Neurons in Artificial Intelligence

Professor Dr. Ahmed Shaker Alalaq

Iraq- University of Kufa

Ahmed.alallaq@uokufa.edu.iq

Summary

Neurons are fundamental to artificial intelligence models, as they emulate the way neurons function in the human brain. These units play a vital role in advancing artificial neural networks, which form the backbone of many AI applications, such as deep learning, natural language processing, and computer vision. Understanding how neurons work can enhance algorithm performance, leading to significant advances in areas like robotics, medical diagnostics, and data analysis. By studying neurons, we can develop more accurate and faster-learning models, paving the way for new horizons in technological innovation.

Study Limitations: This study is confined to analyzing neurons within the scope of artificial neural networks only, without addressing the biological or chemical aspects of neurons in the human brain. It also focuses on specific AI applications, such as deep learning, which may overlook other AI techniques or models. Furthermore, factors like data availability and quality may impact the generality and effectiveness of the findings across different scenarios.

This study contributes to enhancing our understanding of how to improve AI models by drawing design inspiration from neurons. However, its limitations highlight

Section One: What are nerve cells?

Neural networks, or artificial neural networks, are a type of computational engineering based on a model of how the human brain works—hence the name "neural." Neural networks consist of a collection of processing units called "nodes." These nodes transmit data to each other, just as neurons in the brain transmit electrical impulses to one another. Each node is a computational unit that receives one or more inputs, processes them, and produces an output. These neurons are the fundamental building blocks of neural networks, which are algorithms designed to recognize patterns (Manu, 2018). The design of smart neurons mimics the hierarchical arrangement of neurons in biological sensory systems. In both smart neural networks, when inputs are processed, they decide whether to pass the output to the next layer as input. This decision to

the need for future research to explore new and integrated aspects.

In our study, we relied on a valuable and important collection of articles, studies, and scientific research that discussed neurons in artificial intelligence, among which are:

Manu, Mitra. (2018). Neural processor in artificial intelligence advancement

Sigurdson, Peter.(2023). The Engines of Excellence: From Ancient Secrets to AI Mastery

Great Learning Editorial Team.(2024). Types of Neural Networks and Definition of Neural Network

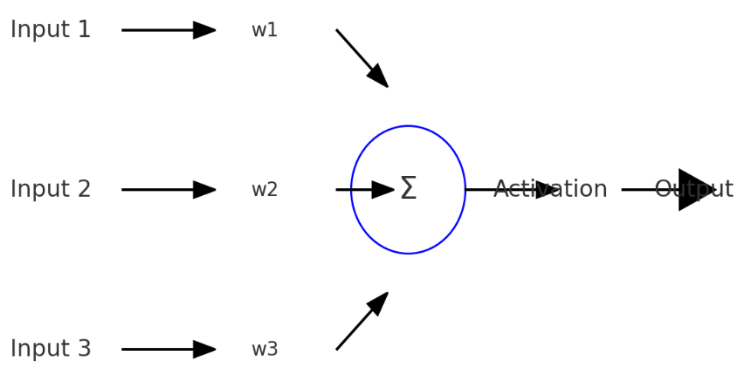
Keywords (artificial intelligence, neurons, technological revolution, scientific research, academic context)

sensory systems. In the visual system, for example, light input passes through neurons in successive layers of the retina before being passed to neurons in the thalamus of the brain and then on to neurons in the brain's visual cortex. As the neurons pass signals through an increasing number of layers, the brain progressively extracts more information until it's confident it can identify what the person is seeing. In artificial intelligence (AI), this fine-tuning process is known as deep learning. In both artificial and biological networks, when neurons process the input they receive, they decide whether the output should be passed on to the next layer as input. The decision of whether to send information on is called bias, and it's determined by an activation function built into the system. For example, an artificial neuron can only pass an output signal on to the next layer if its inputs, which are voltages, sum to a value above some particular threshold value. Because activation functions can either be linear or non-transmit information is called bias (Robinson, n.d.).

Neural networks require data to learn, and the more data fed into the network, the more accurate it becomes. When researchers or computer scientists begin training a neural network, they typically divide their data into three groups. The first group is the training set, which helps the network determine the different weights between its nodes. They then fine-tune it using the validation dataset. Finally, they use a test set to check if it can successfully convert inputs into the desired outputs (Mihajlovic, 2019).

