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Artificial Neural Network Related to Biological Neuron Network: A Review

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Abstract

In an artificial neuron**,** the operation process of $W_1x_1 + W_2x_2$ has emulated the action of Dendrite of human neuron. The x_1, x_2 were the inputs and W_1, W_2 were the weights. $W_1x_1 + W_2x_2 + b$ has emulated the Axon Hillock of human neuron to obtain the membrane potential. The b was the bias. When $W_1x_1 + W_2x_2 + b$ was equal (or larger than n) to n and then it emulated Axon of human neuron by which an action potential was obtained by converting the membrane potential. In order to emulate an inspiring of artificial neuron, activation function emulated Synapse of human neuron by which action potential was converted to electrical energy and chemical energy and passes it to the next artificial neuron as inputs.

Keywords: Human Neuron, Artificial Neural Network (ANN), Dendrite, Weights, Axon Hillock, Membrane potential, Bias, Action potential, Axon, Synapse, Activation function

1 Introduction of Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is a type of supervised learning approach in machine learning with labelled inputs (supervised learning) [20, 21] and is an emulation of the biological neural network in the human brain (Fig.1). The human brain controls thinking and behaviour. Emulation of the structure of the brain, including neurons and neuronal function, helps in gaining in-depth knowledge about the composition of biological neuron networks. The human brain has a large number of neurons, or nerve cells, and each nerve cell is linked to many other nerve cells via synapses, forming very complex neural networks [6, 7].

Therefore, synaptic function [17] is very important. A neuron sends messages via synapses to another neuron, which establishes a good foundation for modern neuroscience. Humans have the ability of self-learning because neural networks have a large number of parallel computing and distributed information processing. Therefore, scientists hope to apply modern computer-based programs to utilize the self-learning ability of humans to emulate the human brain [8, 19, 24]. Therefore, the structure of an ANN is defined similar to the parallel computing model of the human nervous system. An ANN is a technology that emulated for processing information related to the brain and the nervous system, and is commonly referred to as parallel distributed processing (PDP) model or connectionist model. An ANN is composed of many classes of artificial neurons (also known as nodes). Currently, an ANN can already has a large number of for parallel computing and distributed information processing by using the fast calculation speed of a computer [11]. However, an ANN still cannot emulate the function of human brain cells because they are very large in number. All the operations of the human brain cells cannot be implemented completely in an ANN. The computation time is a big problem, and therefore improvement of ANN algorithms is required. According to anatomical information, the human brain has a layered structure, which belongs to the six layers of the mature brain cortex. All higher-order cognition is carried out in the brain. Performing such a complex thinking operation depends on the layered structure and the number of neurons, as well as the type of link style. ANN is emulated a biological neuron network operation with mathematical function i.e. activation function and parameters i.e. weights and bias [8, 18, 24].

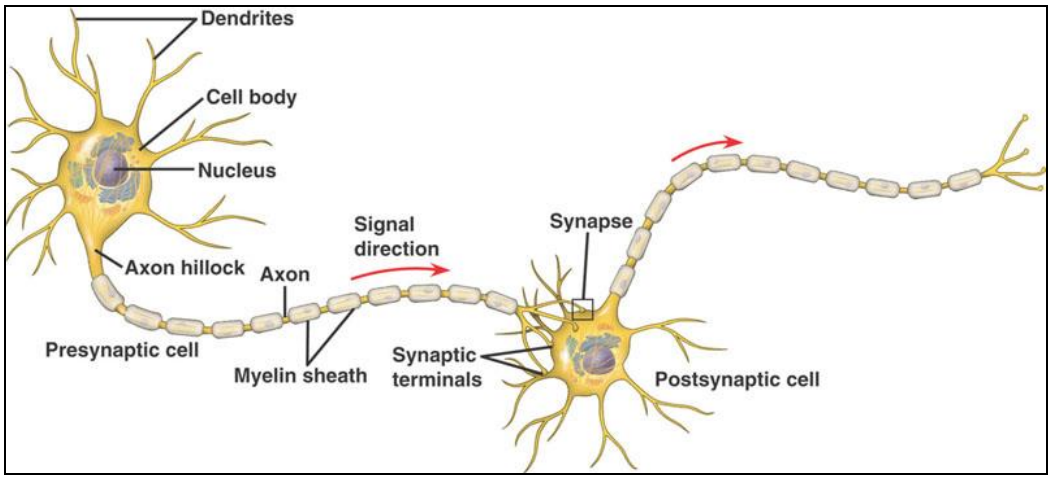

Fig.1 This figure shows the simple structural map of a biological neuron [13].

