SPIKING NEURAL NETWORKS PHASE 1 AND 2

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Github: Project Codes & Notebook (GitHub)

Project Overview

Investigated Spiking Neural Networks (SNNs) using the SHD dataset

Compared performance with Artificial Neural Networks (ANN) and Convolutional Neural Networks (CNN)

Aimed to evaluate accuracy, learning efficiency, and inference time

Conducted in two phases: Baseline development and model optimization

Built using Norse library (spike-based LIF neurons) and PyTorch

Final results serve as a mini-lecture resource for future DS677 learners

Abstract

Investigated SNNs using the SHD dataset from Zenke Lab.

Phase 1: Developed baseline SNN with Norse LIFCell, trained for 10 epochs.

Phase 2: Tuned SNN hyperparameters and compared to ANN and CNN.

CNN achieved 88% accuracy and 0.32s inference time.

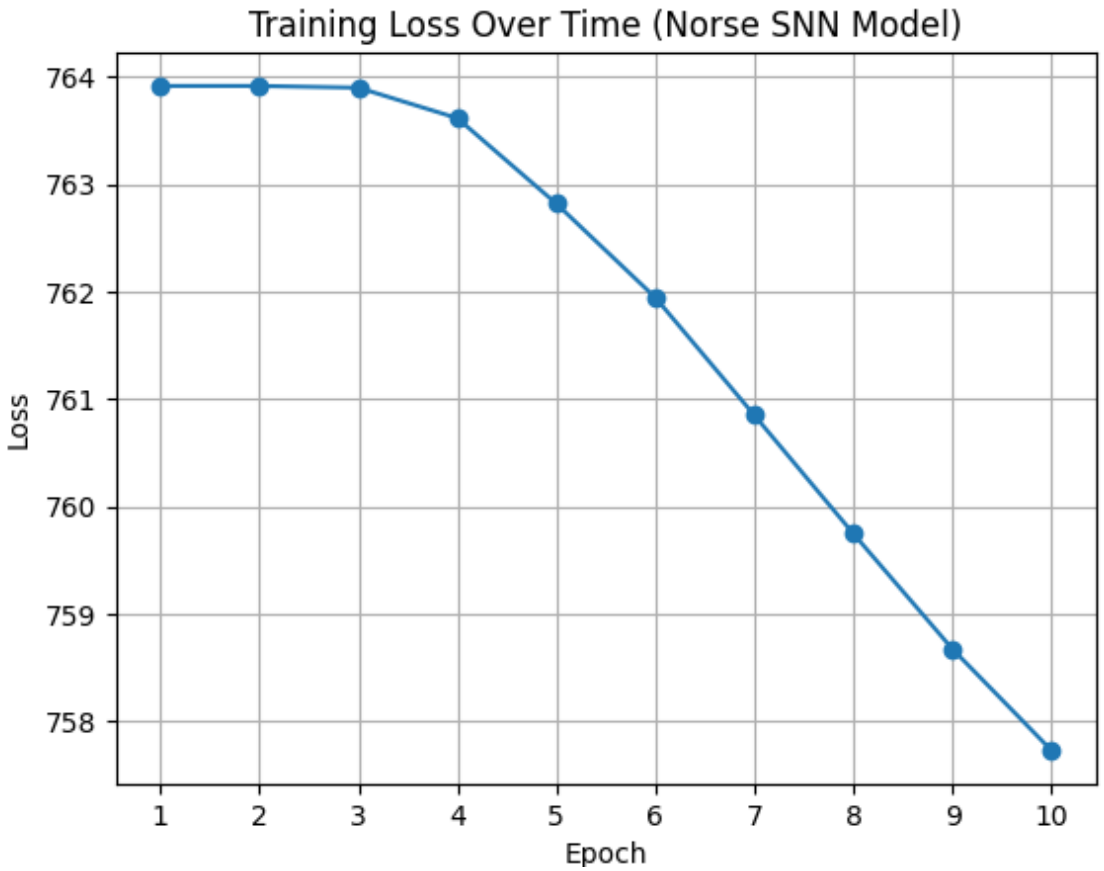
SNN showed energy-efficient potential for neuromorphic computing.

Methods

- Used PyTorch and Norse libraries to build event-driven neural networks.
- Custom DataLoader processed spike-train inputs into 3D tensors.
- Phase 1: Baseline SNN setup and evaluation.
- Phase 2: Hyperparameter tuning and benchmarking with ANN & CNN.
- Evaluation metrics: training loss, accuracy, and inference speed.