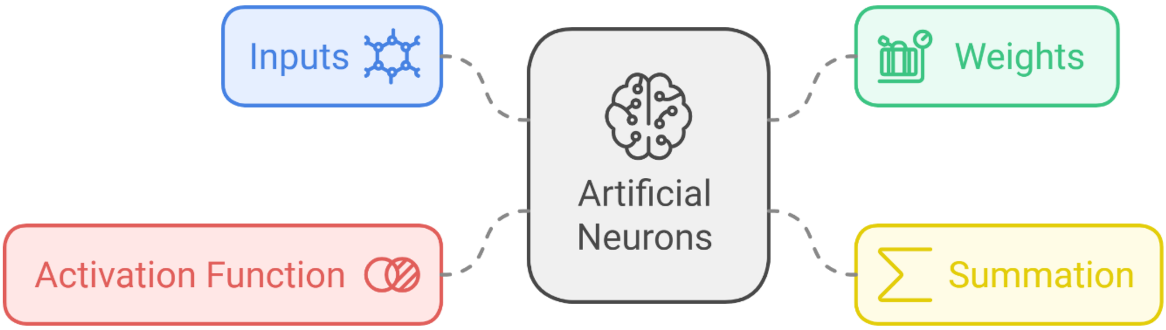
In both artificial and biological architectures, the nodes are called neurons, and the connections are characterized by synaptic weights, which represent the significance of the connection. As new data is received and processed, the synaptic weights change, and this is how learning occurs. Artificial neurons are modeled after the hierarchical arrangement of neurons in biological linear, neurons often have a wide range of convergence and divergence. Convergence is the ability for one neuron to receive input from many other neurons in the network, and divergence is the ability for one neuron to communicate with many other neurons in the network.(Scott,n.d).

Neural Network Neuron Operation in AI



• **Weights**: Each input has an associated weight, which is adjusted during training to improve the model’s predictions.

• **Bias**: A constant added to the weighted sum of the inputs to provide flexibility to the model.

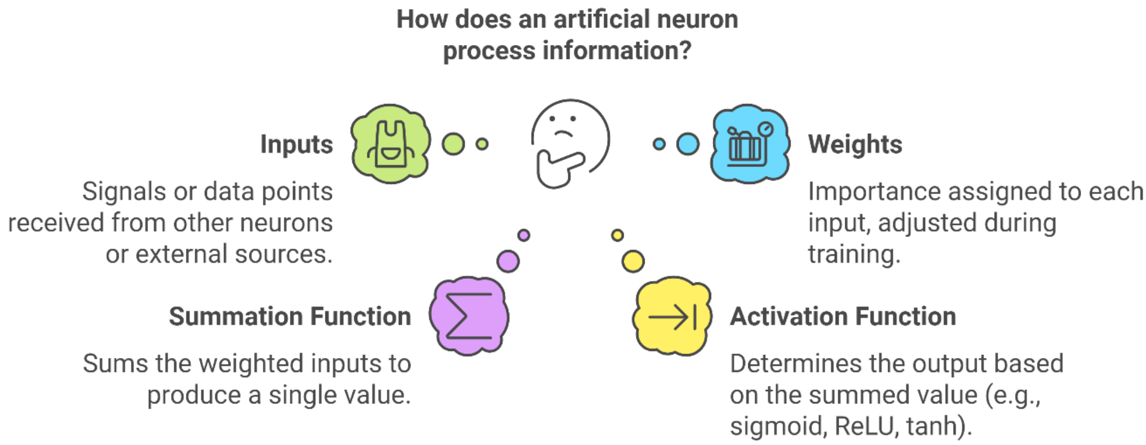


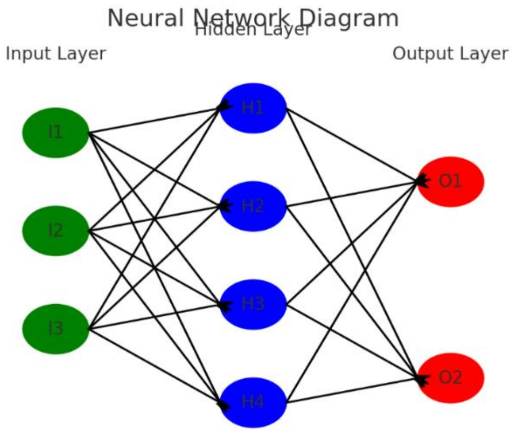
• **Activation Function**: As discussed in the main article, this function introduces non-linearity, allowing the model to learn from errors and make complex decisions (Sigurdson, 2023).

