

Convolutional Neural Networks for Beginners

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Abstract—Artificial Intelligence (AI) and its subfields: Machine Learning (ML) and Deep Learning (DL), have triggered a revolution in the world. Convolutional Neural Networks (CNNs) are the Deep Learning models that have gained widespread popularity due to excellent performance in image classification, object detection, image segmentation, image captioning, action recognition, audio processing, video and text analysis, etc. This paper presents a fresh and all-inclusive tutorial on CNNs for beginners — at both “macro” and “micro” levels. It starts with explaining basic terminologies: Biological Neural Networks (BNNs), Artificial Neural Networks (ANNs), Convolutional Neural Networks (CNNs), neurons, types of ANNs and CNNs, and their “learning” mechanisms. A generic CNN pipeline is then dissected into 6 layers (input layer, convolutional layer, pooling layer, flattening layer, fully connected layer, output layer) and each related part and concept is described with its function, need, types, advantages, disadvantages, etc. Rich information is provided about: neurons, convolutions, filters or kernels, weights, biases, gradients, activation functions, pooling, neural receptive fields, parameters, hyper-parameters, loss functions, optimization algorithms, etc. In the end, a comparison of 13 CNNs (LeNet, AlexNet, VGGNet, ZFNet, GoogLeNet, MobileNets, ResNets, EfficientNet, DenseNet, etc.) is presented. Readers will gain strong foundational knowledge through this article and it will empower them to do advanced research by providing answers to many important, critical, basic questions.

Keywords—Artificial Neural Networks, ANNs, Convolutional Neural Networks, CNNs, ConvNets, Convolutions, Gradient Descent, Loss Function, Activation Function, Backpropagation, LeNet, AlexNet, VGG16, MobileNet, GoogLeNet, ResNet-34, ResNet-152, ResNeXt-101, EfficientNetB0, DenseNet-169.

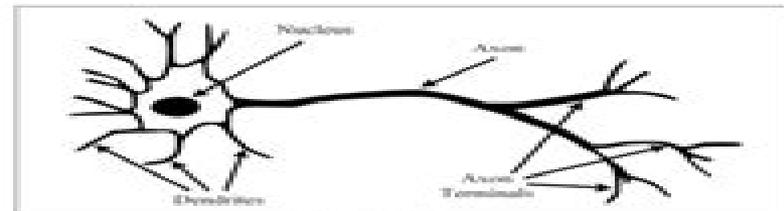
I. INTRODUCTION

A. Neural Networks (NNs)

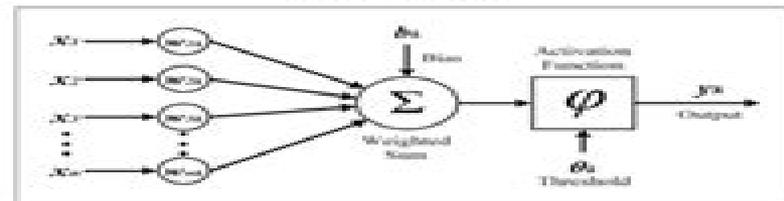
Human body contains a network of billions of neurons, called Neural Network (NN), Biological Neural Network (BNN), or Neural Circuit [1]. “Neurons” are the building blocks of BNNs, used to learn information. They are present in the Central Nervous System (brain & spinal cord) and Peripheral Nervous System (nerves & ganglia). BNNs enable humans and animals to learn **consciously** and **subconsciously** using different stimuli received from their senses [1]. Humans have diverse types of senses including: vision, hearing, touch, taste, smell, balance (equilibrioception), body awareness (proprioception), movement (kinaesthesia), temperature (thermoception), conscience (morality), pain (nociception), consciousness, hunger, thirst, and suffocation. All senses work in a collaborative, collective manner through a process called **multisensory perception** and assist learning [1].

B. Learning in Biological Neural Networks (BNNs)

Learning in brain happens through a process called “**neural plasticity**” that strengthens or weakens neural connections in



(a) Biological neuron.



(b) Artificial neuron.

Fig. 1. Structure of biological and artificial neurons.

BNNs on the basis of neural activity [1]. Signals reach neural network through sensory nerves in the form of “**electrical impulses**” and travel in between when the pertinent neurons are “**activated**” (or fired). A neuron is said to be activated when it passes its energy (or signal) to other neuron(s). Based on these activated neural paths or patterns, the connections between relevant neurons keep on evolving by forming new connections, strengthening the most active connections, and eliminating the inactive connections over time [1] e.g. if a task is repeated, the unique activation paths of neurons related to the task becomes stronger. Finally “**learning**” occurs when the neural pattern solidifies and the task is “**learned**” [1].

C. Artificial Neural Networks (ANNs)

Artificial Neural Networks (ANNs), also called Neural Nets or Neural Networks, are learnable “**computational models**” related to Artificial Intelligence (AI) [2]. They are developed after inspiration from BNNs, however, both are significantly different [2]. BNNs are vast, complex, diverse, adaptable, and intricate [1]. They exist in the form of “**amorphous**” mesh of neurons. Whereas, ANNs are relatively small and simple, comprised of “**artificial neurons**” (also called nodes) which are “**efficiently arranged**” in the form of “**layers**”. Artificial neurons are individual “**processing units**” that perform computations and activations [2] (as shown in Fig. 1). Layers in ANNs are primarily categorized as **input layer**, **hidden**

Neural Computation A Beginners Guide

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