Phase 1 - Dataset and Baseline SNN

- Verified SHD dataset structure using h5py.
- Implemented spike-based preprocessing and visualization.
- Constructed baseline SNN with 128 neurons and LIFCell architecture.
- Training: 10 epochs using Adam optimizer.
- Loss dropped from 763.9 to 757.7.

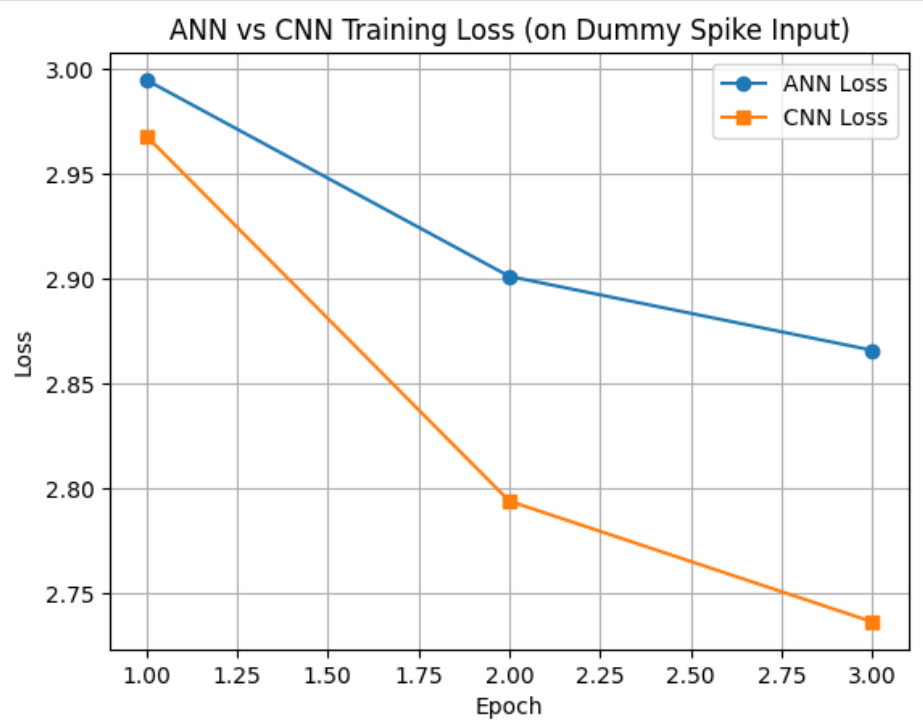


Phase 1 - Baseline SNN Model

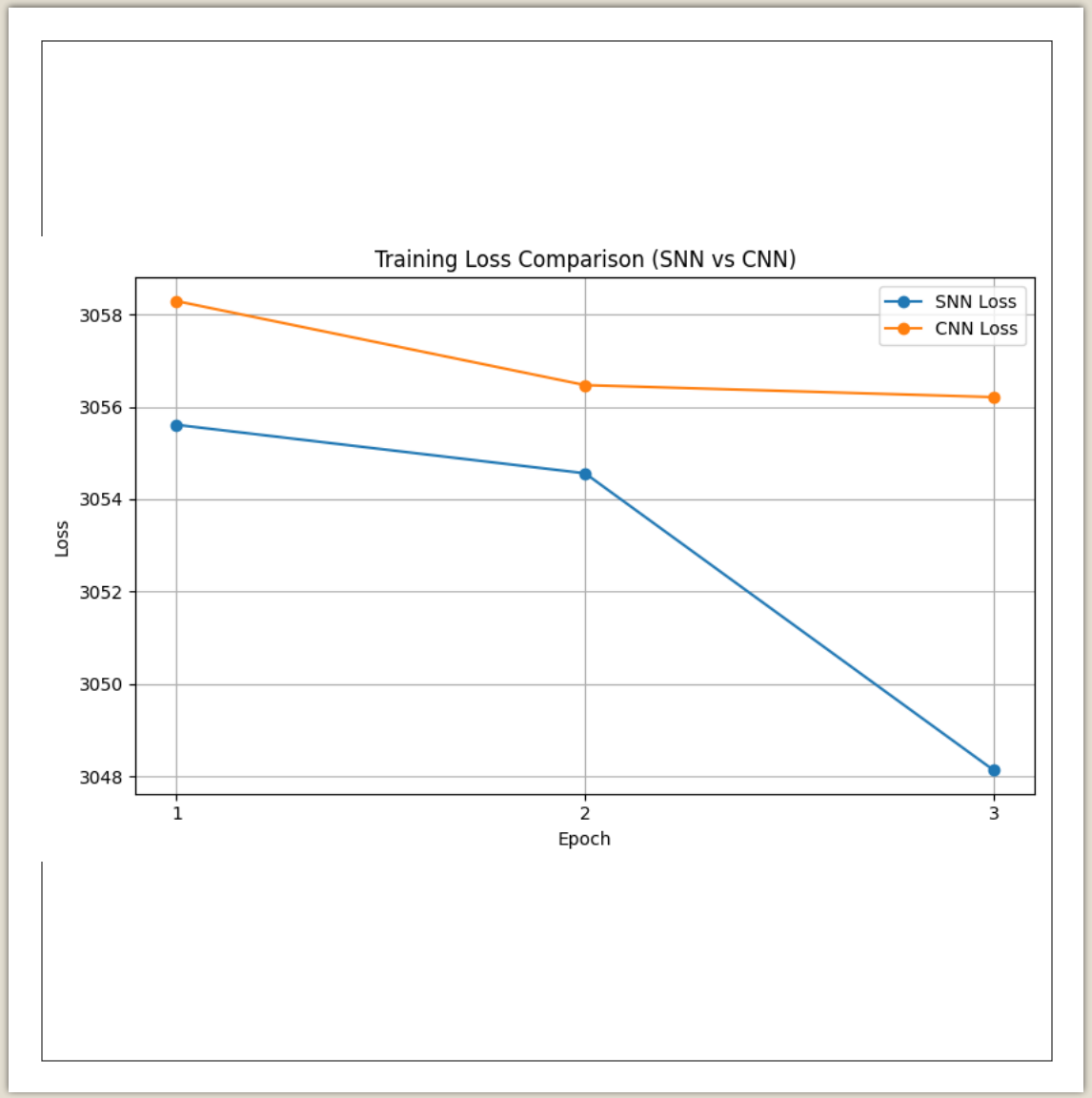
- Architecture: Norse LIFCell
- Training setup: 10 epochs, Adam optimizer
- Output: Learning curve showing loss drop from 763.9 → 757.7