Section Two: Components of Neurons are

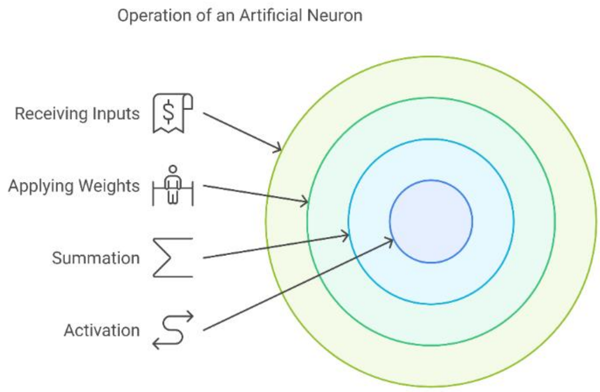
Artificial neurons are the basic building blocks of neural networks, which are computational models inspired by the human brain. Just as biological neurons transmit signals through synapses, artificial neurons process inputs and produce outputs based on mathematical functions. Each artificial neuron receives input signals, applies a weight to each signal, sums them up, and then passes the result through an activation function to determine the output.

• **Inputs**: These are the data points or features that are fed into the neuron.





Each neural node is connected to another and is characterized by its weight and a threshold. It gets an input on which it does some transformation and post that, it sends an output. If the output of any individual node is above the specified threshold value, that node gets activated. Then, it sends data to the next layer of the network. Otherwise, it remains dormant and thus doesn't transmit any data to the next layer of the network.(Nikhil,2024)



The operation of an artificial neuron can be summarized in a few steps:

1. **Receiving Inputs**: The neuron receives multiple inputs, each potentially coming from other neurons in the network.
2. **Applying Weights**: Each input is multiplied by its corresponding weight, reflecting the significance of that input.
3. **Summation**: The weighted inputs are summed to produce a single value.
4. **Activation**: The summed value is passed through an activation function, which introduces non-linearity into the model, allowing the network to learn complex patterns.

consisting of a single node that performs binary classification by applying a linear decision boundary.

- **Application**: It is primarily used for linearly separable problems like simple binary classification tasks.
- **Analysis**: While foundational in neural network theory, it is limited in scope and not used for modern, complex tasks due to its inability to solve non-linear problems.

2. Feed Forward Neural Network (FFNN)

- **Function**: A basic neural network architecture where information flows in one direction—from input to output—without any cycles or feedback loops.
- **Application**: Used in various tasks such as classification and regression problems, and serves as the foundation for more complex architectures.

The third topic: Types of neurons in artificial intelligence

The nine types of neural network architectures are:

- Perceptron
- Feed Forward Neural Network
- Multilayer Perceptron
- Convolutional Neural Network
- Radial Basis Functional Neural Network
- Recurrent Neural Network
- LSTM – Long Short-Term Memory
- Sequence to Sequence Models
- Modular Neural Network.(Great Learning Editorial Team,2024)

1. Perceptron

- **Function**: The simplest form of a neural network,

- **Function**: Designed specifically for processing structured grid data like images by using convolutional layers to detect spatial hierarchies and features.
- **Application**: Widely used in computer vision tasks such as image and video recognition, object detection, and segmentation.
- **Analysis**: CNNs excel in tasks involving spatial data because they are highly efficient at recognizing local features and patterns, like edges and textures. However, they require large amounts of labeled data for training and are computationally demanding.

5. Radial Basis Function Neural Network (RBFNN)

- **Function**: This network uses radial basis functions as activation functions and is

- **Analysis**: This architecture is simple and effective for many tasks, but it struggles with sequential or time-dependent data because it lacks memory components.

3. Multilayer Perceptron (MLP)

- **Function**: An extension of the perceptron with multiple hidden layers, allowing it to solve more complex, non-linear problems.
- **Application**: Commonly used in image recognition, speech recognition, and other applications requiring deep learning models.
- **Analysis**: The additional hidden layers enable MLPs to capture intricate patterns in the data. However, they are computationally intensive and require careful tuning of hyperparameters like the number of layers and nodes.

4. Convolutional Neural Network (CNN)

processing (NLP), and speech recognition.

- **Analysis**: RNNs are powerful for tasks where context or memory is important. However, they can suffer from issues like vanishing gradients, which makes training long sequences difficult.

