Case study 16.2 Artificial neural networks

Artificial neural networks, simply called **neural networks**, are computer-based representations of theoretical (mathematical) models that consist of several layers of interconnected units called processing elements or 'neurons', where the units have some of the properties of CNS neurons in animals.

For example, just like real neurons, each processing element receives inputs either from outside the network or from other processing elements via 'synapses'; the inputs are then processed by each individual element according to a mathematical function that simulates the process of synaptic integration at the level of CNS neurons. The processed outputs are sent either to other processing elements, or outside the network.

Neural networks are of two types

Figure A shows examples of two types of neural networks, where the 'neurons' are organized in three layers. The first layer is called the input layer, because the 'neurons' in this layer receive inputs from outside the network, and the last layer is called the output layer because neurons in this layer send their output outside the network. The layers sandwiched between the input and the output layers are called hidden layers. 'Neurons' in the hidden layers receive and process input signals from other 'neurons'.

In some neural networks the flow of information is unidirectional, from 'neurons' in one layer that is closer to the input layer, to 'neurons' in another layer that is closer to the output layer, as shown in Figure A(i). This type of neural network is called a **feed-forward network**, because there is no flow of feedback information. Other type of networks that also have connections between 'neurons' of the same layer or in which information also flows backwards, towards neurons closer to the input layer, are called **recurrent networks**. A simple example of a recurrent network is shown in Figure A(ii).

In the process of signal integration, each artificial neuron also simulates activation-based plasticity of the neuron, by updating its memory with respect to variable parameters in the mathematical function that manipulate the data in the calculations. For example, 'synapses' store parameters called 'weights' which are updated every time the 'synapse' is activated. The update of the local memory with respect to such variables can be compared to subtle changes in neuron membrane properties following activation of synapses, such as memory formation at synapses as we discuss in Section 16.3.6 and **Experimental Panel 16.2** (online below).

Neural networks can be trained to learn

A major advantage of neural networks compared to other computing models is that they can be trained to learn. Learning methods are grouped into two categories: 'unsupervised learning' and 'supervised learning'. In unsupervised learning the neural networks are provided with a set of inputs and the network determines outputs based on similarity of characteristics in the data provided. Supervised training consists of providing not only inputs but also desired outputs and the neural network is trained for yielding responses as close as possible to the provided outputs. After the learning phase, the neural network can predict outcomes for a given set of inputs.

Neural networks are particularly successful for resolving tasks associated with **pattern recognition** by learning to predict future events based on previously observed patterns. For example, NASA developed a self-learning neural network system for aircraft which continuously compares operating data from the aircraft's computers with a database and predicts how the aircraft would optimally perform in an emergency situation, in which case it automatically adjusts the flight controls to compensate for any damaged or inoperative control surfaces or systems.

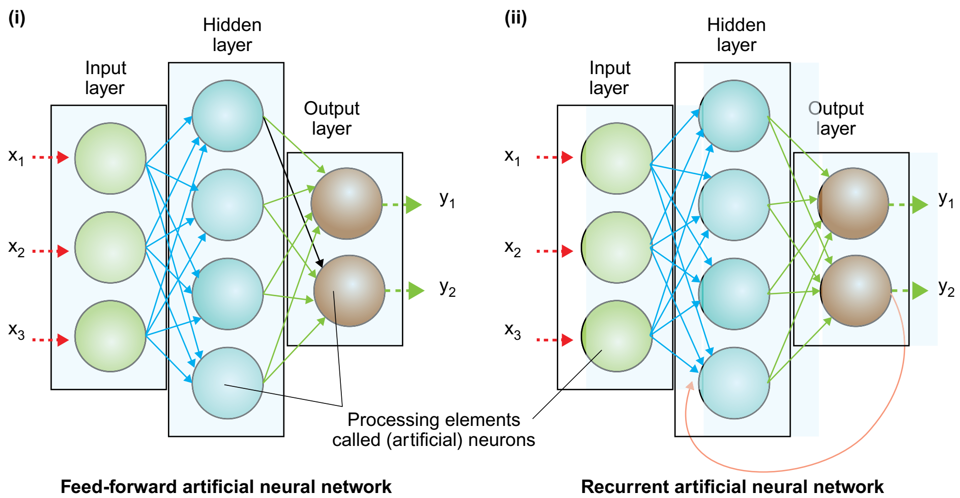

Figure A Artificial neural networks consist of interconnecting processing elements with properties of CNS neurons

(i) Example of feed-forward artificial network, where the flow of information (indicated by arrows) is unidirectional. An input layer of 'neurons' receives inputs from outside the network (indicated by dashed red arrows) and an output layer transmits the outputs from the neural network to the outside (indicated by dashed green arrows). An uninterrupted arrow represents a connection from the output of one 'neuron' to the input of another in the network. The layers between the input and the output layers are called hidden layers.

(ii) Example of recurrent artificial neural networks where there are feedback loops like that shown by the orange arrow between a 'neuron' in the output layer and a neuron in the hidden layer.

Similarly, neural networks are used for predicting future events in control systems used in vehicles and robotics; in the development of management strategies of complex activities; in the progress of clinical disorders and management of various therapies; in automated trading systems in shares, commodities and currency exchange; and in game-playing and decision making.

Neural networks are also successful in classifying new data into pre-defined groups of data. For example, neural networks now play a major role in object recognition in radar and computer vision, speech recognition, face identification, handwriting text identification, gesture recognition and detection of cancers and other medical disorders from radiological images.

Neural networks are also capable of clustering data into natural groups based on similarity of characteristics. Therefore, the neural networks have become an important tool in data mining, which is known as knowledge discovery in databases, e-mail filtering and identification of suspicious transactions and fraudulent purchases using credit cards. Due to their versatility and ability to 'learn', the artificial neural networks are extensively used in computer systems known as **artificial intelligence** or AI, which are able to perform tasks normally associated with human intelligence.

We must not lose sight, however, that each individual neuron in the CNS of vertebrates is as complex (or even more complex) than any of our computers. For this reason, neural networks have a long way to go to simulate in depth how the animal brain functions.

Find out more

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