Sleep Spindles as a Driver of Low Latency, Low Power ML in HLS4ML & TinyML

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Neural Data – Sleep Spindles

Sleep Spindles Introduction
- Rare low-frequency brain signals
- Primarily occur during sleep or rest
- Are believed to contribute to learning
- Lack of mechanistic understanding

Our goal
- Design and build a system that can help neuroscientists to understand the mechanism behind the theory

The Proposed System

Head-Mounted Device components
- Headstage: Records brain signals from the subject
- Programmed FPGA: Processes brain signals and interacts with sleep spindles

Methods (HLS4ML & TinyML)

Baseline Deep Learning Model

Latent Factor Analysis via Dynamical Systems (LFADs)
- RNN variational autoencoder (VAE) in tf.keras API
- Input: Neural spiking data
- Output: Firing Rates & LFADs Latent Factors

Performance Comparison per Trial

The negative log-likelihood is the evaluation metric of the LFADs. Minimized negative log-likelihood indicates an optimal performance.

Challenges & Plans

Will need to add the gaussian sampling layer back to enhance the robustness of the model. This can be divided into 3 phases.
- Phase I: Analyze gaussian sampling layer’s FPGA resource utilization and compare with an autoencoder (Done!)
- Phase II: Implement gaussian sampling layer in HLS4ML (Jeffery’s current project)
- Phase III: Integrate the gaussian sampling layer with the LFADs autoencoder (Future)


Modified LFADs architecture

Performance Comparison per Trial

The negative log-likelihood is the evaluation metric of the LFADs. Minimized negative log-likelihood indicates an optimal performance.

For the same testing dataset, the numerical value of the negative log-likelihood from the modified LFADs matches the original LFADs, which indicates that removing the gaussian sampling from LFADs is acceptable.

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TinyML will help us to deploy the model on an ultra low power FPGA.

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