7. Long Short-Term Memory (LSTM)

- **Function**: A specialized type of RNN designed to overcome the vanishing gradient problem by using memory cells to capture long-term dependencies in data.
- **Application**: Applied in long-sequence tasks such as machine translation, speech synthesis, and video analysis.
- **Analysis**: LSTMs are capable of learning long-term dependencies and handling both short- and long-sequence data effectively. They require

known for its excellent interpolation capabilities.

- **Application**: Applied in function approximation, classification, and time-series prediction tasks.
- **Analysis**: RBFNNs are effective in situations where you need to interpolate data or when the relationship between inputs and outputs is complex but well-defined. However, they may not scale well with larger datasets and require a careful choice of radial basis functions.

6. Recurrent Neural Network (RNN)

- **Function**: A neural network with loops that allow information to persist, making it well-suited for sequential data.
- **Application**: Commonly used for tasks involving sequences, such as time series forecasting, natural language

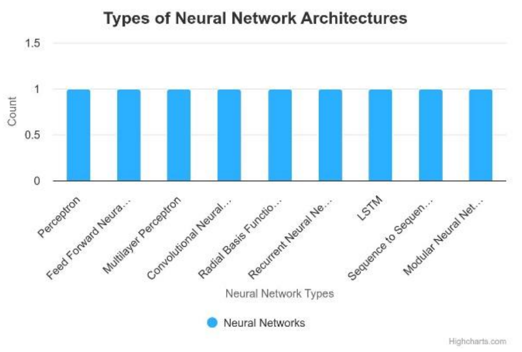
- **Function**: A system composed of multiple independent networks (or modules), each specializing in a sub-task, with their outputs combined to produce a final result.
- **Application**: Used in complex systems requiring different parts to process different types of data or perform different subtasks.
- **Analysis**: MNNs are scalable and flexible, allowing complex problems to be divided into simpler components. However, they can be difficult to manage and require careful design to ensure that the modules work harmoniously. (Chat GPT).

more computational resources compared to standard RNNs but are significantly more robust for sequential tasks.

8. Sequence to Sequence Models (Seq2Seq)

- **Function**: A model architecture that maps an input sequence to an output sequence, often using an encoder-decoder framework.
- **Application**: Used in machine translation, text summarization, and other tasks that require converting one sequence into another.
- **Analysis**: Seq2Seq models are highly effective for tasks where the input and output are sequences of different lengths or structures. However, they rely heavily on good training data and can be difficult to fine-tune for long sequences.

9. Modular Neural Network (MNN)



References

Alalaq, Ahmed (2024), "Augmented Reality and Its Relationship to Artificial Intelligence in Historical Studies", Mendeley Data, V1, doi: 10.17632/kzc5bt9578.1

Manu, Mitra. (2018). Neural processor in artificial intelligence advancement. 1(1):2-14. doi:10.32629/JAI.V1I1.13

Robinson, Scott.(n.d). artificial neuron. https://www.techtarget.com/searchcio/definition/artificial-neuron

Mihajlovic, Ilija.(2019). Introduction To Artificial Intelligence — Neural Networks. https://medium.com/@ilijamihajlovic/introduction-to-artificial-intelligence-neural-networks-5c7244f60425

Conclusion

In conclusion, neurons form the foundation for the design of artificial neural networks and play a central role in advancing modern AI technologies. By emulating how neurons function in the human brain, these models can process vast amounts of data and learn from complex patterns. We have witnessed significant advancements in fields like deep learning and natural language processing, enabling AI to achieve groundbreaking accomplishments in many applications, including healthcare and autonomous driving.

However, there are still technical and scientific challenges that require the attention of researchers and developers. Improving the efficiency and flexibility of artificial neurons can enhance model accuracy and expand their range of applications. Additionally, exploring new methods to bridge the gap between machine learning and human cognition is essential.

A deep understanding of neurons and their applications in AI is key to building smarter and more innovative systems, paving the way for a future where technology integrates into our daily lives in unprecedented ways.

Sigurdson, Peter.(2023). The Engines of Excellence: From Ancient Secrets to AI Mastery. https://www.linkedin.com/pulse/engines-excellence-from-ancient-secrets-ai-mastery-peter-sigurdson

Scott Robinson.(n.d). What is an artificial neuron?. https://www.techtarget.com/searchcio/definition/artificial-neuron

Nikhil Bhargav.(2024). Neurons in Neural Networks. https://www.baeldung.com/cs/neural-networks-neurons

Great Learning Editorial Team.(2024). Types of Neural Networks and Definition of Neural Network. https://www.mygreatlearning.com/blog/types-of-neural-networks/