Assignment 01 : Deep Learning

Instructors: Sir Irfan Malik, Sir Sheraz Naseer

Student name: Ashna Shakih

Convolutional Neural Networks (CNNs):

A **Convolutional Neural Network (CNN)** is a type of artificial neural network designed to process **visual data**, such as images and videos. CNNs are widely used in **computer vision tasks** like image classification, object detection, and facial recognition.

How CNNs Work ?

Ans : Unlike traditional neural networks, which process images as **flat vectors**, CNNs preserve the **spatial structure** of images. They do this using these key operations:

Convolution Layer

- The core operation of CNNs.
- Uses small filters (also called kernels) to scan the input image.
- Each filter detects a specific feature (edges, textures, patterns).
- The result is a feature map that highlights important patterns in the image.

It's like looking at an image through a magnifying glass, focusing on different parts one at a time.

Activation Function (ReLU)

- ReLU (Rectified Linear Unit) introduces non-linearity to help CNNs learn complex patterns.
- It replaces negative values with zero, making computations efficient Like a light switch that only turns on for positive signals and stays off otherwise.

Pooling Layer

- Reduces the size of feature maps while keeping important information.
- Max Pooling takes the largest value from a small region.
- Helps make CNNs faster and less sensitive to noise.

Think of it like summarizing a large paragraph into key points.

Fully Connected (FC) Layer

- The final layer flattens all the extracted features into a 1D vector.
- It connects to neurons that make the final decision.
- Uses Softmax or Sigmoid activation to classify the image.

Like a final decision-making step after analyzing all details.

Real-World Applications of CNNs

1. **Image Recognition -** Deep Learning is used in facial recognition, medical imaging, and object detection using Convolutional Neural Networks (CNNs). Examples include face unlock systems and X-ray analysis.

2. **Autonomous Vehicles -** CNNs and Reinforcement Learning allow self-driving cars to detect objects, pedestrians, and road signs to make driving decisions.

3. **Industrial Defect Detection -** Uses Convolutional Neural Networks (CNNs) and Anomaly Detection to analyze images of products for identifying defects in manufacturing lines.

Recurrent Neural Networks (RNNs)

A Recurrent Neural Network (RNN) is a type of artificial neural network designed to process **sequential data**, such as time series, text, speech, and videos. Unlike traditional neural networks, RNNs have a **memory** that allows them to remember past inputs, making them great for tasks where context matters.

. How RNNs Work

Unlike a normal neural network, where inputs are processed **independently**, RNNs use **loops** to pass information from one step to the next.

The Core Idea – Memory Through Loops

- In a standard neural network, input flows **straight through** the layers.
- In an RNN, there is a **hidden state** that stores past information.
- The **same function** is applied at every step, updating the hidden state based on new input.

Why they are preferred?

- **Handles sequential data** (Text, Time Series, Speech, etc.).
- **Maintains memory** of previous inputs.
- **Captures patterns over time.**

Real-World Applications of RNNs

- **Speech Recognition** – Used in virtual assistants like Google Assistant and Siri.
- **Text Generation** – Powers AI-driven chatbots and content generators.
- **Machine Translation** – Enables real-time translation in tools like Google Translate.
- **Stock Price Prediction** – Analyzes trends for financial forecasting.

Activation Functions in Neural Networks

Activation functions introduce non-linearity in neural networks, enabling them to learn complex patterns. While **Sigmoid** was initially popular, modern networks often use **ReLU** and **Tanh** due to their efficiency and improved gradient flow.

---

1. Rectified Linear Unit (ReLU)

Definition:

ReLU outputs the input directly if positive; otherwise, it returns zero.

How It Works:

- If x>0x > 0, output remains x.
- If $x \leq 0$, output is 0.

Advantages:
Prevents vanishing gradient (better than Sigmoid & Tanh).
Computationally efficient and speeds up training.

Common Usage:

- Deep learning models (CNNs, object detection, NLP).
- Image classification .

Limitation:
Dying ReLU Problem – Some neurons may become inactive (always output 0).

Hyperbolic Tangent (Tanh)

Definition:

Tanh maps inputs between **-1 and 1**, making it centered around zero.

How It Works:

- If xx is positive, output is close to 1.
- If xx is negative, output is close to -1.

Advantages:
Outputs centered around zero, leading to better optimization.
Provides stronger gradients than Sigmoid.

Common Usage:

- **Recurrent Neural Networks (RNNs)** for sequential data (e.g., language models).
- **Speech and text processing** applications.

Limitation:
- Still suffers from **vanishing gradient**, though less severe than Sigmoid.

Conclusion

- **ReLU** is preferred in **deep neural networks** due to efficiency.
- **Tanh** is useful for **RNNs** where values need to be centered around zero.
- Choice depends on the **architecture and task** (ReLU for images, Tanh for sequences).

3. Exploring Loss Functions

Loss functions evaluate how well a neural network's predictions match actual values. Two commonly used loss functions are **Mean Squared Error (MSE)** for regression and **Cross-Entropy Loss** for classification.

1. Mean Squared Error (MSE)

It calculates the average squared difference between actual and predicted values.

Usage:

- Best suited for **regression problems** where the output is continuous.

Why It's Suitable:

- Penalizes large errors more than small ones, making optimization smoother.
- Ensures small, consistent updates during training.

Real-World Applications:

- **House price prediction** 🏡
- **Stock market forecasting** 📈
- **Weather prediction** 🌦️

---

2. Cross-Entropy Loss (for Multi-Class Classification)

It measures how different the predicted probability distribution is from the actual one.

Usage:

- Used for **classification tasks**, especially when multiple categories exist.

Why It's Suitable:
- Works well with **softmax activation**, ensuring valid probability outputs.
- Encourages confident and correct predictions.

Real-World Applications:

- **Image classification (identifying objects in images)**
- **Spam detection** 📧
- **Sentiment analysis**
- **Language modeling (chatbots, translation)**

Conclusion

- **MSE** is ideal for **regression** due to its sensitivity to large errors.
- **Cross-Entropy** is essential for **classification**, as it ensures accurate probability distributions.
- Choosing the right loss function depends on the **nature of the problem (regression vs. classification).**