As shown in Figure 1, a biological neuron can be divided into the following parts [1, 3, 6, 10, 13, 23, 26, 29]. (1) Dendrite: It receives electrical chemical energy from last neurons as inputs of a neuron. (2) Axon Hillock: It is the part between the cell body and the Axons. It transfers the electrical chemical energy into

membrane potential. (3) Axon: it is a component of a nerve fibre and it transfers the membrane potential formed by the Axon Hillock into an action potential. (4) Synapse: Its role is to transfer the action potential into electrical and chemical energy and conduct them to the next neuron when the action potential is equal to (or larger than) a certain threshold. However, a biological neuron is very complex, so only four main parts are introduced because an ANN emulates these parts.

2 Algorithm of a Neuron in ANN

A mathematical algorithm procedure of a neuron in ANN is described. Fig. 2 describes this procedure.

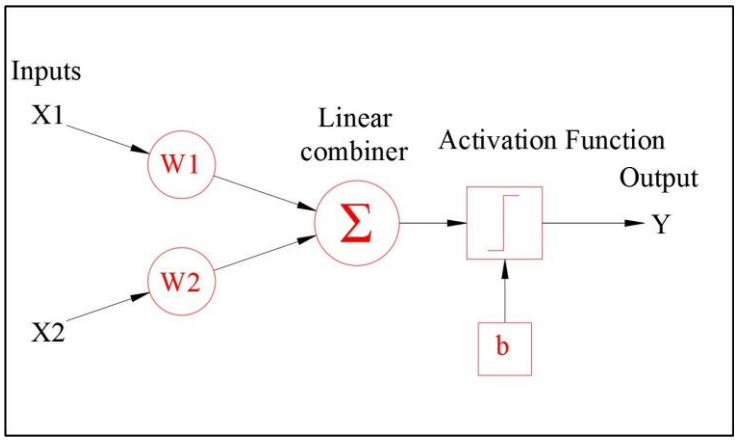

Fig. 2 This figure shows the algorithm procedure of an artificial neuron that emulates a human neuron.

In Fig 2, the mathematical operation of this neuron for given inputs to form

$$n = \begin{bmatrix} w_1 w_2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + b \quad [19] \tag{1}$$

where x_1, x_2 are the inputs from the last neurons. W_1 and W_2 are the weights. b is the bias of this neuron. n can be called a threshold.

Therefore $n = W_1 x_1 + W_2 x_2 + b$ (2)

where is the linear combination function of the neuron operation.
The function f is an activation function that is nonlinear differentiable function [21, 28] and then the parameter

$y = f(n)$ is output (3).

The concepts of Formulas (1) (2) (3) associated with weight and bias that learned rule draw the decision boundaries using ANN when dealing with recognition problems e.g. pattern recognition [8, 9; 15].

3. Discussion

The operation process to form $W_1x_1 + W_2x_2$ that emulated an action of human Dendrite when receiving an input message from last neuron. In the sense of the digital signal processing (DSP) is in an artificial neuron, the weight and bias values are updated by inputs similar to the Modulation) [4, 22] similar to Amplitude Modulation (AM) of radio [2]. $W_1x_1 + W_2x_2 + b$ is an action that emulates an Axon Hillock to form the membrane potential. Under the condition of $W_1x_1 + W_2x_2 + b$ be equal (or larger than n) to n, and then transforms the membrane potential formed into an action potential by Axon. Therefore, the Axon is emulated to check whether it can inspire the neuron. Weight and bias are adjusted by inputs to be equal (or larger than n) to n, and then they seem to emulated for inspiring an artificial neuron.

The Synapse similar to activation function converts the action potential into electrical energy and chemical energy and passes it to the next neuron as inputs. This emulated action includes a process by which the combination function is transferred to obtain the output through activation function. When human neurons process external stimuli, there is a limit on the output because if the output pulse signal is too strong, the neurons may get damaged through inspiring. Supposed the operating system of the human neuron is a linear time-invariant system (LTI). When the input signal to the neurons is an impulse, then the output response is impulse [12, 17, 22), so that the output of the neuron is a pulse. Therefore, the activation function of the neuron cannot be LTI.