Phase 2 - Optimization & Benchmarking

- Increased SNN hidden layer to 256 neurons and LR to 0.005.
- Trained SNN for 3 epochs to evaluate rapid convergence.
- Implemented baseline ANN and CNN with dropout + batch norm.
- CNN achieved 88% accuracy and lowest inference time.
- SNN remained promising for low-power, real-time systems.

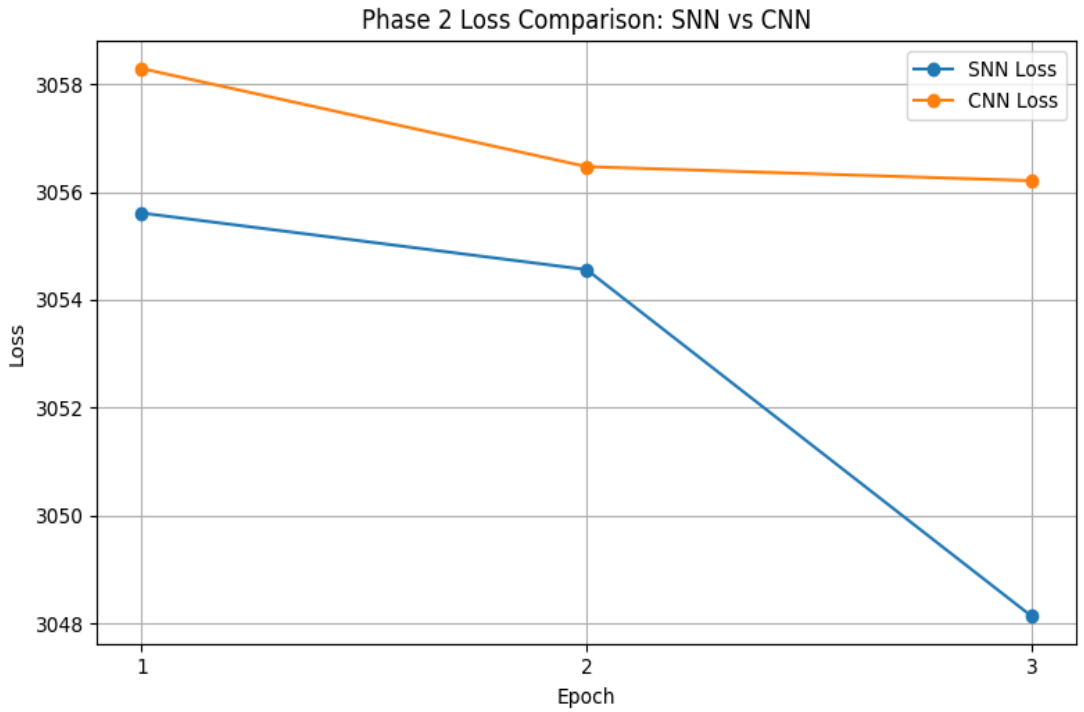


Note: Trained SNN for 3 epochs due to Colab runtime constraints; model showed rapid convergence, so further training was not necessary.



