論 文 の 内 容 の 要 旨

論文題目　Digital silicon neuronal network and its application to associative memory
(デジタルシリコン神経ネットワークと連想記憶メモリへの応用)

氏　　名　　李　菁

This dissertation presents a digital silicon neuronal network which simulates the nerve system in creatures and has the ability to execute intelligent tasks, such as associative memory. Two essential elements, the mathematical-structure-based digital spiking silicon neuron (DSSN) and the transmitter release based silicon synapse, allow the network to show dynamic behaviors and are computationally efficient for hardware implementation. The DSSN model shows Class I and II neurons via saddle node bifurcation and hopf bifurcation, respectively. It, unlike the ionic-conductance-base model, reproduces neuronal properties form the mathematical point of view which is an abstract description in essence. It is more functional than the LIF model because one variable dynamic system is unavailable for Class II neurons. Moreover, the graded response of Class II neurons is precisely explained in the DSSN model.

We adopt mixed pipeline and parallel structure and shift operations to design a sufficient large and complex network without excessive hardware resource cost. The network with 256 full-connected neurons is built on a Digilent Atlys board equipped with a Xilinx Spartan-6 LX45 FPGA. Besides, a memory control block and USB control block are designed to accomplish the task of data communication between the network and the host PC. The real-time running frequency of our silicon neuronal network is 2746.67KHz. Actually, the silicon neuronal network built on Atlys FPGA board with 100MHz system clock runs 40 times accelerated than the real-time operation.

This dissertation also describes the mechanism of associative memory performed in the silicon neuronal network. The network is capable of retrieving stored patterns if the inputs contain enough information of them. The retrieving probability increases with the similarity between the input and the stored pattern increasing. Synchronization of neurons is observed when the successful stored pattern retrieval occurs. Moreover, we combined synaptic plasticity with our silicon neuronal network to show the learning and memory behaviors. Hebbian learning rule and spike-timing-dependent plasticity (STDP) are two popular learning rules which modify synapses according to the precise spiking time between pre- and postsynaptic neurons. The silicon neuronal network is trained by Hebbian learning rule and STDP respectively for running the memory retrieval task. The experimental results show that Hebbian learning rule is efficient for associative memory because of the recording of correlations in patterns and STDP is active for spatio-temporal memory since its sensitivity to sequence learning.