Master Thesis: How to make a neural network build itself in an autonomous way.

By Antonio García Díaz, Université Libre de Bruxelles 2017-2018.

Deep Learning is a promising subfield of Machine Learning, which is itself a subfield of Artificial Intelligence (AI). It can be seen as the "cutting-edge of the cutting-edge" of AI, focusing on a narrow subset of tools from Machine Learning to solve a very wide range of applications.

Machine Learning (ML) is the field of AI that focuses on the development of programs which can automatically learn a task and improve on it without being explicitly programmed, but through the usage of external data that is relevant to the task. ML programs achieve this by looking for patterns in the data that is fed to them, and by rectifying their decisions based on the success they have when performing the task. The primary aim of ML is to allow a program to learn and adjust itself with as little human intervention or assistance as possible.

Within the larger context of ML, Deep Learning (DL) is related to the development of algorithms called artificial Neural Networks (NN). These algorithms take inspiration from the structure and function of the brain: they consist of various simple interconnected processors called neurons, organized together in layers. There is no unique definition for the term "Deep Learning", rather various specific and nuanced perspectives have been established by the leaders and experts in the field, and from these one can make sense of what DL is about. The general idea of DL could be simply defined as "solving ML problems by means of multi-layered artificial Neural Networks".

It is estimated that, by 2030, AI will contribute 12.8 trillion euros to the global economy. This will represent an increase of 14% on today's world gross domestic product (GDP) and as a consequence could boost productivity by up to 40% by 2035. Many governments around the globe are deploying extensive AI strategic plans with comprehensive policy programmes, research activities, and extensive financial support measures for private investment. Asian governments (China, Japan, Singapore or South Korea) are currently taking the lead in AI. At the same time, Canada and the United States are also developing their own AI strategies. In Europe, only the United Kingdom and Finland have already adopted an AI strategy, but France will surely join in soon.

> *"Artificial Intelligence is becoming a general-purpose technology, [..] it will deeply transform society in years to come.."*

AI technologies, especially those based on ML, are increasingly being adopted both in the private and public sectors, for purposes such as pattern recognition in images and object detection, game playing, decision-making, medical and financial applications, and many more. In the future, AI will be present in the likes of self-driving cars, automated package delivery by drones, precision health analytics, and automated factory production processes. AI is becoming a general-purpose technology, aiming to profoundly change all aspects of modern life, and many researchers predict that it will deeply transform society in years to come.

One of the key problems when implementing Neural Networks with multiple layers is to determine the network's topology: how many layers, and how many neurons per layer, the network should have. Indeed, in most cases today, the inner structure of a NN is crafted manually by a software engineer or a programmer, based on experimentation and testing of different topologies, and the results that they provide. A technique that would automatize the process of designing parts of a DL algorithm, adapting them towards a predefined classification goal, would be more than welcome.

"A technique that would automatize the process of designing parts of a Deep Learning algorithm […] would be more than welcome."

Over the past few years, companies such as Google, Netflix and Amazon have popularized DL as a revolutionary technology. But during the mid-90's, several novel ML algorithms involving NNs have been developed that could already be qualified as DL algorithms. One of these algorithms, developed at the IRIDIA Laboratories of the Université Libre de Bruxelles, is EMANN (Evolving Modular Architecture for Neural networks). It is notably for building the NN's topology automatically thanks to an incremental approach. During the NNs training phase, new layers and neurons may be added and/or pruned at different moments, following certain criteria, until an optimal network structure is selected.

My master thesis aims to study the specifics of this incremental solution under the light of the currently relevant DL trends and techniques. Using Google's open-source TensorFlow library, new and updated versions of EMANN (called EMMAN-like algorithms) were implemented. A simple image classification task, the CIFAR-10 dataset, was used as the benchmark for testing the performance of these algorithms. Different algorithms were compared in terms of accuracy, and the effects of certain parameter values on their accuracy were also assessed. The NN topologies produced by these algorithms were used to understand the influence of the number of layers and neurons on the accuracy of fully connected NNs, when applied to a specific learning context such as CIFAR-10.

Two pertinent conclusions were taken from the experiments and tests performed within my thesis. Firstly, EMANN seems to perform much better when the activation functions of its modules behave in a similar way to a sigmoid. In particular, the softmax activation function seems to provide very good results. This can be explained by the fact that CIFAR-10 is a classification task with mutually exclusive classes, precisely the kind of task that softmax was designed for. Although popular, the ReLU activation function seems in no way relevant for an algorithm centered such as EMANN, whose performance relies on increasing connection strength in neurons.

Secondly, in cases where the activation function behaves similarly to a sigmoid, it appears for now that any parameter correlated to an increase in the number of neurons will have a very positive effect on the accuracy of the constructed network. This is true both for parameters already in the original formulation of EMANN and for newly introduced parameters in the EMANN-like algorithms.