A Neuromorphic Head Direction Cell System

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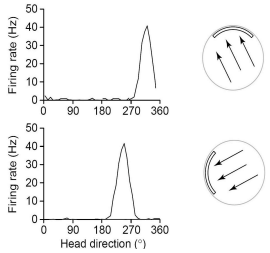
Introduction

The Head Direction (HD) cell system is a neural circuit of special interest for performing spatial navigation. The HD is composed of neurons that preferentially fire when the head of the animal faces a particular direction in the environment. Using a population of neurons with different preferred directions, all directions can be represented. The HD system represents the animal's current direction estimate by integrating rotational velocity information (from visual or vestibular sensors) or by receiving direct angular information provided by other sensory sources.

Many different models have been proposed to describe the computation performed in the HD system. In this poster, we present a neuromorphic VLSI system implementing an attractor-based model for the HD system.

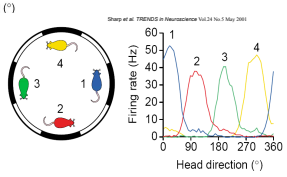
Biological Head Direction Cell Systems

Head-Direction (HD) cells were first discovered in the postsubiculum of rats, however, subsequent studies have shown the existence of HD cells in many other areas of the rat brain. The specific functionality of these populations of HD cells differs with their location; as we are interested in the spatial navigation problem, we will focus on the HD cells in the postsubiculum.



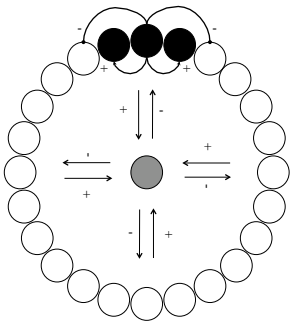
Each cell fires in response to the head facing a preferred direction in space.

The collective activity of the neurons encode for all possible orientations.



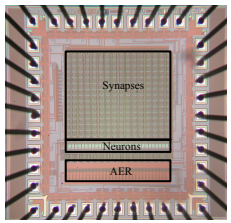
Neuromorphic Head Direction Cell System

I. Bump Formation (Model)

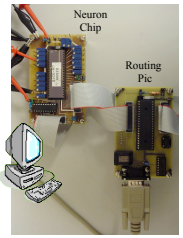


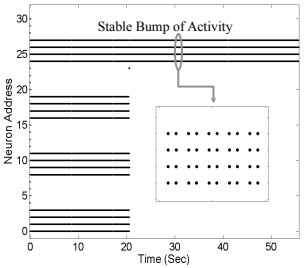
- Ring of neurons
- Lateral connections
- Global Inhibitor
- Attractor network
- Stable bump of activity without external input

I. Bump Formation (Hardware & Testing)

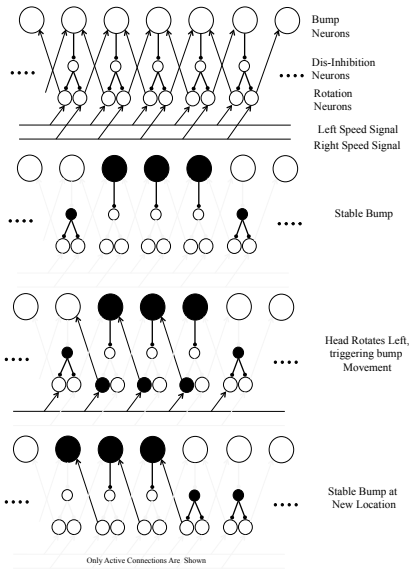


- 32 I&F Neurons
- AER (Digital) Readout
- 14 Synapse per neuron
- Global Inhibitor for WTA
- AER (Digital) stimulation
- dsPIC Implementing the routing
- Data sent to PC through serial Connection

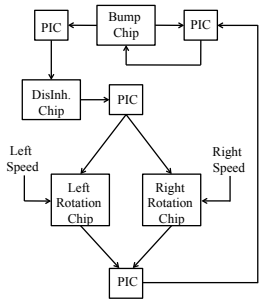




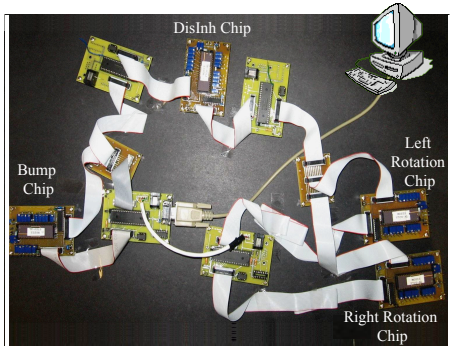
II. Moving the Bump (Model)



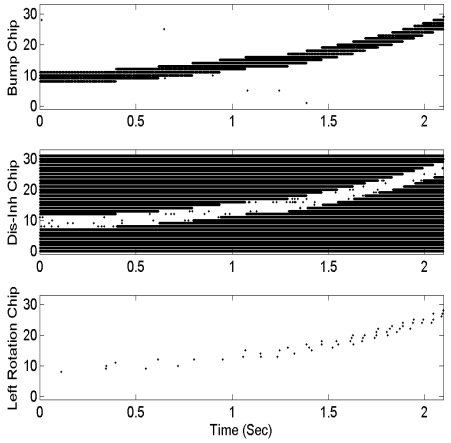
II. Moving the Bump (Hardware &Testing)



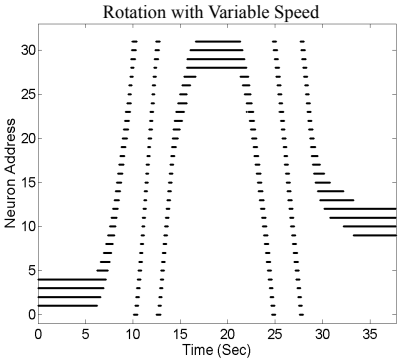
- 4 Neuron Chips
- AER (Digital) Routing
- 4 dsPICs for Routing
- Analog Speed Signals to Control Bump Rotation
- Data sent to PC through serial Connection

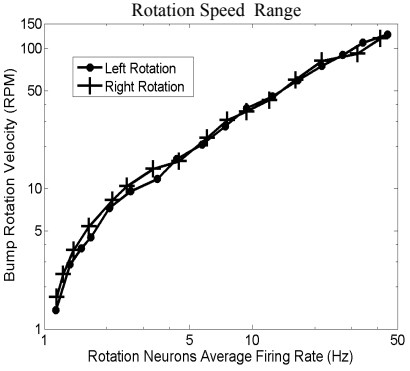


System Data for Left Rotation



Characteristics of the Neuromorphic Head Direction System





Conclusions

- We have shown a neuromorphic implementation of the head direction cell system
- Neuron chips consume 1.556 mW
- The system can be used for a wide range of rotation speeds ~ 2 orders of magnitudes
- Our next step is to use an actual robot for testing the system rather than providing the rotation speeds manually.

Acknowledgments

We thank Steve Moskovchenko for help with the microcontrollers.

This work was supported by a CRCNS grant from the National Science Foundation (R01EB004750), the Air Force Office of Scientific Research (FA95500710446) and the National Science Foundation (CCF0347573).