MAIN UNIVERSITY EXAMINATIONS 2022/2023 EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN SOFTWARE ENGINEERING SPC 2409 Artificial Neural Networks Year IV Semester I Date: Monday, 5th December 2022 Time: 11.00am – 1.00pm INSTRUCTIONS i. This EXAMINATION has TWO sections. ii. SECTION A is compulsory. Answer ALL questions in this section. iii. Answer ANY TWO questions in SECTION B.

SECTION A

QUESTION ONE (30 MARKS)

a) Distinguish between each of the following terms as used in Neural Networks (i) Supervised and unsupervised learning
(ii) Pattern classification and pattern association
(iii) Feedforward network and recurrent network
(iv) Artificial neural networks and Biological neural networks

Answer: (i) Supervised learning involves training a model using labeled data, where the model learns to predict the output from the input data. Unsupervised learning involves training a model using unlabeled data, where the model learns patterns and structures from the input data without explicit supervision.
(ii) Pattern classification involves categorizing input data into predefined classes or categories. Pattern association involves identifying relationships or correlations between different patterns in the input data.
(iii) Feedforward networks process data in one direction, from input to output, without feedback loops. Recurrent networks have connections that form loops, allowing information to persist over time and enabling them to process sequences of data.
(iv) Artificial neural networks are computational models inspired by the structure and function of biological neural networks. Biological neural networks are networks of interconnected neurons in the nervous system of living organisms.

b) The basis operation of an artificial neuron involves summing its weighted input signal and applying an activation function to determine whether it will 'fire' or not (i) Explain what you understand by the term 'activation function'
(ii) Using appropriate illustrations, explain each of the following activation functions
i. Binary Step Function
ii. Bipolar Sigmoid Function

Answer: (i) An activation function is a mathematical function applied to the weighted sum of inputs of a neuron, determining its output. It introduces non-linearity into the neural network, allowing it to learn complex patterns in the data.
(ii) i. The Binary Step Function outputs 1 if the input is greater than or equal to zero, and 0 otherwise.
ii. The Bipolar Sigmoid Function maps the input to a value between -1 and 1, smoothly transitioning from 0 at large negative inputs to 1 at large positive inputs.

c) Artificial neural networks (ANNs) are modeled from biological neurons. Outline the biological properties that are borrowed into ANNs

Answer: Biological properties borrowed into ANNs include parallel processing, distributed representation, adaptation and learning, fault tolerance, and scalability.

d) Briefly explain any application areas of Neural networks

Answer: Neural networks are applied in various fields such as image and speech recognition, natural language processing, financial forecasting, medical diagnosis, autonomous vehicles, and recommendation systems.

e) You have been hired as the data scientist in the meteorological department. Your first assignment involves the use of neural networks for time series prediction, specifically weather forecasting. Explain the techniques that you would apply for this task and justify why

Answer: For weather forecasting, recurrent neural networks (RNNs) or long short-term memory (LSTM) networks are commonly used due to their ability to model temporal dependencies in sequential data. These networks can learn patterns from historical weather data and make predictions based on current and past observations.

QUESTION TWO (20 MARKS)

a) Distance metrics play a significant role in neural network problems in determining the similarity and diversity of sample sets. Using appropriate examples, explain each of the following distance methods i. Euclidean distance
ii. Jaccard index
iii. Hamming distance

Answer: i. Euclidean distance measures the straight-line distance between two points in Euclidean space. For example, in clustering algorithms like k-means, Euclidean distance is

used to measure the similarity between data points. ii. Jaccard index measures the similarity between two sets by comparing their intersection to their union. For example, in document clustering, Jaccard index is used to compare the similarity between documents based on their shared features. iii. Hamming distance measures the number of positions at which corresponding symbols differ between two strings of equal length. For example, in error detection and correction codes, Hamming distance is used to quantify the difference between transmitted and received data.

b) Self-organizing maps are widely used in clustering problems of neural networks. Explain how the Kohonen self-organizing map works

Answer: Kohonen self-organizing maps (SOMs) are a type of unsupervised learning algorithm used for clustering and dimensionality reduction. SOMs organize high-dimensional input data onto a low-dimensional grid, preserving the topological properties of the input space. During training, neurons in the SOM compete to be activated based on their similarity to the input data. Neurons that are close to the input data become more similar to it, while distant neurons become less similar. This process results in a map where neighboring neurons represent similar input patterns, facilitating clustering and visualization of complex data.

c) You have been hired in a Big Data company involved in the prediction of traffic patterns. Explain the techniques that you would apply for this task and justify why

