Technik & Architektur
Master of Science in Engineering
Specialization: Computer Science

Master of Science in Engineering – Master Thesis

Position Estimation of Space Objects with SNNs

Solving a regression task with spiking neural networks

Regression with Spiking Neural Networks

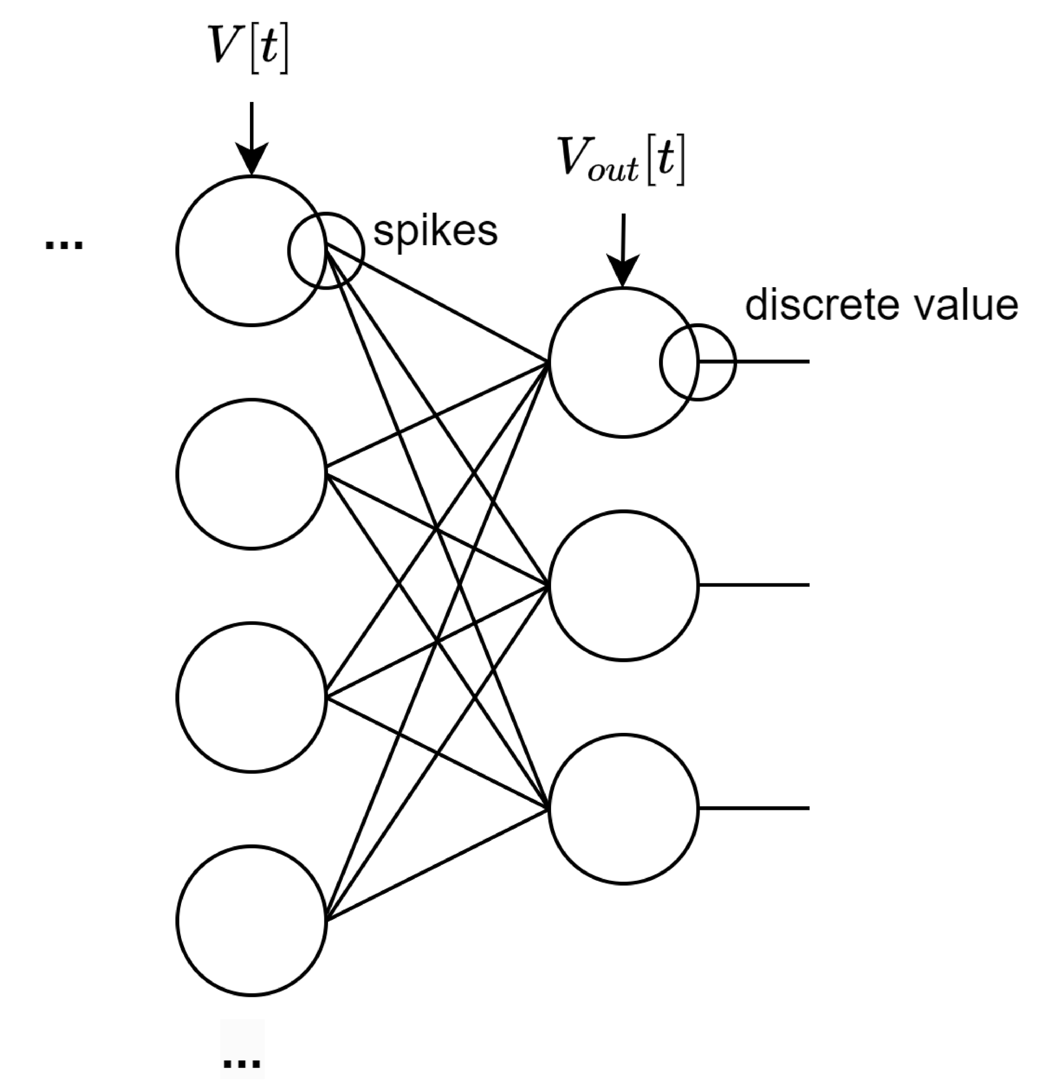

Figure 1: Last two layer for position model.