An example shown in Figure 3, in which $n = 0$ is a boundary from Formula (2). If it determinates at $n \geq 0$, the neuron will be inspired. In contrast, for $n < 0$, the neurons are inhibited. The weight and bias will be determined by training ANN in which learns how to e.g. identify particular classes by their typical input data characteristics, so that ANN can emulate the human neuron's ability for learning by adjusting the values of weight and bias that emulated for inspiring an artificial neuron for feedforward ANN with target outputs [25]. The previous statements were described similarly [27]. That means that such Neural Network has three rules that are multiplication, summation and activation. The activation function converts a combined function into the transient pulse-like instantaneous output and passes it to the next neuron as the instantaneous input [14, 19, 20]. The inputs convert the combination function to outputs via the weights and biases. This is a mapping rule. The nonlinear factor is imported in training ANN because the activation function is a nonlinear function. The activation function of each artificial neuron is nonlinear, which is an analog of the human neuron's recall [5].

4. Conclusion

$W_1x_1 + W_2x_2$ was emulated an action of human Dendrite, $W_1x_1 + W_2x_2 + b$ emulated the Axon Hillock to transform a membrane potential.

When $W_1x_1 + W_2x_2 + b$ has been accessed (or larger than n) to n then an action potential is generated by Axon. The action potential was converted by Synapse served as a Activation function into electrical energy and chemical energy for the next neuron as inputs.

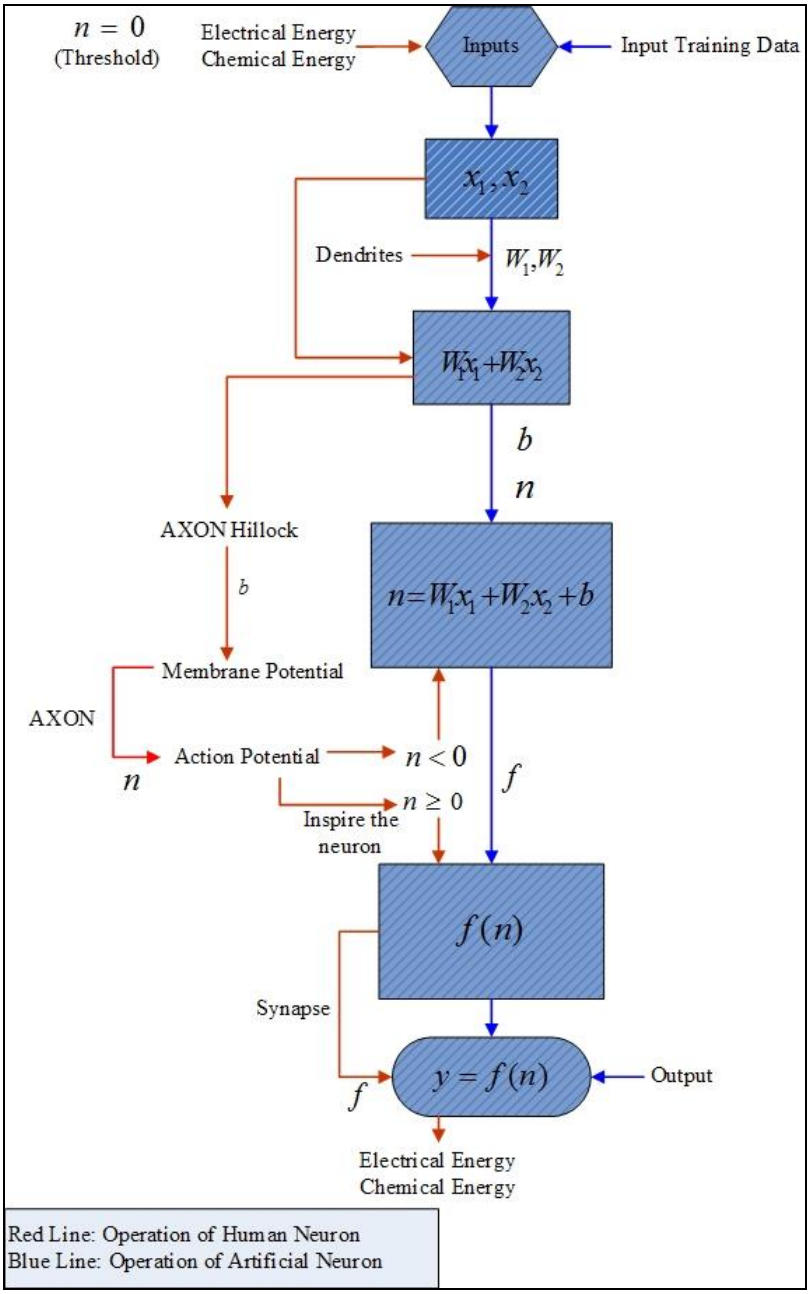

Figure 3 Flowchart of the operations of artificial neuron that emulated: operation process in a human neuron.

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