Artificial Neural Networks

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INTRODUCTION

Artificial neural networks (ANNs) is a subfield of machine learning within the research domain of artificial intelligence (see Artificial Intelligence, this volume). Research in developing ANNs started after McCulloch and Pitts (1943) proposed a mathematical model of neuronal activity in the brain and Hebb (1949) created a reinforcement based learning mechanism to explain learning in the human brain. Rosenblatt (1958) then created a computational model of brain processing elements called perceptrons and ANN research started in earnest. The goal of ANN research is to develop machine learning systems that are based on a biological model of the brain, specifically the bioelectrical activity of the neurons in the brain.

ANNs are a popular solution method in numerous domains including: business (Tkáč & Verner, 2016; Wong, Lai, & Lam, 2000), engineering (Ali et al., 2015; Bansal, 2006), and medicine (Reggia, 1993; Yardimci, 2009). Research and development with ANNs continues to be highly productive with the quantity of articles published in this subfield increasing annually. Using the search query *artificial neural network* on a university article database search produced 27,736 articles from 1985 to 2000 and 203,328 from 2001 to 2016 with over 51 percent of the publications appearing from 2011 to 2016; indicating a tenfold increase in ANN articles published over the same amount of time (16 years) and the trend continuing to accelerate.

It is important to understand the terminology used to discuss ANN architectures. A sample ANN architecture for a supervised learning multi-layer perceptron is shown in Figure 1. Modern ANNs are composed of:

- A layer of input elements also called the input vector, representing independent variables,
- Optionally, one or more hidden processing layers,
- Weighted connections between nodes in adjacent layers, and
- An output layer of one or more elements, representing the dependent variable(s).

Every processing element or neurode in a layer is connected to all processing elements in the next layer, with input neurodes connected to hidden layer neurodes etcetera, until the neurodes in the last hidden layer are connected to the output layer neurodes. These connections all carry a value, commonly called a weight, that is adjusted to permit learning. It is possible for an neurode to not be fully connected to the subsequent layer, but to be connected selectively to one or more neurodes in the following layer. Some ANN architectures also have weighted connections from a layer to not only the next layer, but also to one or more subsequent layers of neurodes.

What types of research problems are amenable to an ANN approach? Essentially, ANNs are intelligent pattern recognition machines. Thus, any problem which may be defined as a pattern recognition problem is suitable for ANN solutions. This includes all types of classification problems and also most prediction problems, such as time-series forecasting or medical diagnosis. Additional research has shown that ANNs may be used as a tool for evaluating medical or business decision making heuristics (Walczak, 2008).

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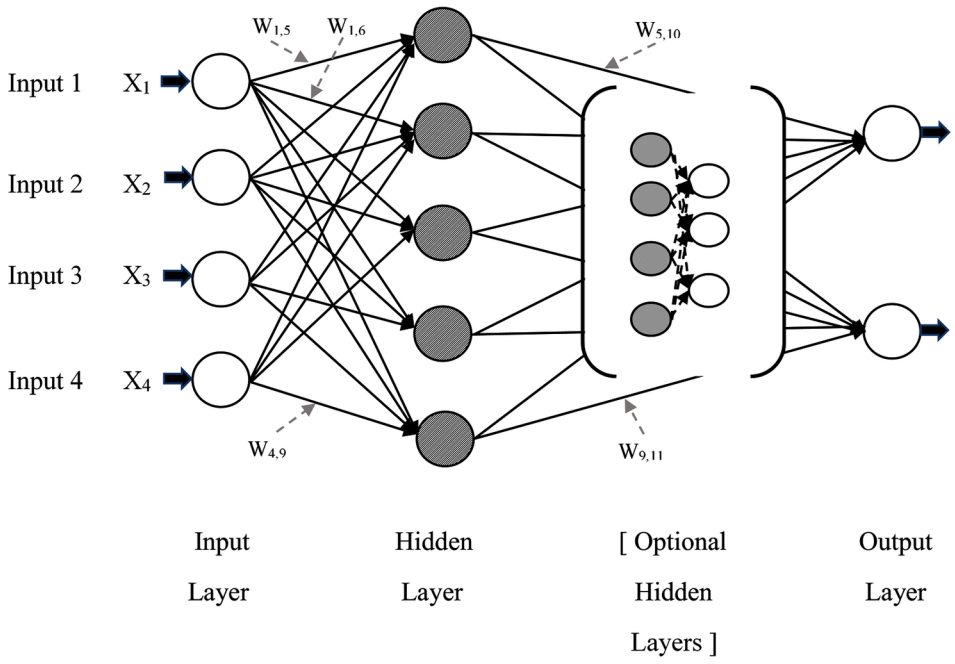
Figure 1. Supervised learning ANN architecture (only a few connection weights shown)



BACKGROUND

Research on ANNs and development of ANN applications started out strongly throughout the 1960's following Rosenblatt's (1958) discovery of perceptrons. Early work in ANNs used perceptrons and multiple layer perceptrons, that used a supervised learning rule to adjust connection weights based on the difference between the desired output and the output produced by the perceptron. Other learning rules were also developed including the ADALINE (ADAptive LINear Element) and MADALINE (Multiple Adaline) (Widrow, 1964).

Minsky and Papert (1969) demonstrated limitations of simple perceptrons, specifically difficulty in solving the exclusive or problem. A simple perceptron is defined as an ANN where the input layer is connected directly to the output layer with no intervening layers. The backpropagation algorithm, also referred to as a multi-layer perceptron, was created in 1974 (Werbos, 1974), enabling rapid training of multilayer perceptrons (MLPs) and thus overcoming the limitations identified by Minsky and Papert. In the late 1970's and early 1980's ANN research exploded and has continued to increase ever since.

Processing Criteria of ANNs

As mentioned in the introduction, ANNs are composed of processing elements called neurodes arranged in layers that are connected. In addition to the physical elements of the ANN, there are several soft processing criteria that are also important to understand. The learning rule is the algorithm that permits the ANN to learn, typically through updating of connection weights. The learning rate is how fast and how large updates are made to connection weights. Typically the learning rate starts out large enabling rapid changes in the weights and subsequent output values. The rate gradually decreases over time so that changes become smaller and smaller. A random adjustment of the rate upward is randomly performed to prevent the ANN from settling into a local minimum in the solution surface and to move towards the global minimum.