes," making it difficult to understand or explain their decision-making processes. This lack of interpretability can erode trust, particularly in high-stakes domains like healthcare, where understanding the rationale behind recommendations is essential for patient safety and accountability.

Privacy concerns also arise, as AI systems often require access to large volumes of personal data, raising questions about consent, data security, and potential misuse. Furthermore, the deployment of AI could lead to labor market disruptions, with automation threatening both blue-collar and white-collar jobs and potentially increasing economic inequality if the benefits are not broadly distributed.

Addressing these challenges requires a combination of technical solutions (such as fairness-aware algorithms and explainable AI), regulatory oversight, and ongoing stakeholder

engagement to ensure that AI systems align with societal values and promote positive outcomes.

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#### **Question 4:**

**Explain the concept of transfer learning in deep neural networks and discuss its advantages and limitations.**

#### **Answer:**

Transfer learning is a machine learning technique where a model developed for one task is adapted for use on a different, but related, task. In deep learning, this typically involves taking a neural network pre-trained on a large dataset (such as ImageNet for image tasks) and fine-tuning it for a new task with a smaller dataset. The process usually involves replacing the final layers of the pre-trained model with new layers suited to the target task and retraining either just these new layers or the entire network with a lower learning rate.

The main advantage of transfer learning is its ability to leverage knowledge from large, diverse datasets, making it possible to build effective models even when the target dataset is small. This reduces the need for extensive labeled data, speeds up training, and often leads to better performance by providing a strong starting point for learning. Transfer learning also helps prevent overfitting by transferring general feature representations learned from the source task.

However, transfer learning is most effective when the source and target tasks are similar; if the domains are too different, the transferred knowledge may not be useful or could even hinder performance—a phenomenon known as negative transfer. Additionally, pre-trained models may carry over biases from their original training data, and their architectures may not always be optimal for the new task.

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#### **Question 5:**

**Describe the principles of natural language processing (NLP) and how transformer-based models like BERT have revolutionized language understanding tasks.**

#### **Answer:**

Natural Language Processing (NLP) is the field that focuses on enabling computers to analyze, understand, and generate human language. Traditional NLP approaches relied on rule-based systems and statistical models, which often struggled to capture the complexity and context of language.

The introduction of transformer-based models, such as BERT (Bidirectional Encoder Representations from Transformers), has dramatically advanced NLP. Transformers use self-attention mechanisms, allowing the model to consider the relationships between all words in a sentence simultaneously, rather than processing them sequentially. BERT introduced the concept of bidirectional context, enabling the model to understand the meaning of a word based on both its left and right surroundings.

These models are pre-trained on massive text corpora using tasks like masked language modeling and next sentence prediction, then fine-tuned for specific applications such as sentiment analysis, question answering, and text classification. This approach allows for the development of rich, contextual word representations that capture semantic and syntactic nuances. As a result, transformer-based models have set new performance benchmarks across a wide range of NLP tasks, enabling more accurate and natural human-computer interactions. Despite challenges such as high computational requirements and potential biases, transformers have become the foundation of modern NLP systems.