Carleton University

Capstone Project Proposal

An Artificial Neural Network For Simulating Silicon Photonic Devices

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1 Artificial Neural Networks

Artificial Neural networks (ANNs), or more recently coined "Deep Learning", are an approach to machine learning in which a computer can learn the relationship between a system's inputs and outputs through a network of nodes, weights and activation functions. A simplified diagram of a neural network is shown in Figure [1] below.

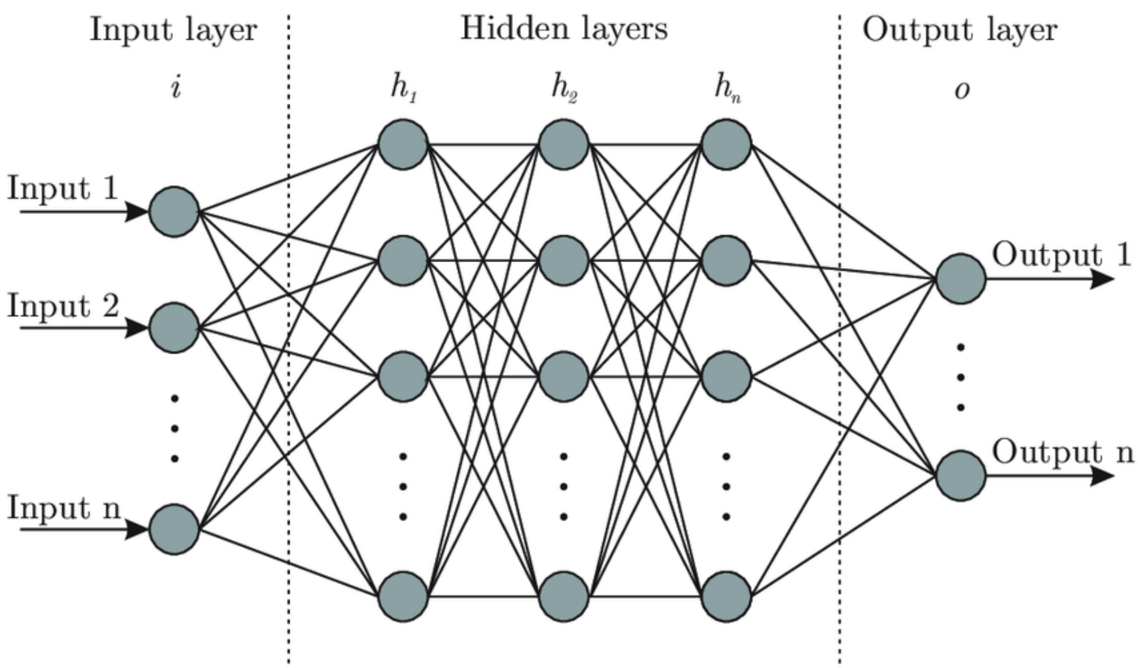

Figure 1: Neural Network Architecture [1]

Each of the nodes or *perceptrons* in the hidden layers, are connected to the next layer by weights and activation functions. These activation functions can be non-linear enabling the entire network to learn non-linear relationships between inputs.

Because of a neural network's ability to learn non-linear relationships, they have recently become very popular in Computer Aided Design (CAD) as they can offer quick and accurate simulation performance compared to traditional numerical techniques [2].

2 An Artificial Neural Network For Silicon-Photonic Devices

As described in the previous section, computer aided design is typically done by numerical calculations.

The design of silicon-photonic devices requires finite-difference time-domain (FDTD) optical simulations. These FDTD simulations can be very time-consuming and demand high performance hardware to run. Often it can take tens or hundreds of simulations to design a silicon-photonic device, further delaying the design process and the time to fabrication and testing [3]. An artificial neural-network can offer a powerful alternative to the standard numerical computation techniques by offering fast and accurate simulations.

3 Objective

The main objective of this project is to develop with PyTorch an artificial neural network to simulate a silicon-photonics device.

Depending on the pace of the project, our neural network could be developed to model several silicon-photonic devices. And we could investigate the performance of different hardware architectures for neural network training and inference.

4 Significance

The significance of this project is far reaching. We aim to offer a faster approach to simulating silicon-photonic devices which would speed up device design time and drastically shorten the time from initial design to fabrication.

5 Method and Individual Roles

The design of the neural network for this project can be broken down into two main sections: **data acquisition** and **model training**. The data acquisition will be done by Deng Mading and Randi Wan and the neural network training and development will be done by Jacob Ryall and myself.

