# NANSNA: Improving Neuromorphic Computing Efficiency with Neuromorphic Accelerators with Novel Spiking Neural Subnetwork Ensemble-Based Architecture

Dean Jordan<sup>1,\*</sup>, Bob Author<sup>2</sup>, Christine Author<sup>1,2,+</sup>, and Derek Author<sup>2,+</sup>

## **ABSTRACT**

As a field, neuromorphic computing is expected to nearly double annually until 2032 and have an expected valuation of \$9.5 trillion USD. However, current implementations of neuromorphic accelerators contains models which are not large enough for Vision and Language (VaL) tasks and are relatively incapable of multi-domain learning due to the specialization of current Spiking Neural Network (SNN) architectures. As a result, the NANSNA architecture aims to improve the efficiency of SNNs by developing a novel encoder/decoder-based SNN architecture which utilizes a neural subnetwork ensemble. The architecture contains multiple novel neuron and layer types within the central subnetwork for increasing efficiency, specialization, and multi-domain learning. Additional efficiency improvements occur due to the encoder and decoder being non-spiking. The NANSNA model is trained on an adapter-based approach. Each subnetwork in the subnetwork ensemble is assigned a single adapter. This allows for specialization to occur while simultaneously increasing the performance of multi-domain tasks. The NANSNA model and architecture demonstrate statistically significant improvement in several key metrics within neuromorphic computing, including Synaptic Operations per Second (SOPS), synaptic density, Neuromorphic MNIST (N-MNIST), and the cost per neuron.

## Introduction

Artificial Neural Networks (ANNs) are a firmly established state of the art method in machine learning. The artificial neuron converts an input tensor to an output tensor via a linear transformation combined with a nonlinear activation function. Due to this methodology, several state of the art machine learning architectures such as the Recurrent Neural Network (RNN) and Transformer have developed. A majority of the architectures developed from ANNs have drawn similarities from the field of neuroscience. However, despite the arrival of novel machine learning architectures, balancing specialization alongside multi-domain performance and efficiency has proven to be a major challenge of researchers within Machine Learning (ML). Thus, the SNN was proposed as a novel paradigm separate from ANNs. While ANNs utilize continuous-valued outputs, SNNs intend to utilize action potentials to convert an input tensor into an output tensor.

#### Results

Up to three levels of **subheading** are permitted. Subheadings should not be numbered.

# Subsection

Example text under a subsection. Bulleted lists may be used where appropriate, e.g.

- First item
- · Second item

#### Third-level section

Topical subheadings are allowed.

<sup>&</sup>lt;sup>1</sup>University of Michigan, Artificial Intelligence, South Lyon, 48178, United States

<sup>&</sup>lt;sup>2</sup>Affiliation, department, city, postcode, country

<sup>\*</sup>corresponding.author@email.example

<sup>\*</sup>these authors contributed equally to this work

# **Discussion**

The Discussion should be succinct and must not contain subheadings.

#### Methods

Topical subheadings are allowed. Authors must ensure that their Methods section includes adequate experimental and characterization data necessary for others in the field to reproduce their work.

LaTeX formats citations and references automatically using the bibliography records in your .bib file, which you can edit via the project menu. Use the cite command for an inline citation, e.g.?

For data citations of datasets uploaded to e.g. *figshare*, please use the howpublished option in the bib entry to specify the platform and the link, as in the Hao:gidmaps:2014 example in the sample bibliography file.

# **Acknowledgements (not compulsory)**

Acknowledgements should be brief, and should not include thanks to anonymous referees and editors, or effusive comments. Grant or contribution numbers may be acknowledged.

#### **Author contributions statement**

Must include all authors, identified by initials, for example: A.A. conceived the experiment(s), A.A. and B.A. conducted the experiment(s), C.A. and D.A. analysed the results. All authors reviewed the manuscript.

## **Additional information**

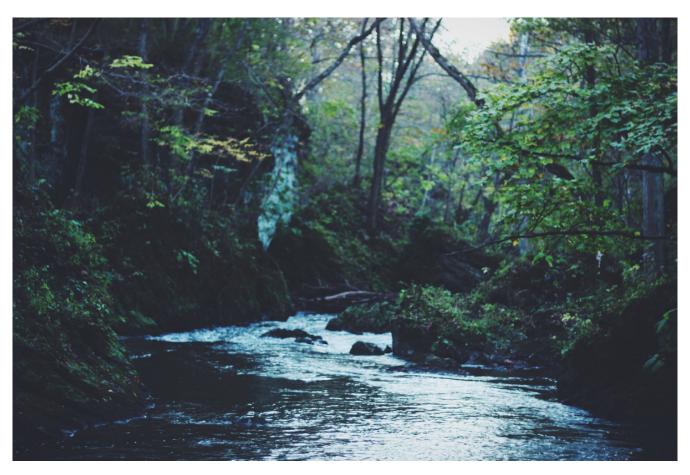
To include, in this order: **Accession codes** (where applicable); **Competing interests** (mandatory statement).

The corresponding author is responsible for submitting a competing interests statement on behalf of all authors of the paper. This statement must be included in the submitted article file.

Condition	n	p
A	5	0.1
В	10	0.01

**Table 1.** Legend (350 words max). Example legend text.

Figures and tables can be referenced in LaTeX using the ref command, e.g. Figure 1 and Table 1.



**Figure 1.** Legend (350 words max). Example legend text.