Manual: 7.2.1. Neural Networks

A neural network consists of nodes that are connected to each other (not unlike the neurons, connected by synapses). The input data enters the network on special nodes and then begins to travel through the network. Every time a piece of data travels over a connection or encounters a node, it is modified according to mathematical rules. The modified data then exits the network on other special nodes. Each connection and each node carry parameters that specify exactly what is done there. In this way, the network represents the relationship between the output and the input data and thus represents a mathematical function just like the straight line equation. So a neural network is nothing more than an equation with parameters to be determined from the data that this network is supposed to represent.

All the fuss about neural networks is based on the fact that there exists a mathematical proof which we won't go into here, that shows that if the network has enough nodes in it, then it is capable of accurately and precisely representing any data set, as long as the data set is internally consistent. This holds true even if the relationships in that data set are highly non-linear or time-dependent.

What does internally consistent mean? It means that the source of that data should always obey the same laws. In the case of industrial production, the data is produced by the laws of nature. As they do not change, the data set is internally consistent. The driving forces underlying the stock market, for example, are not constant over time and that is why neural networks cannot represent these data sets well.

In summary, a neural network is a complex mathematical formula that is capable of representing accurately any set of internally consistent data. The general approach to doing this is to take a formula with parameters and to determine the values of the parameters using a computational method. That is what we call machine learning.

It is useful to view a neural network as a summary of data -- a large table of numbers is converted into a function -- similar to the abstract of a scientific paper being a summary. Please note, that a summary cannot contain more information than the original set of data; indeed it contains less! Due to its brevity, however, it is hoped that the summary may be useful. In this way, neural networks can be said to transform information into knowledge, albeit into knowledge that still requires interpretation to yield something practically usable.

The summarization of data is nice but it is not sufficient for most applications. To be practical, we require interpolative and extrapolative qualities of the model. Supposing that the dataset included measurements taken for the independent variable x taking the values $x=1$ and $x=2$, then the model has the interpolative quality if the model output at a point in between these two is a reasonable value, i.e. it is close to what would have been measured had this measurement been taken, e.g. at $x=1.5$. Of course, this can only hold if the original data has been taken with sufficient resolution to cover all effects. The model has the extrapolative quality if the model output for values of the independent variable outside the observed range is also reasonable, e.g. for $x=2.5$ in this case. If a model behaves well under both

interpolation and extrapolation, it is said to generalize well.

A neural network model is generally used as a black-box model. That is, it is not usually taken as a function to be understood by human engineers but rather as a computational tool to save having to do many experiments and determine values by direct observation. It is this application that necessitates both above aspects: We require a function for computation and this is only useful if it can produce reasonable output for values of the independent variables that were not measured (i.e. compute the result of an experiment that was not actually done having confidence that this computed result corresponds to what would have been observed had the experiment been done).

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