The data acquisition will be done with Lumerical. Lumerical simulations will be used because device parameters can be varied and measurements can be done in an automated fashion. Lumerical has a MATLAB and Python API, so scripts can be written in those languages to automate simulations.

The neural network will be developed using the Python PyTorch library. With simulations of different device parameters, we can select what features impact a device the most and select those as the input into the neural-network.

The specific size and number of the hidden-layers of the network will be determined with trial and error. However a good starting point from the paper, "An Open-Source Artificial Neural Network Model for Polarization-Insensitive Silicon-on-Insulator Subwavelength Grating Couplers," set the dimension of the hidden layers to 100-50-50, plus 5 input neurons and 4 output neurons.

Initially each perceptron will be equipped with the Rectified Linear Unit (ReLu) Activation function; however this may be subject to change throughout the development process. The learning rate of the network will also be determined through trial and error.

6 Tools

The tools needed for this are separated into software and hardware.

6.1 Software

The software requirements for this project consist of:

1. Lumerical Photonic Simulation Software
2. Python and PyTorch.

6.2 Hardware

The hardware requirements for this project consist of:

1. Carleton's computation servers

7 Expected Results

The speculated final goal of this project is to have a neural network that accurately models a silicon-photonic device. Similar work has been done by a Graduate student at Carleton University, Dusan Gostimirovic, where he developed a neural network to model polarization-insensitive sub-wavelength grating couplers [3]. In his paper he was able to develop a neural network that performed to 93.2% accuracy of numerical simulations. Our goal is to match or better Dusan's achievement and to generalize our model to other silicon-photonic devices.

This project will also offer us the opportunity to tie all of our studies in engineering together, from computer aided design to software engineering and data analysis. This project could also give us the opportunity to test the ability of different hardware architectures such as CPU's, GPU's and ASIC's for training and inference of ANN's.

And finally, with the exploding field of machine learning, whether from a software perspective, or hardware perspective, this project will offer us a great stepping stone into further graduate studies or the real-world.

8 Management and Time Table

For managing the project and ensuring that we stay on track, we will be having weekly meetings as a team every Friday from 1:00pm-2:00pm. Each member of the group is part of

Discord server where we report on our progress. Meetings throughout the week will also be scheduled from time to time to catch up.

The Friday afternoon meetings will be used to present each team members progress of the past week and assess what the next steps are. The overall project timeline can be found in Figure [2] below and the ANN development timeline can be found in Figure [3].

