The Implementation of a Realistic Neural Network

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Abstract

Neural networks have been quite successful in the area of static pattern recognition. Real-world pattern recognition requires systems capable of handling noisy patterns that also vary over time. Most neural network techniques available today are quite capable of dealing with noise, but have quite limited performance with time varying input data. A serious limitation of the commonly used feed forward neural network is that the structure is task dependant and so must be redesigned for each different task.

A new framework for performing computations on time series and in particular on spike trains, was recently presented. It called Liquid State Machine. In contrast to common computational models LSM does not require that information can be stored in some stable states of a computational system. It has been shown that such models where all events are transient can be not only successfully applied to analyze computations, but can also be used to solve engineering tasks such as design of non linear controllers, pattern recognition tasks (speech recognition, image recognition etc...).

A Liquid State Machine comprises three parts, an input layer, a large randomly interconnected unit which has the intermediate states transformed from input, and an output layer. Typically recurrent neural nets that employ Leaky Integrate and Fire (LIF) Neurons are used to implement the large randomly interconnected unit, which is the main part of the system. This unit is not task dependant and the same structure can be used to solve different problems. Only the output layer must be appropriately trained in order to achieve the desired response.

The goal of this project was to design and implement the intermediate unit of an LSM system. This is a highly recurrent neural microcircuit, consists of 129 LIF neurons and 803 synapses. Due to the need to implement a randomly generated interconnect, it was required that a design flow be developed that allowed for the automatic construction of any generated interconnect structure.

In first part of the project mathematical models were supplied for neuron, static synapses and synaptic short term plasticity that had been used in the software simulations of LSM. In addition, a specific connectivity matrix generated by the simulation was also supplied. Using the mathematical models as a basis, analog VLSI sub-modules that behaviorally correlate with the mathematical models were designed and implemented. The sub-modules were used to implement the complete network as defined by the given connectivity matrix. Several versions of the synapse models had to be developed in accordance with the behavioral models.

Extensive circuit simulations were performed to prove correct functionality and to characterize the network in terms of input/output basic functionality, frequency and power consumption.

In second part of the project, optimizations were performed on the analog circuits in terms of area and power consumption. The layouts of each of the modules were adapted to the automatic place and route design methodology. This allowed automatic conversion of any randomly generated network into layout with minimal user effort thus laying a foundation to enable the future implementation of networks of much greater complexity.

In our project we faced the challenge of implementing a non-conventional computational circuit which is based on Liquid-State-Machine computational model. The design flow, from basic VLSI circuits of neurons and synapses, to a full network design and layout, was defined and implemented. The circuit of the recurrent network was characterized, in terms of power, area and network. This project enables the completion of Si Liquid-State-Machine based on the developed flow and implemented design.

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