Assignment: Demystifying Convolutional Neural Networks (CNNs)

Objective: This assignment aims to deepen your understanding of Convolutional Neural Networks (CNNs), their fundamental components, operational mechanisms, and diverse applications, drawing insights from the provided context.

Part 1: Introduction to Convolutional Neural Networks

Definition and Purpose:

Based on your understanding and the provided context, define what a Convolutional Neural Network (CNN) is.

Explain the primary purpose of CNNs, particularly highlighting their strength in pattern recognition. How does the context draw an analogy between CNNs and image processing, natural language processing, and even fMRI time-series data?

Part 2: Key Components of a CNN Architecture

CNNs are built from several distinct layers, each serving a specific function. Describe the role and characteristics of the following key components:

Convolutional Layers:

Explain the concept of "filters" (or kernels) and "feature maps" in a convolutional layer. How do these filters help in detecting specific features?

Discuss the significance of "channels" in convolutional operations, referencing the RGB channels in images and the multi-channel nature of fMRI data mentioned in the context.

Differentiate between 1-D and 2-D convolution, providing examples of when each might be applied based on the context. What is the typical output shape of a 1D convolutional layer?

Pooling Layers:

What is the main purpose of pooling layers in a CNN?

Describe the two common types of pooling layers mentioned: Max-pooling and Average pooling. Explain how each operates and what effect it has on the data.

Activation Functions:

Explain the general role of activation functions in neural networks.

Based on the context, describe the following activation functions and their typical use cases:

ReLU (Rectified Linear Unit): Where is it commonly applied within a CNN's hidden layers?

Softmax: For what type of output layer is Softmax typically used?

Sigmoid: In what specific scenario, as described in the context, is the Sigmoid activation function utilized for an output layer?

Fully Connected Layers:

Explain the role of fully connected layers at the end of a CNN architecture.

What preprocessing step (e.g., "flattening") is often required before passing data from convolutional/pooling layers to fully connected layers?

Other Components:

Briefly explain the purpose of **Dropout layers** as mentioned in the context.

Part 3: How CNNs Work – The Data Flow

Typical CNN Workflow:

Describe the typical sequence of operations as data (e.g., an image) flows through a CNN, from the input layer to the final output. You can refer to the architectural descriptions of the 4-layer or 5-layer CNNs provided in the context as examples.

How do CNNs build a hierarchical representation of features?

Part 4: Applications of CNNs

Diverse Applications:

Based on the provided context, list and briefly describe at least three distinct applications or domains where CNNs are effectively utilized. Include examples like image classification (e.g., MNIST), time-series analysis (e.g., fMRI data), and their role within more complex models like Generative Adversarial Networks (GANs).

Mention the high-level APIs and frameworks commonly used for building and training these models, as indicated in the context.