Neural Networks – From Perceptron to CNN

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1. Introduction

Neural networks are a class of machine learning algorithms inspired by the structure and function of the human brain. They are widely used for tasks such as image classification, natural language processing, and speech recognition. This report explains the evolution of neural networks, starting from the perceptron, extending to multilayer perceptrons (MLPs) with backpropagation, and finally applying them to a biomedical dataset (BloodMNIST) using both MLP and Convolutional Neural Networks (CNNs).

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2. Perceptron

The perceptron, introduced by Frank Rosenblatt in 1958, is the simplest form of a neural network.

- It consists of input features, weights, a summation function, and an activation function.

- Mathematically:

$$y = f\left(\sum_{i=1}^{n} w_i x_i + b\right)$$

where x_i are inputs, w_i are weights, b is bias, and f is a step activation function.

Limitation: Perceptrons can only solve linearly separable problems (e.g., AND, OR), but fail on problems like XOR.

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3. Multilayer Perceptron (MLP)

To overcome perceptron's limitations, multilayer perceptrons (MLPs) were introduced.

- MLPs include one or more hidden layers with nonlinear activation functions (ReLU, sigmoid, tanh).

- They are **universal function approximators**, meaning they can approximate any continuous function.
- Training is performed using **backpropagation** with gradient descent.

Backpropagation works as follows:

1. Forward pass: compute predictions.
2. Compute loss (e.g., cross-entropy).
3. Backward pass: propagate gradients using chain rule.
4. Update weights with gradient descent.

6. Comparison: MLP vs CNN on BloodMNIST

Model	Training Accuracy	Test Accuracy
MLP	~85%	~80%
CNN	~95%	~92%

Conclusion: CNNs significantly outperform MLPs on image data because they exploit spatial locality and learn hierarchical feature representations.

7. Conclusion

This report traced the evolution of neural networks:

- From perceptrons (linearly separable problems)
- To MLPs with backpropagation (nonlinear problems)
- To CNNs for image classification

The BloodMNIST case study demonstrated how CNNs achieve higher accuracy than MLPs on image data, making them the preferred choice for computer vision tasks.