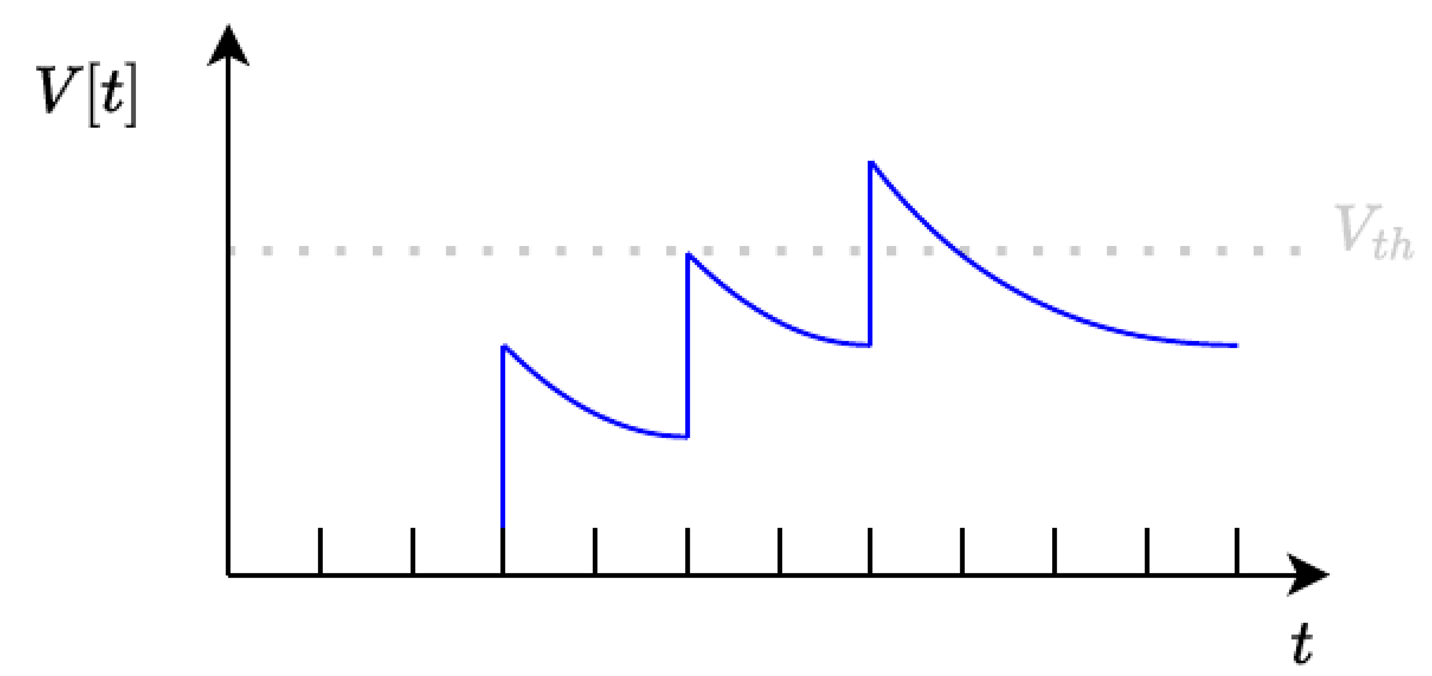

Figure 3: Membrane potential over time.