Answer: For traffic prediction, techniques such as time series analysis, regression models, and neural networks can be applied. Neural networks, particularly recurrent neural networks (RNNs) or convolutional neural networks (CNNs), are well-suited for modeling the temporal and spatial dependencies in traffic data. RNNs can capture sequential patterns in traffic flow, while CNNs can extract spatial features from traffic images or sensor data. These techniques allow for accurate prediction of traffic congestion, travel times, and traffic flow dynamics, aiding in traffic management and planning.

d) Compare and contrast an artificial neural network and the biological neuron

Answer: Artificial neural networks (ANNs) are computational models inspired by the structure and function of biological neurons. While both artificial neural networks and biological neurons process information using interconnected nodes (neurons) and weighted connections (synapses), there are several differences between them. ANNs typically have a simpler structure with fewer neurons and layers compared to biological neural networks. Additionally, ANNs use mathematical functions as activation functions to compute the output of neurons, whereas biological neurons generate output signals

through complex electrochemical processes. Despite these differences, ANNs strive to mimic the learning and adaptive capabilities of biological neurons, enabling them to perform various tasks such as pattern recognition, classification, and regression.

QUESTION THREE (20 MARKS)

a) Using an illustration, explain the key components of a simple neural network

Answer: [Insert illustration of a simple neural network with input layer, hidden layer, and output layer, along with connections and weights.]

b) A network topology is the arrangement of a network along with its nodes and connecting line. Explain two main categories of network topology

Answer: Two main categories of network topology are:

- **Physical Topology:** This refers to the physical layout of nodes and connections in a network. Examples include bus, star, ring, mesh, and tree topologies.
- **Logical Topology:** This refers to the way in which data is transmitted between nodes in a network. Examples include point-to-point, broadcast, and token ring topologies.

c) ART network is a vector classifier which accepts an input vector and classifies it. With respect to vector classification, explain three operations of ART

Answer: Three operations of ART (Adaptive Resonance Theory) network in vector classification are:

- **Comparison:** The input vector is compared to prototype vectors stored in the network's memory. The comparison is based on similarity measures such as cosine similarity or Euclidean distance.
- **Competition:** Neurons in the network compete to be activated based on their similarity to the input vector. The neuron with the closest match becomes active, while others remain inactive.
- **Learning:** If no neuron closely matches the input vector, a new category is created, and the input vector is stored as a new prototype vector in the network's memory. If a neuron closely matches the input vector, its prototype vector is updated to better represent the input.

d) Differentiate between auto-associative memory and hetero-associative memory

Answer: Auto-associative memory and hetero-associative memory are two types of associative memory models:

- **Auto-associative memory:** In auto-associative memory, the network is trained to associate an input pattern with itself. It is used for pattern completion and reconstruction, where noisy or incomplete input patterns are corrected or completed based on learned associations.
- **Hetero-associative memory:** In hetero-associative memory, the network is trained to associate one pattern with another pattern. It is used for pattern recognition and recall, where an input pattern is mapped to an associated output pattern based on learned associations.

e) Boltzmann machine is an asymmetric coupled random feedback binary unit neural network, which includes a visible layer and multiple hidden layers. Explain two importance of Boltzmann Machine

Answer: Two important aspects of Boltzmann machines are:

- **Energy-based learning:** Boltzmann machines model the joint probability distribution of binary variables using an energy function. This allows them to learn complex patterns and correlations in the data by minimizing the energy of the system through iterative updates.
- **Stochastic sampling:** Boltzmann machines use stochastic sampling techniques such as Gibbs sampling or simulated annealing to explore the state space and converge to the optimal solution. This enables them to escape local minima and find globally optimal configurations in the data.

QUESTION FOUR (20 MARKS)

a) Artificial neural networks differ with biological neural networks because of the few characteristics. Explain three characteristics that define neural networks

Answer: Three characteristics that define neural networks are:

- **Parallel processing:** Neural networks consist of interconnected nodes (neurons) that can process information simultaneously, enabling parallel computation and efficient handling of large datasets.
- **Learning and adaptation:** Neural networks are capable of learning from experience and adjusting their internal parameters (weights and biases) to improve

performance on specific tasks. This learning process is based on feedback mechanisms such as supervised or unsupervised learning.

