# Modeling Early Vision: Probabilistic Computation Using Spiking Neurons, Population Codes, and CUDA


Daniel Coates[1]

[1]Portland State University, Computer Science Department

*Present Affiliation*: UC Berkeley, Vision Science Program


## Objectives

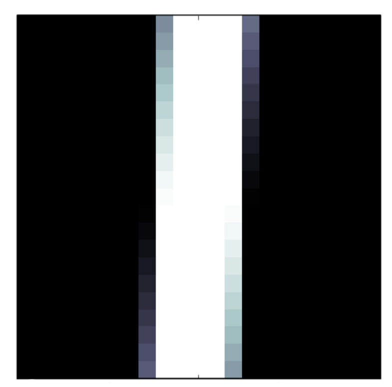
•Implement established[1][2][3] **computational model of early visual areas** that utilizes:

- •Hubel and Wiesel connectivity
- •Spiking neurons
- •Population coding

•Quantify performance on simple **image processing** task: stimulus orientation detection from noisy spike counts using statistical classifiers

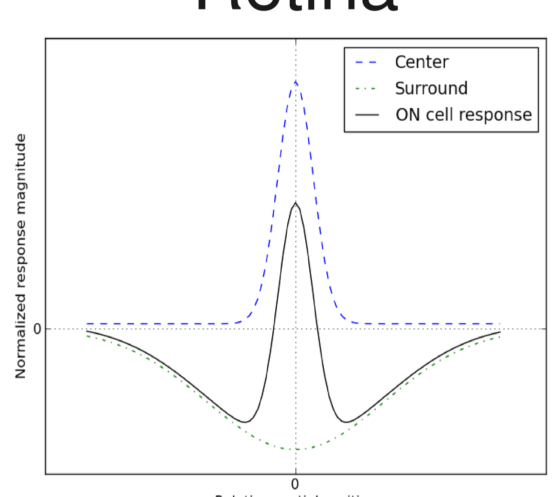
•Accelerate simulation using CUDA **parallel programming** architecture on NVIDIA GPUs

## Input stimulus



- Small (21x21) grayscale image of bar rotated at some orientation θ
- Anti-aliasing is crucial for small angles