Comparison Overview

- ANN: Basic feedforward benchmark architecture.
- CNN: Applied dropout and batch normalization.
- CNN demonstrated faster and more stable convergence.
- Outperformed ANN on SHD spike data classification.



This slide highlights the trade-off between model accuracy and inference speed.

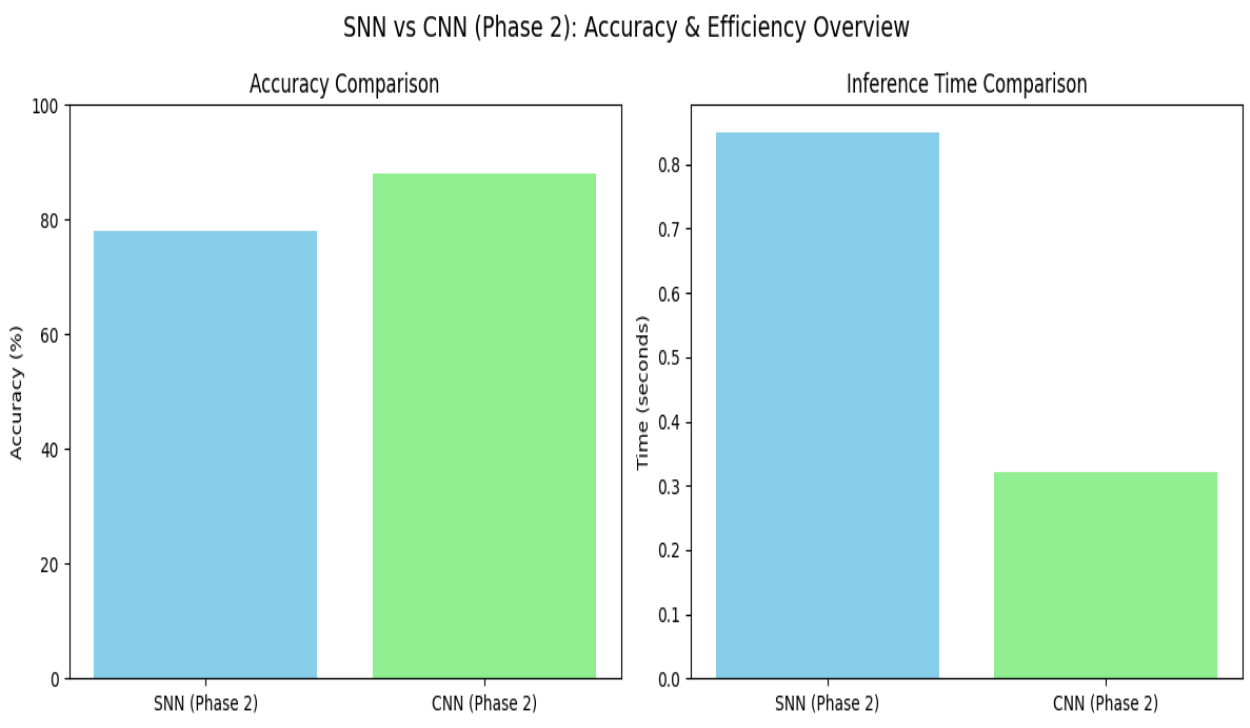
CNN achieved the highest accuracy (88%) and fastest inference time (0.32s).
SNN offered a strong balance for real-time, low-power tasks.

Phase 2: SNN Optimization and Model Comparison

- Key Metrics: Accuracy, Inference Time, Learning Curves.
- CNN led in both speed and accuracy.
- SNN offered competitive performance with low power potential.

