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“SCENE SEGMENTATION USING NEUROMORPHIC NETWORKS”

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Jordi Cosp Vilella

Advisor: *Jordi Madrenas*

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To everyone that has really taught me.

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ABSTRACT

Advances in neurosciences have induced the development of complex models of artificial neurons closer to their biological counterparts. These models improved functionality of artificial neural networks and novel applications have appeared. Nevertheless, complexity of new neuron models makes their simulation difficult, and time and power consuming. This is not a major drawback for applications that have no restrictions on power consumption and system complexity as simulation of natural neurons or exploration of different abilities of artificial neural networks. But, there are other applications, as found in real time portable systems, that require fast and small systems and low power requirements for which simulating complex artificial neurons is not a good solution. Finding a feasible solution to this problem is the aim of this work.

This dissertation describes and analyzes a hardware model of an artificial neural network based on coupled oscillators that have been adapted to fit VLSI requirements and its applications to scene segmentation tasks. To reduce area overhead and power consumption, neurons, which are modeled as astable oscillators, are implemented on a full custom ASIC instead of being simulated on a standard hardware architecture. The implementation of a physical oscillator instead of their simulation, allows the system to perform the same tasks and reduce power consumption compared to requirements needed for a computer to simulate the network.

First, a current-mode astable oscillator is modeled as an integrator and a hysteresis comparator. Then, this scheme is used to study algebraically and numerically the synchronization of excitatory coupled oscillators with and without external inhibition and mismatch. After this, the analysis is repeated with an improved model composed of two integrators with different timescales. This allows us to simulate secondary effects as oscillator output capacitance. From these results, the behavior of one–dimensional and two–dimensional arrays of coupled oscillators is studied and then, the network is applied to synthetic image segmentation.

Based on results of the mathematical analysis, a microelectronic network is designed on a double-poly 0.8μm CMOS ASIC. This circuit is described and extensively simulated to check its functionality as a segmentation layer. Then, experimental results validate the network functionality as a segmentation network and confirm the importance of secondary effects modeled in the mathematical analysis section. Finally, this dissertation ends with an estimation of the scheme complexity, compares it to other methods, sets out concluding remarks and explores future trends on implementation of neuromorphic segmentation schemes.

Mathematical analysis and simulations demonstrate that astable oscillators can be used as basic cells of segmentation networks. They also demonstrate that delays due to cell output capacitance combined with device mismatch have to be limited below certain boundaries for the network to work properly. The physical implementation of a

neuron model based on a non-linear oscillator demonstrates that it is possible to implement an oscillatory segmentation scheme that runs much faster that its simulated counterpart on powerful computers.

Future lines of research are the deeper study of synchronization mechanisms with weaker coupling strength combined with device mismatch, the use of faster current comparators with low power consumption figures and the use of gray level input images.

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- J.Cosp, J.Madrenas. Scene Segmentation Using Neuromorphic Networks. IEEE Transactions on Neural Networks. *Submitted*
- J.Cosp, J.Madrenas. A Microelectronic Implementation of a Bioinspired Analog Matrix for Object Segmetation of aVisual Scene. *9th European Symposium on Artificial Neural Networks (ESANN'2001), pp. 69-74, 2001*
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