Semester of Fall 2024-2025

EEE 391
Basics of Signals and Systems

Makeup Assignment

Exploring Neural Networks
Questions and Answers

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Introduction

This document contains the answers to the questions assigned as a makeup homework for whom missed the mandatory lecture on Neural Networks in the EEE 391 course.

The primary goal of this assignment is to self-study of the basics of neural networks and to develop an understanding of the fundamental concepts of the topic, as required by the Department of Computer Engineering and as a result of missing the lecture.

Throughout the document, the ten questions provided below will be answered in detail while supported by various credible sources and references.

1. What is a neural network (NN)?
2. What is a NN used for?
3. Why would you prefer a NN over another computational approach?
4. Give an example of a task especially well performed by a NN. Why?
5. What is a convolutional NN (CNN)?
6. What is a CNN used for?
7. Why would you prefer a CNN over another kind of NN?
8. Give an example of a task especially well performed by a CNN. Why?
9. What is a graph neural network (GNN)?
10. Give an example of a task especially well performed by a GNN. Why?

Answers

1. What is a neural network (NN)?

A neural network (NN), or also known as an artificial neural network (ANN), is a computational model inspired by the human brain, and/or animal brain, where neurons and synapses are represented as vertices and edges, respectively, in a graph [1, 2]. Such networks function by organizing their input variables into an initial layer of vertices and assigning weights to the connections between them. The remaining vertices are arranged into layers based on their proximity to the input nodes [2, 3].

2. What is a NN used for?

Neural networks are primarily utilized in areas where classical/other programming approaches either completely fail or perform poorly, or not expectedly, such as classification problem, function approximation, autonomous driving, memory management, pattern recognition, system optimization, and clustering [4].

3. Why would you prefer a NN over another computational approach?

Neural networks can be preferred over other computational approaches as they can be developed with minimal formal statistical training, inherently identify intricate nonlinear relationships between input and output variables, capture all potential interactions among predictor variables, and can be built using a variety of training algorithms [5].

4. Give an example of a task especially well performed by a NN. Why?

Neural machine translation (NMT) may be an example of a task that a neural network excels at [6]. This is because, in contrast with traditional models, which frequently depend on context windows of a certain length, NMT systems use processes like as attention to concentrate on pertinent portions of the source phrase. Long-range relationships and complicated phrase patterns can be handled more effectively as a result [7].

5. What is a convolutional NN (CNN)?

A convolutional neural network (CNN) is a distinct variation of a feed-forward neural network, designed to automatically identify and learn important features by optimizing filters, often referred to as kernels. This potent deep learning model is frequently employed for tasks like classification and prediction across several domains and is very good at processing a wide variety of input, including text, audio, and pictures [8].

6. What is a CNN used for?

CNNs are used in image recognition, classification, and analysis tasks [9, 10]. For example, in the field of medicine, CNNs have been used to classify medical images and detect

cancerous tissue in histopathological[1] images from tissue microarrays[2] (TMAs) of human tumors based on chromatin[3] patterns, extract predictors, and classify tumor nuclei [10].

7. Why would you prefer a CNN over another kind of NN?

One of the many advantages of CNNs over other neural networks is the weight-sharing mechanism: which reduces the number of parameters that can be trained, enhances generalization, and reduces overfitting. CNNs can also, at once, learn the feature extraction and classification layers, generating an output that is highly relevant to the features retrieved and well-defined in terms of structure. Moreover, they facilitate the large-scaled-network designing compared with other neural network architectures [14].

8. Give an example of a task especially well performed by a CNN. Why?

As already stated in the question 6, CNNs perform well on medical image processing and analysis [10]. This is due to the property of CNNs that they automatically encode spatial hierarchies in images. It takes us gradually from simple edges to complex structures. It is essential for recognizing complex patterns in medical images, like tumors or anatomical anomalies [15]. Another point is that CNNs learn relevant features from the data directly, in contrast to traditional methods requiring handcrafted features. This flexibility enables them to mimic intricate and slight differences in medical images, resulting in better diagnostic accuracy [16].

9. What is a graph neural network (GNN)?

Graph Convolutional Networks (GCNs) are a type of convolutional neural network designed to work directly with graphs and their structural data. Unlike other types of convolutional neural networks, which generally use 2D/3D arrays as their input, GCNs take a graph as input. Similar to how convolutional neural networks extract key features from an image for classification, GCNs apply a filter to a graph, identifying important vertices and edges that help classify the nodes within the graph [17].

10. Give an example of a task especially well performed by a GNN. Why?

A concrete example of a task in which GNNs excelled with node classification is social networks. GNNs extract the relational structure of the graph for information exchange from neighboring nodes. Thus, both node features as well as the features of connected nodes can jointly contribute towards GNNs in predicting labels on nodes, making it efficient at capturing both local and global context. [18]

[1] "Histopathology is the diagnosis and study of diseases of the tissues, and involves examining tissues and/or cells under a microscope. Histopathologists are responsible for making tissue diagnoses and helping clinicians manage a patient's care" [11].

[2] "Microarrays are a collection of DNA probes that are usually bound in defined positions to a solid surface, such as a glass slide, to which sample DNA fragments can be hybridised. The probes are generally oligonucleotides that are 'ink-jet printed' onto slides (Agilent) or synthesised in situ (Affymetrix)" [12].

[3] "Chromatin refers to a mixture of DNA and proteins that form the chromosomes found in the cells of humans and other higher organisms" [13].

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