Design and implementation of training in hardware for efficient Artificial Intelligence

Master thesis project | Neuromorphic Engineering

Introduction | Organic neuromorphic materials

Brain-inspired (**neuromorphic**) computing has recently demonstrated major advancements in pattern and image recognition as well as classification of unstructured (big) data [1]. These artificial **neural networks (ANN)** (figure 1) are ideal for classifying difficult ambiguous data such as biomarkers or cells.

Organic materials are excellent candidates for hardware-based neural networks as they are cheap, easy to use, flexible and biocompatible [1]. However, fabricating large crossbar array (figure 2) of these devices remains a challenge.

In particular it is very difficult to properly train these hardware-based networks. For neural networks to work efficiently, it is important to update or train the individual devices to new levels, much like modifying a connection in the brain.

This **write** step is crucial but is not straightforward in hardware. In software, the update is calculated as the product of the **error** (desired output – real output) and the **input**, but this is difficult to achieve in hardware. This is also called **backpropagation** (figure 3).

Project | Design and testing of simple backprop training sequence

In this project we will try to implement this training step in hardware. First we will develop a simplified software network that can act as a digital twin. Errors are calculated in software and used as an inputs to the hardware backpropagation array.

Goal | milestones and achievements

The goals of this project are:

1. To develop a simple 1 layer software neural network and understand its workings
2. Manually optimise this network and the train sequence (backprop) using the error
3. Develop a hybrid software/hardware training sequence

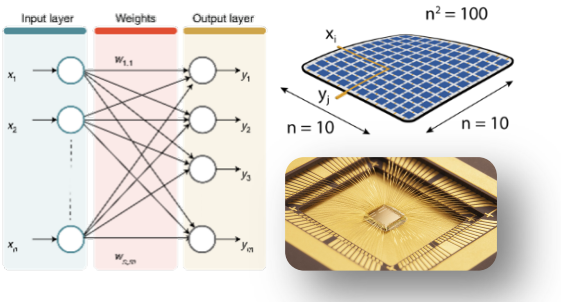

Figure 1. Schematic of an Artificial Neural Network [1,2]

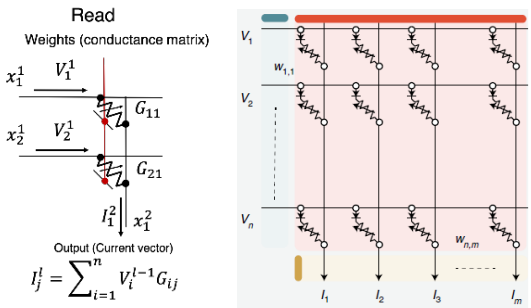

Figure 2. Schematic of the read principle with a figure of the hardware implementation in a cross bar configuration

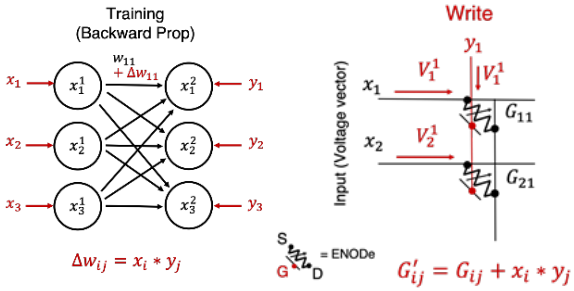

Figure 3. Calculation of the update according to backpropagation and a schematic of the write principle

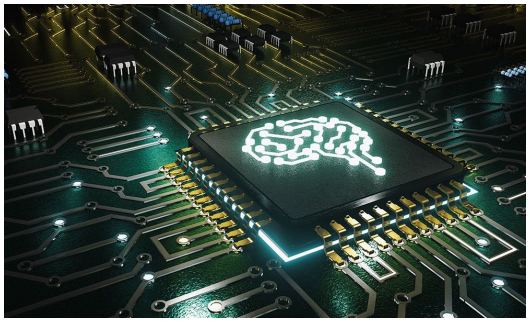

Figure 4. Hardware ANN chip [3]

References

1) Organic Electronics for Neuromorphic Computing, Y van de Burgt, et al. **Nature Electronics**, 2018
2) Organic Electronics for Neuromorphic Computing, Y van de Burgt, et al. **Nature Materials**, 2017
3) https://datafloq.com/read/artificial-intelligence-starts-with-trusting-data/6341

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