Simulation results

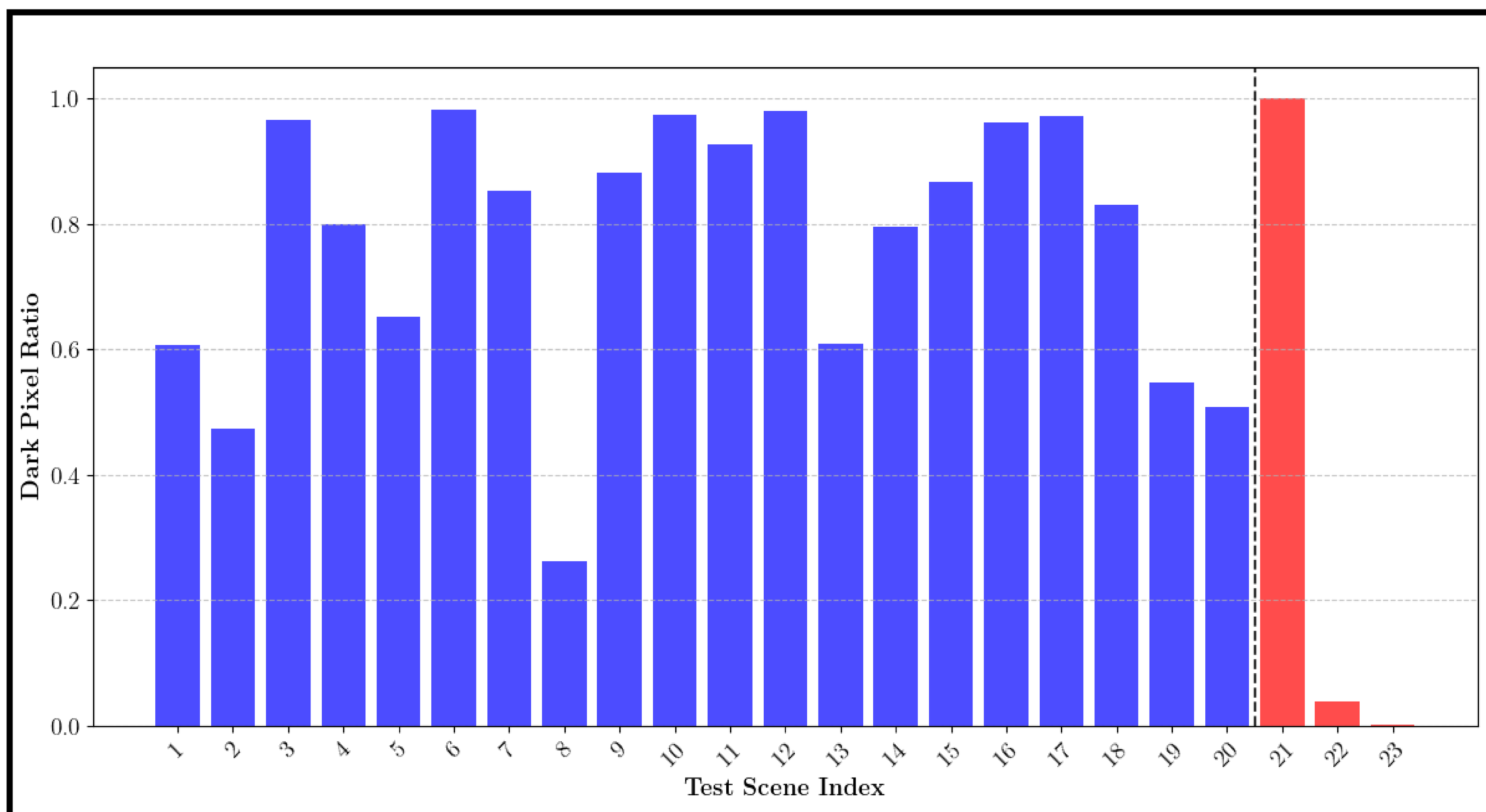

Figure 2: Dark pixel ratio of the test dataset.