- **Non-linearity:** Neural networks are inherently non-linear systems, allowing them to model complex relationships and patterns in the data that may not be captured by linear models. This non-linearity arises from the activation functions applied to the weighted inputs of neurons, enabling the network to represent non-linear transformations of the input space.

b) With a clear structure, interpret the following function as used in artificial neural networks: $\blacksquare=\sum\blacksquare=1\blacksquare\blacksquare\blacksquare\cdot\blacksquare\blacksquare Y=\sum i=1n\,xi\cdot wi$

Answer: This function represents the weighted sum of inputs $\blacksquare\blacksquare xi$ multiplied by their corresponding weights $\blacksquare\blacksquare wi$, where $\blacksquare i$ ranges from 1 to $\blacksquare n$. The weighted sum is computed across all input neurons in the network and serves as the input to the activation function of a neuron or layer. The weights $\blacksquare\blacksquare wi$ represent the strength of the connections between input neurons and the neuron or layer under consideration, determining the contribution of each input to the overall output $\blacksquare Y$ of the neuron or layer.

c) Biological neural networks are a series of interconnected neurons whose activation defines a recognizable linear pathway. Explain the function of the following components a. Dendrites
b. Axon
c. Soma

Answer: a. **Dendrites:** Dendrites are branched extensions of a neuron that receive incoming signals (chemical or electrical) from other neurons or sensory receptors. They act as input terminals, integrating and transmitting signals towards the cell body (soma) of the neuron. b. **Axon:** The axon is a long, slender projection of a neuron that conducts electrical impulses away from the cell body to other neurons or effector cells (e.g., muscle fibers or glands). It serves as the output pathway of the neuron, transmitting signals (action potentials) to communicate with other cells. c. **Soma:** The soma, also known as the cell body, is the central region of a neuron that contains the nucleus and organelles responsible for metabolic and synthetic functions. It integrates incoming signals from dendrites and generates output signals that are propagated along the axon.

d) Artificial intelligence is the ability of a computer or a robot controlled by a computer to do tasks that are usually done by humans because they require human intelligence and discernment. Explain three branches of artificial Intelligence

Answer: Three branches of artificial intelligence are:

- **Machine Learning:** Machine learning is a branch of AI that focuses on developing algorithms and models that enable computers to learn from data and make predictions or decisions without being explicitly programmed. It encompasses supervised learning, unsupervised learning, reinforcement learning, and deep learning.
- **Natural Language Processing (NLP):** NLP is a branch of AI that deals with the interaction between computers and human languages. It involves tasks such as speech recognition, language translation, sentiment analysis, and text generation, enabling computers to understand, interpret, and generate natural language.
- **Computer Vision:** Computer vision is a branch of AI that enables computers to interpret and understand the visual world through digital images or videos. It encompasses tasks such as image classification, object detection, facial recognition, and image generation, allowing computers to perceive and analyze visual information like humans.

QUESTION FIVE (20 MARKS)

a) What is Multi-layer feedforward networks? What is the importance of hidden and output layers in it?

Answer: A multi-layer feedforward network, also known as a multilayer perceptron (MLP), consists of multiple layers of interconnected neurons. Information flows in one direction, from the input layer through one or more hidden layers to the output layer, without any feedback loops. The hidden layers perform feature extraction and transformation, while the output layer produces the final prediction or classification. The hidden layers are essential for learning complex patterns and relationships in the data, while the output layer synthesizes the information learned by the hidden layers into a useful output.

b) A recurrent neural network (RNN) is a type of artificial neural network which uses sequential data or time series data. With the aid of a diagram, explain fully recurrent network and Jordan network

Answer: [Insert illustration of a recurrent network and Jordan network.]

c) Suppose that a credit card company decided to deploy a new system for assessing creditworthiness of its customers. The new system is using a feedforward neural network with a supervised learning algorithm. Suggest what the bank should have before the system can be used? Discuss problems associated with this requirement

Answer: Before deploying the system, the bank should have:

- Sufficient labeled data for training the neural network, including historical credit data with known outcomes (e.g., approved or denied).
- A robust data preprocessing pipeline to handle missing values, outliers, and feature scaling.
- Proper evaluation metrics and validation procedures to assess the performance of the model.
- Adequate computational resources for training and deploying the neural network.

Problems associated with this requirement include:

- Data scarcity or imbalance, leading to biased or inaccurate predictions.
- Overfitting or underfitting of the neural network model due to inadequate data or model complexity.
- Ethical considerations regarding the use of sensitive customer data and potential biases in the model predictions.

d) Explain the following terms a. Neurons
b. Perception

Answer: a. **Neurons:** Neurons are the basic units of a neural network, analogous to the neurons in the brain. They receive input signals, perform computations using weighted connections, and produce output signals. b. **Perception:** Perception refers to the process of interpreting sensory information and making sense of the world around us. In the context of neural networks, a perceptron is the simplest form of a neural network, consisting of a single layer of input nodes connected directly to an output node.