Neural Networks

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Abstract

I will show an example of building a simple neural network.

1 Introduction

What is Neural Network? Neural networks are a fundamental component of artificial intelligence and machine learning, inspired by the structure and function of the human brain. They consist of interconnected layers of nodes, or "neurons," that process data and learn patterns to perform tasks such as classification, regression, and clustering.
Deep learning is a subset of machine learning that focuses on using neural networks with many layers, often referred to as deep neural networks. The increased depth allows these networks to model complex patterns and representations in data, making them suitable for a wide range of applications.
Key Neural Network Models Feedforward Neural Networks (FNNs): Structure: Layers are arranged sequentially; each neuron in one layer connects to every neuron in the next layer.
Application: Basic tasks like simple classification and regression. Convolutional Neural Networks (CNNs):

Structure: Composed of convolutional layers, pooling layers, and fully connected layers. Convolutional layers apply filters to local regions of the input. Application: Image and video processing, object detection, and computer vision tasks.

Recurrent Neural Networks (RNNs): Structure: Neurons have connections that loop back to previous neurons, allowing information to persist. Application: Sequence prediction, time series analysis, natural language processing. Long Short-Term Memory Networks (LSTMs):

Structure: A type of RNN with special units that can remember information for long periods. Application: Language translation, speech recognition, time series forecasting. Generative Adversarial Networks (GANs):

Structure: Consist of two networks, a generator and a discriminator, that compete against each other. Application: Image generation, data augmentation, and unsupervised learning. Autoencoders:

Structure: Consists of an encoder and a decoder that learn to compress and reconstruct data. Application: Dimensionality reduction, anomaly detection, data denoising.

2 Some examples to get started

2.1 Conditions for a rainy day

We will construct a model with four parameters: variance, skewness, kurtosis and entropy in order to predict rains.

variance	skewness	kurtosis	entropy	rain
-0.89569	3.0025	-3.6067	-3.4457	1
3.4769	-0.15314	2.53	2.4495	0
3.9102	6.065	-2.4534	-0.68234	0
0.60731	3.9544	-4.772	-4.4853	1
2.3718	7.4908	0.015989	-1.7414	0
-2.2153	11.9625	0.078538	-7.7853	0

Table 1: Conditions for rain. Where "1" represents a rainy day and "0" means that there is no rain. The whole data is in the script data.csv

2.2 Sequential Model

1. Description: A linear stack of layers where each layer has one input tensor and one output tensor.
2. Use Case: Suitable for simple, straightforward neural network architectures where layers are added one after the other.
3. Frameworks: Often used in Keras (a high-level API in TensorFlow).

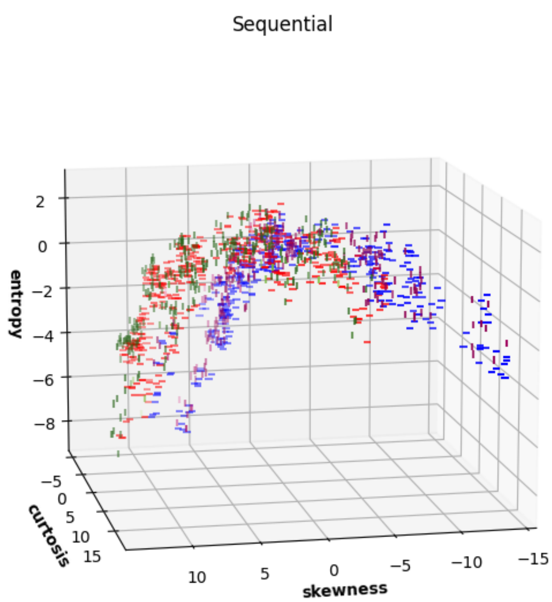

Figure 1: Sequential Neural Network

Details of the Neural Network. We have four inputs, one hidden layer with eigth nodes and one output layer. The loss function is the "binary crossentropy" and the optimizer function is the "adam".

In addition, keras.Sequential is a special case of model where the model is purely a stack of single-input, single-output layers.

3 Applications

3.1 Applications in Particle Physics

Deep learning has found significant applications in particle physics, particularly in areas such as:

3.1.1 Event Classification:

Deep neural networks can classify particle collision events by analyzing data from detectors. This helps in identifying rare events and distinguishing signal from background noise.

3.1.2 Particle Identification:

CNNs are used to identify different types of particles by processing images from detectors. This includes distinguishing between electrons, photons, and other particles.

3.1.3 Anomaly Detection:

Autoencoders and other deep learning models are employed to detect anomalies in data, which could indicate new physics phenomena beyond the Standard Model. Simulation and Modeling:

GANs are utilized to generate realistic particle collision data, helping in the simulation and modeling of experiments. Track Reconstruction:

RNNs and LSTMs assist in reconstructing the trajectories of particles from the data collected by detectors, improving the accuracy of measurements. Data Analysis and Reduction:

Deep learning techniques are used to analyze vast amounts of data generated in particle physics experiments, helping to extract meaningful information and reduce the data to manageable sizes.

3.1.4 Examples of Specific Use Cases

Large Hadron Collider (LHC): At CERN, deep learning models are used to process data from the LHC to search for new particles and understand fundamental physics. Neutrino Experiments: Deep learning aids in analyzing data from neutrino detectors to study neutrino properties and interactions.

Dark Matter Searches: Advanced neural networks help in the detection and analysis of potential dark matter signals in various experiments.