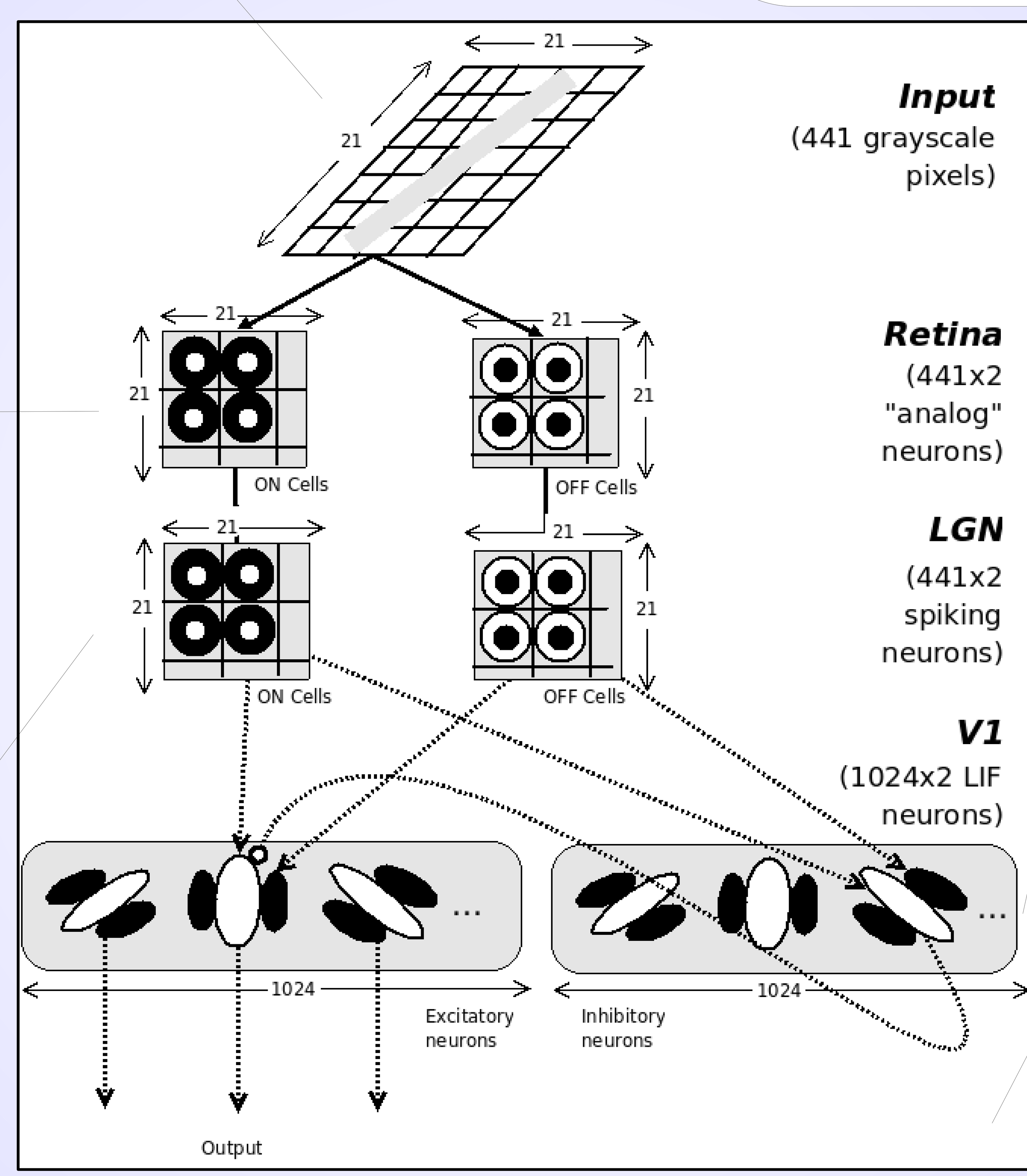
## Retina



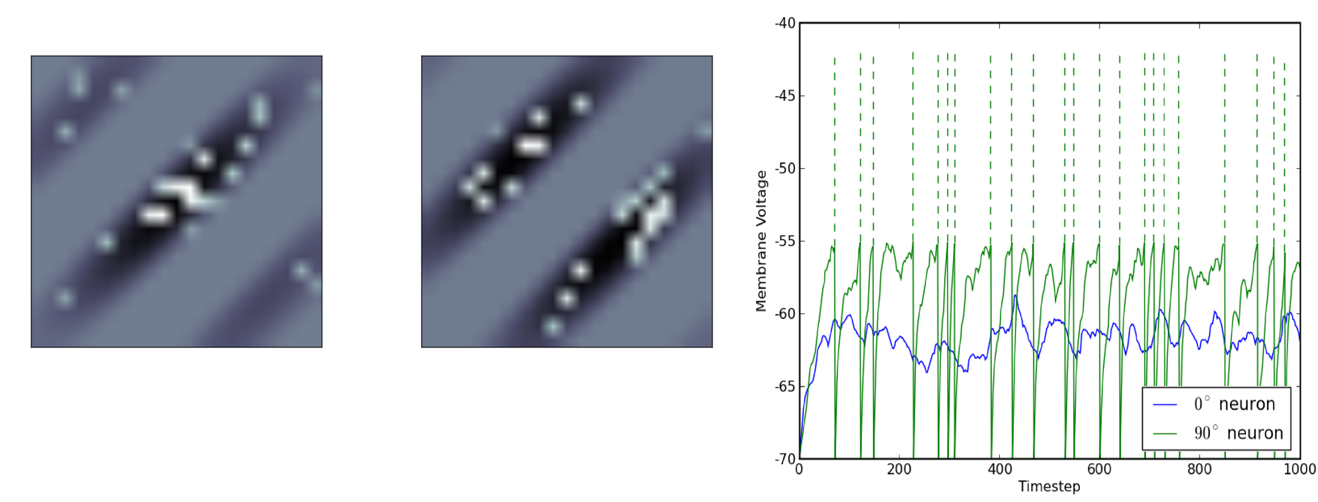

- ON and OFF grids of retinal ganglion cells
- Each neuron simulated as difference of two spatially and temporally distinct Gaussian digital filters operating on image pixels

## LGN

- Each LGN neuron mapped to a single RGC
- Continuous values of RGCs converted to spike trains with Poisson statistics