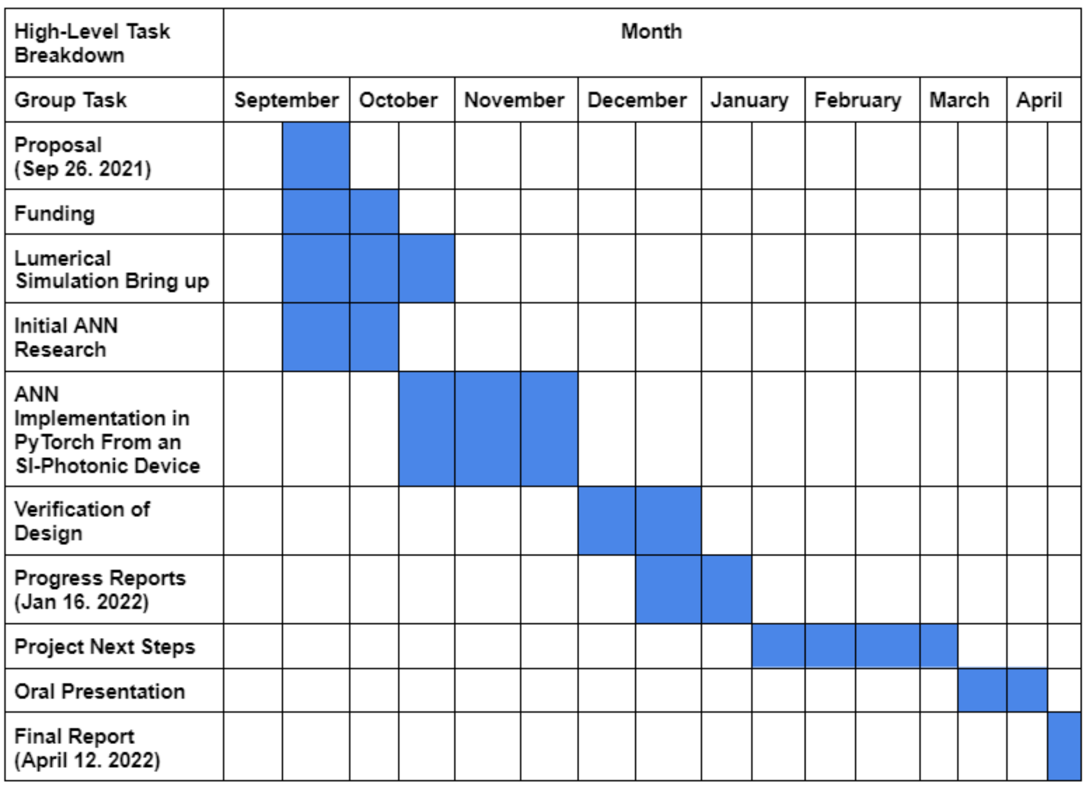

Figure 2: Overall Project Timeline For the Academic Year

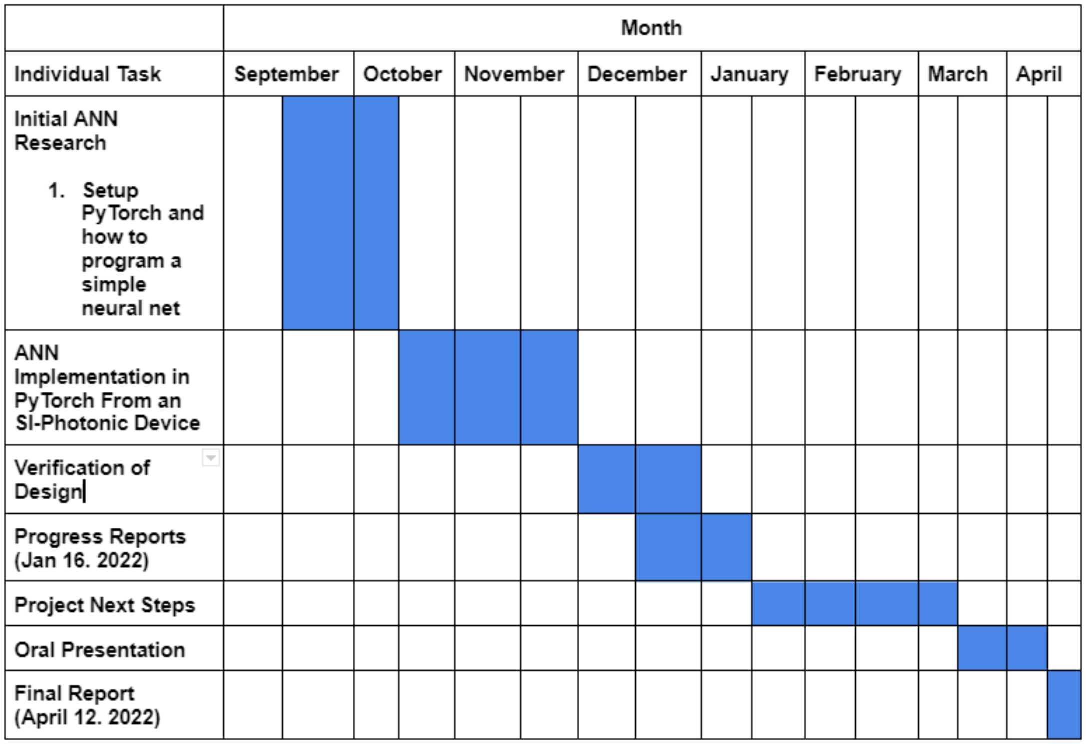

Figure 3: ANN Development Timeline For the Academic Year

References

[1] (2021, Sept. 25). “Designing Your Neural Networks” [Online]. Available: https://www.google.com/url?sa=i&url=https%3A%2F%2Ftowardsdatascience.com%2Fdesigning-your-neural-networks-a5e4617027ed&psig=AOvVaw3eQb6L4YoFnAPSMdc1Ix6m&ust=1632703391203000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCMiYnpu0m_MCFQAAAAAdAAAAABAN

[2] (2021, Sept. 25). “Efficient Modeling of Complex Analog Integrated Circuits Using Neural Networks” [Online]. Available: https://www.researchgate.net/publication/305410960_Efficient_Modeling_of_Complex_Analog_Integrated_Circuits_Using_Neural_Networks

[3] D.Gostimirovic and W.N.Ye, "An Open-Source Artificial Neural Network Model for Polarization-Insensitive Silicon-on-Insulator Subwavelength Grating Couplers," ***I****EEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL, 25, NO.3, MAY/JUNE 2019.*