University Of Palestine

Faculty of Software Engineering and Artificial Intelligence

Artificial Intelligence – Practical Lab

Assignment #1: First Practical Lab Assignment

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Search and explain an algorithm of AI, ML, or DL

(Neural Networks Algorithm)

1. Definition

Artificial Neural Networks (ANNs), often referred to simply as **Neural Networks**, are a class of algorithms in **Machine Learning (ML)** and the foundation of **Deep Learning (DL)**. They are computational models inspired by the structure and functioning of the **human brain**, where billions of biological neurons communicate with each other through electrical impulses.

In artificial form, a neural network consists of **artificial neurons (also called nodes or perceptrons)** that are interconnected. Each neuron processes input signals, applies a transformation, and passes the result to the next layer, enabling the system to learn complex patterns from data.

2. Structure

A typical neural network is organized into **three types of layers**:

- **Input Layer**:
  - This layer receives raw data (e.g., pixels of an image, words in a sentence, or numerical values).
  - Each input is represented as a vector of features.
- **Hidden Layers**:
  - These layers perform the actual computations.
  - Each neuron in a hidden layer calculates a **weighted sum** of inputs from the previous layer, adds a **bias term**, and applies a **non-linear activation function**.
  - Non-linearity (through functions like Sigmoid, ReLU, or Tanh) allows the network to model complex, non-linear relationships in data.
  - Multiple hidden layers stacked together form a **Deep Neural Network (DNN)**.
- **Output Layer**:
  - Produces the final prediction or decision.
  - For classification, it often uses the **Softmax function** to output probabilities.

- For regression tasks, it may output a continuous value.

3. Learning Process

Neural networks learn through a process called **training**, which involves two key steps:

1. **Forward Propagation**:
   - Data flows from the input layer through the hidden layers to the output layer.
   - Each neuron computes its output based on the current weights and biases.
   - The network generates predictions.
2. **Backward Propagation (Backpropagation)**:
   - The difference between predicted and actual results (the **error**) is measured using a **loss function** (e.g., Cross-Entropy for classification, Mean Squared Error for regression).
   - Backpropagation calculates how much each weight contributed to the error.
   - Optimization algorithms like **Gradient Descent** adjust the weights and biases to minimize the error iteratively.

Over time, the network improves its accuracy by continuously updating its parameters until it reaches an optimal state.

4. Example Application

Consider a neural network for **handwritten digit recognition (MNIST dataset)**:

- **Input**: an image of size 28×28 pixels (784 inputs).
- **Hidden Layers**: neurons detect basic features such as edges and curves, then higher-level features like shapes.
- **Output Layer**: contains 10 neurons (0–9), and the one with the highest probability is selected as the predicted digit.

This same principle can scale up to tasks like face recognition, natural language translation, and medical diagnosis.

5. Strengths of Neural Networks

- **High Accuracy**: Can outperform traditional algorithms in tasks like image and speech recognition.
- **Versatility**: Works with different data types (text, audio, images, numerical).
- **Feature Learning**: Automatically extracts useful features from raw data without manual engineering.
- **Scalability**: Performs well with large datasets and increases in capability with more layers.

6. Limitations

- **Data Hungry**: Requires large labeled datasets for effective training.
- **Computationally Expensive**: Needs high-performance hardware (e.g., GPUs, TPUs).
- **Black Box Nature**: Difficult to interpret why a network made a specific decision.
- **Overfitting Risk**: If not regularized (e.g., Dropout, Early Stopping), the model may memorize training data instead of generalizing.

7. Real-World Applications

- **Computer Vision**: Object detection, facial recognition, autonomous vehicles.
- **Natural Language Processing (NLP)**: Machine translation, chatbots, sentiment analysis.
- **Healthcare**: Medical imaging, disease prediction, drug discovery.
- **Finance**: Fraud detection, stock market prediction.
- **Robotics & IoT**: Decision-making and automation in real-time environments.

In summary: Neural Networks are powerful algorithms capable of modeling extremely complex relationships in data. They form the backbone of today's artificial intelligence revolution, powering technologies from virtual assistants like Siri to autonomous driving systems like Tesla's Autopilot.