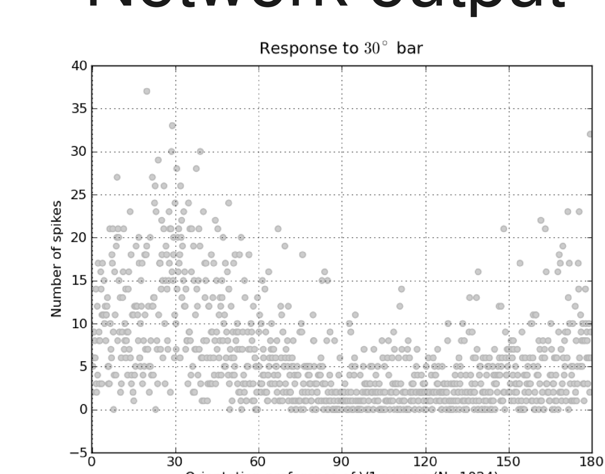



## V1



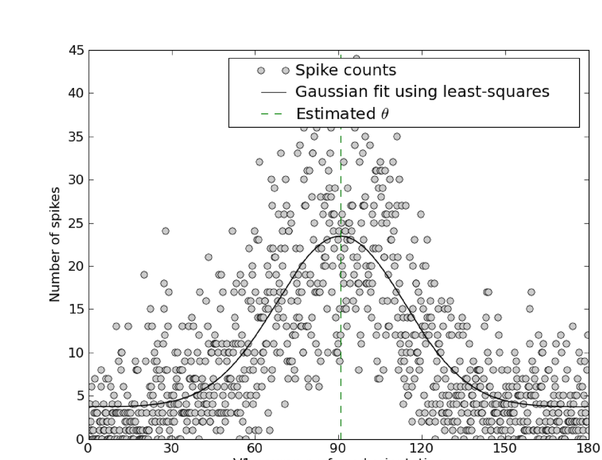

- V1 simple cells act like Hubel and Wiesel "edge detectors"
- Probabilistic LGN->V1 connectivity randomly chosen based on distributions from 2D Gabor functions
- Thousands of *conductance-based* LIF neurons, each with 50 to 75 synapses
- Inhibitory population connected laterally for contrast normalization

## Network output




- Network output consists of spike counts of population of excitatory V1 neurons

## Orientation discrimination

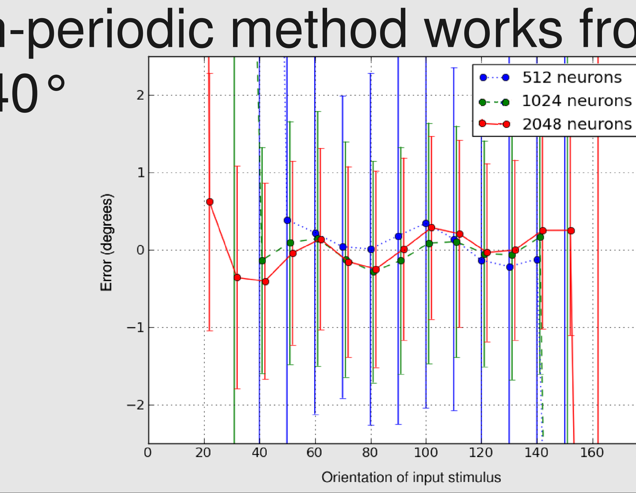



- To interpret population response, maximum likelihood estimator is Gaussian kernel fit

## Results

•With output population of 1024 excitatory neurons, orientation can be estimated with 1° error, even with stochastic spiking, random (but highly specified) connectivity, and low V1 spike rates

•Non-periodic method works from 40° to 140°

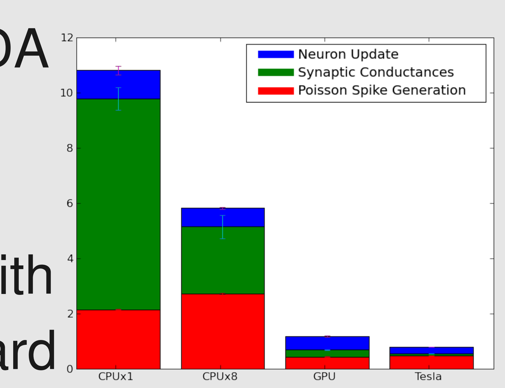



## Implementation

•Network description in Python permits rapid experimentation

•Time-based simulation kernels for Poisson spike train generation and LIF updates parallelized using OpenMP and CUDA

•Unoptimized CUDA port achieves 10-20x speedup over single core with mid-range GPU card




## References


[1] D. C. Somers, S. B. Nelson, and M. Sur. An emergent model of orientation selectivity in cat visual cortical simple cells. *J. Neuroscience*, 15(8):5448–5465, August 1995.

[2] P. Series, P. E. Latham, and A. Pouget. Tuning curve sharpening for orientation selectivity: coding efficiency and the impact of correlations. *Nature Neuroscience*, 7(10):1129–1135, October 2004.

[3] M. I. Chelaru and V. Dragoi. Efficient coding in heterogeneous neuronal populations. *Proceedings of the National Academy of Sciences*, 105(42):16344-16349, 2008.