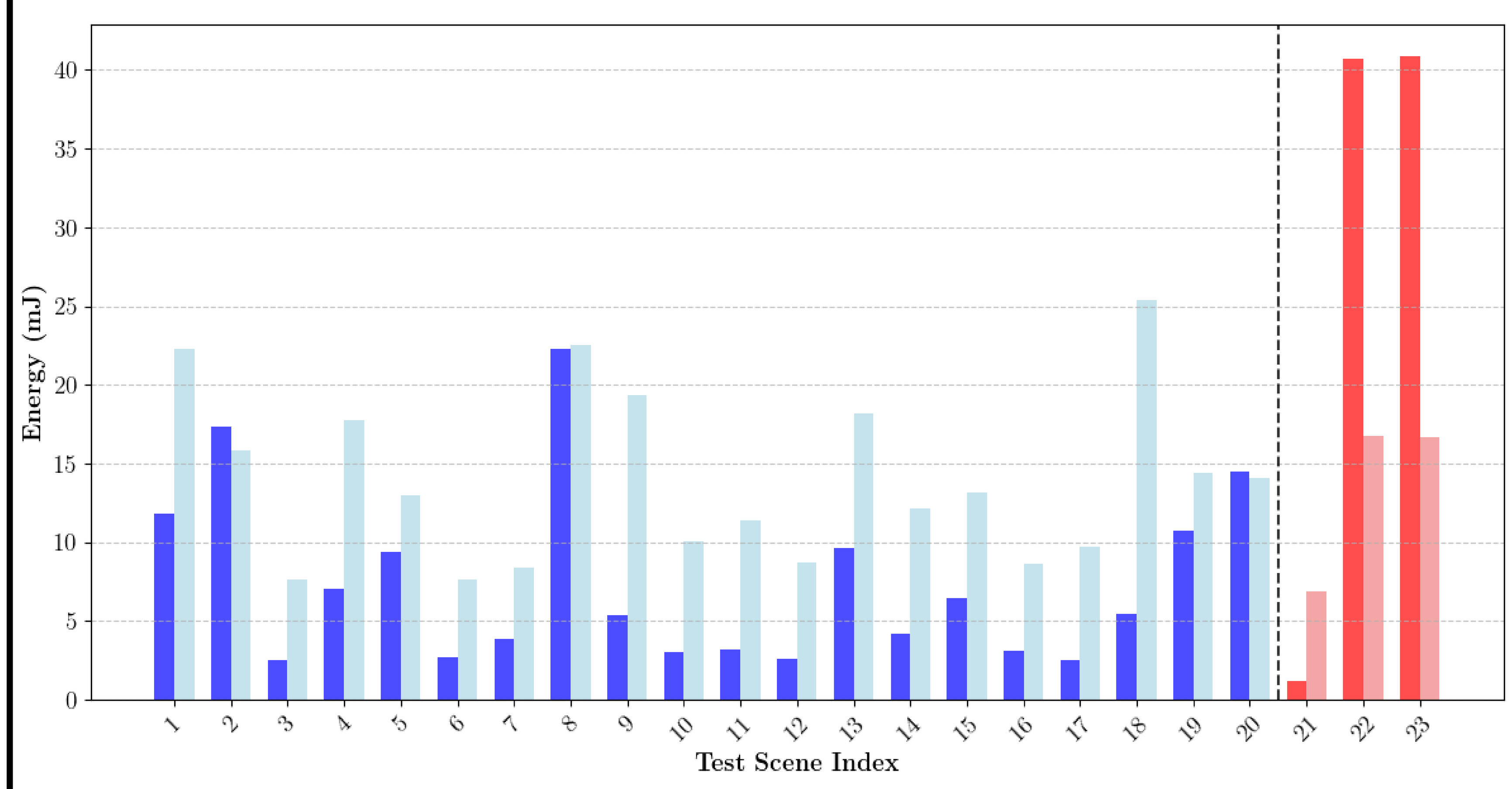

Figure 4: Energy consumption of LIF vs. LTC-SNN.

Project Task
Unlike neurons in conventional Artificial Neural Networks (ANN) which process and generate activations in form of numeric values, the neurons of Spiking Neural Networks (SNN) process and generate binary-valued spike sequences. Previous project have showed that SNNs can compete with ANNs w.r.t. classification accuracy on frame-based input data. However, due to the lack of expressiveness in the network output, SNNs have been applied to regression tasks much less frequently than to classification tasks. The focus of this project is to investigate if SNNs can also be useful for regression-type tasks with frame-based inputs, in particular for applications where the input frames contain a large number of dark background pixels, which after conversion to spike trains yield a low number of input spikes to the SNN. Moreover, a method to estimate the energy consumption of the SNN should be developed to show the data dependent energy demand of SNNs.

Concept
In the literature a method was proposed for a single output variable regression problem. The basic idea of using the continuous membrane potential of the neurons, built the foundation of the developed method used in this project. The energy estimation relied on equations which were extracted from a neuromorphic dataflow architecture to incorporate dedicated SNN hardware.

Results
The results showed that the SNNs are able to solve the position estimation task and that they are also useable for multiple output regression tasks. Moreover, the comparison to the results from non-spiking ANNs from a previous project showed that SNNs can compete w.r.t. error prediction performance with their non-spiking counterparts. For the experiments two different spiking neuron models where evaluated. Once the Leaky Integrate and Fire (LIF) neuron and a novel Liquid Time Constant (LTC) spiking neuron. The LIF neuron showed a better performance not only w.r.t. the error prediction performance but also in terms of energy consumption and implementation feasibilities. In a final step the theoretical requirements to implement this model to a neuromorphic chip like intel's Loihi 2 was discussed.

Student:
Matthias Höfflin

Advisor:
Prof. Dr. Jürgen Wassner

Expert:
Dr. David Perels

Research / Development project:
Visual-Servoing Testbed with AI-Hardware in the Loop (SBFI-633.4-2021-2024)