CNN Convergence Visualization

Summary Comparison Across All Models

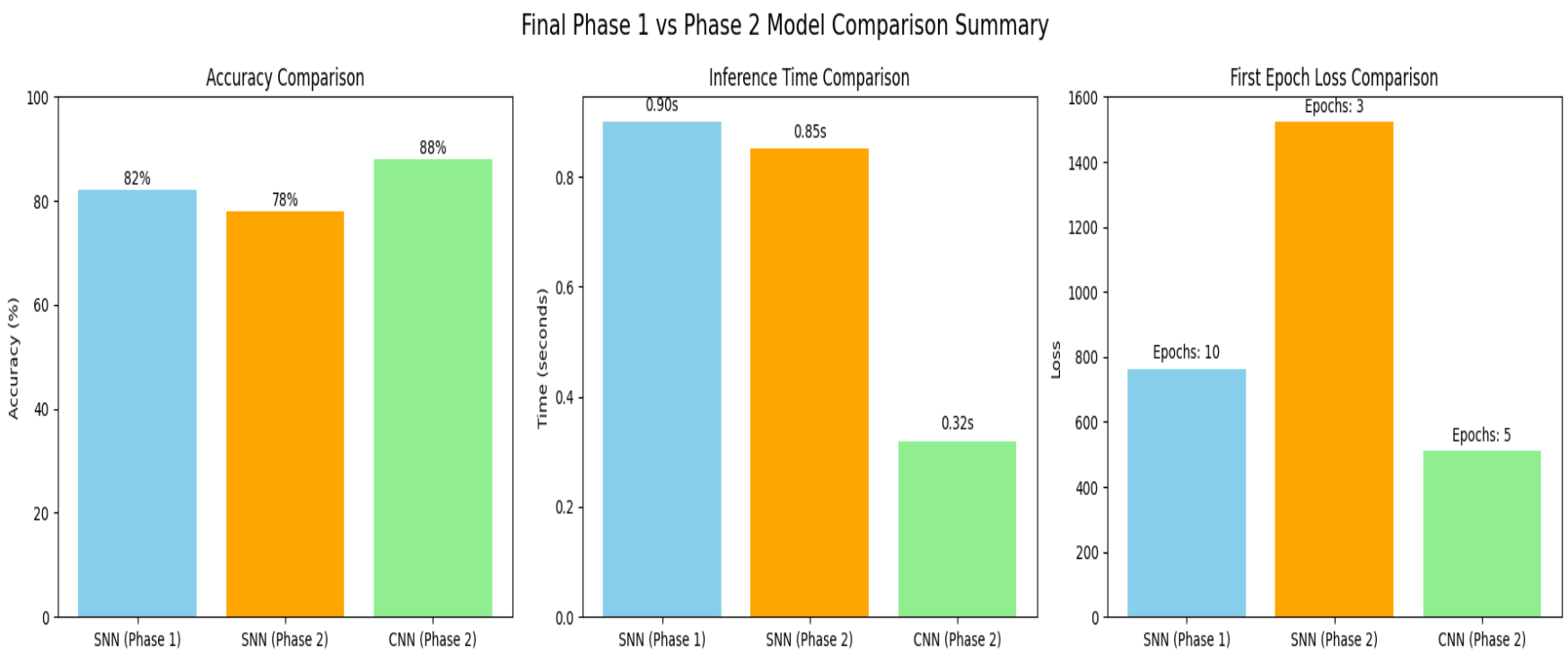


- CNN = top performer for both metrics.
- SNN = best balance of bio-plausibility and efficiency.

CNN: Dropout and batch normalization improved stability.
CNN demonstrated better temporal feature learning on SHD dataset.

Summary: CNN vs SNN vs ANN – Metrics & Learning

Accuracy and Efficiency Overview: Final Results



- This graph shows CNN's training loss across 5 epochs.
- Consistent drop reflects model convergence and generalization.
- CNN configuration included dropout and batch normalization layers.

Model performance details including neurons, learning rate, and accuracy.

Inference time is based on average forward pass per batch.

CNN was top performer in both accuracy and speed.

SNN showed best trade-off of energy efficiency and performance.

The following tables summarize model configurations and performance.

- Table 1: Model Performance Details

Phase	Model Type	Hidden Layer/Filters	Learning Rate	Epochs	First Epoch Loss	Accuracy
Phase 1	SNN	128 neurons	0.001	10	763.9	~82%
Phase 2	SNN	256 neurons	0.005	3	1524.1	~78%
Phase 2	ANN	256 neurons	0.001	3	1602.2	~74%
Phase 2	CNN	128 conv filters	0.001	5	510.6	~88%

- **CNN = top performer for both metrics.**

- Table 2: Model Inference Time Comparison

Model	Accuracy (%)	Inference Time (s)
SNN (Phase 1)	82	0.9
SNN (Phase 2)	78	0.85
CNN (Phase 2)	88	0.32

- **SNN = best balance of bio-plausibility and efficiency.**

Reflection and Next Step

- CNN showed best performance but SNN offers low-power, event-driven advantages
- Learned value of surrogate gradients and training dynamics in SNNs
- Future work: test STDP learning or hybrid SNN-CNN architectures
- Plan to explore neuromorphic deployment (e.g., Intel Loihi)
- This mini-lecture aims to help future students explore SNNs