Oscillatory Computing using Optoelectronic Sensors

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Introduction

Von Neumann architecture requires considerable movement of data between compute and memory blocks, leading to bandwidth limitations when running intensive AI algorithms. Due to the end of Moore's Law, continued performance gains through transistor scalings are no longer feasible. This has driven the community to search for a new device and system architectures to improve the speed and energy usage of computing systems.

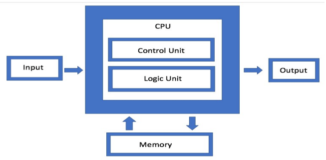

Fig. 1 Von Neumann Architecture
PC: Semiconductor Engineering

Objective & Impact of Research

We are looking to increase computing speeds by processing in parallel through two possible methods. The first method is finding a replacement for silicon using other semiconductor compounds with better electronic and optoelectronic properties. The second method is using optoelectronic sensors to compute on a function of frequency rather than a function of time. Both methods look for faster processing speeds to surpass the Von Neumann architecture.

Generating Oscillations

Optoelectronic devices can convert optical energy into electrical energy. When combined with capacitors or inductors, oscillatory signals are generated. Depending on how the circuits are connected, the resulting signal can have various amplitudes, frequency, and periods. Other research groups have created oscillations through various components such as resistive random-access memory, phase change memory, and ion-based electrolyte-gated transistors. However, we focus on using optics since photonic synapses combine sensing and processing into a single device [1].

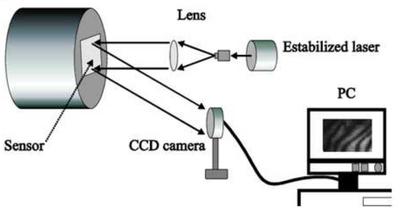

Fig. 2 Setup of an Optoelectronic sensor to shine light and store data
PC: Research Gate

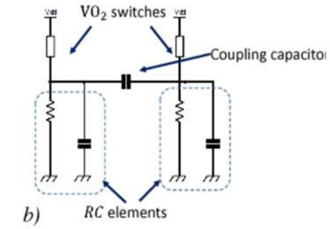

Fig. 3 Voltage dependent oscillators made from VO2 switches and connected with a coupling capacitor PC: [2]

Combining Oscillators Together

Multiple oscillators can be connected to generate an average of all oscillations. Using an LCD screen between the light source and the lens, we can illuminate a set group of oscillators and change the frequency and amplitude of the oscillations. We can achieve the same effect by changing the values of each of the coupling capacitors. We can then extract frequency data to complete various tasks using a neural network and a machine learning algorithm. Such applications can be used in fields such as autonomous vehicles, automated fabrication systems, and robotics [1]. An example is identifying images such as numbers with Gaussian noise.

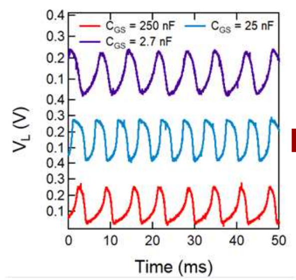

Fig. 4 Voltage vs. Time graph for oscillators with various capacitor values PC: Ragib Ahsan

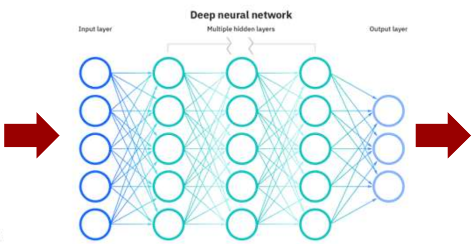

Fig. 5 Neural Network to compute based on frequencies of oscillators
PC: IBM

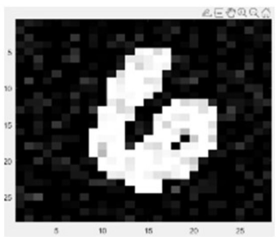

Fig. 6 28x28 Image of number six with Gaussian Noise
PC: Jason Kim

Skills Learned

- Lab Equipment and Safety
- Circuitry Basics
- Logic Gates
- How semiconductors are created
- Creating PCBs
- Microcontroller Usage
- Utilizing AutoCAD
- C Programming Language
- Matlab Coding

How This Relates to Your STEM Coursework

SHINE has given me the knowledge and hands-on experience for work in circuitry by creating circuit simulations and creating PCBs, skills that will greatly benefit me in my upcoming Digital Electronics class. I also gained experience working in mechanical engineering, being able to design a station to be able to measure oscillations. In addition to new knowledge, SHINE has built upon my current programming knowledge from AP CSA by being able to implement my learnings into a research environment by processing datasets into images with MATLAB.

Acknowledgements

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References

[1] J. Tao, J. S. Vazquez, H. U. Chae, R. Ahsan, and R. Kapadia, "Machine Vision with InP based Floating-gate Photo-field-effective Transistors for Color-mixed Image Recognition," *IEEE Journal of Quantum Electronics*, pp. 1–1, 2022, doi: 10.1109/JQE.2022.3169565.

[2] G. Csaba and W. Porod, "Perspectives of Using Oscillators for Computing and Signal Processing," arXiv:1805.09056 [nlin], May 2018, [Online]. Available: https://arxiv.org/abs/1805.09056