A bird's-eye view of PetaVision, the world's first petaflop/s neural simulation.

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1 Introduction

Despite decades of intense research, fundamental aspects of visual processing in the cortex are still poorly understood[1]. Even the mechanisms for pre-attentive early vision remain elusive. To address such questions, the PetaVision project at Los Alamos National Laboratory aims to demonstrate synthetic visual cognition using a simulation of mammalian cortex running on the Roadrunner supercomputer. Visual computation is realized through the temporal dynamics of a massive anatomically-derived network of spiking neurons responding to images presented to an artificial retina.

2 Motivation

Several results from neuroscience inform the approach. First, it is now well-established that the connectivity of neurons in the early visual path is highly specific[2]. Lateral connections in V1 have been rigorously quantified[3], and recent theories hypothesize a role in contour integration[3, 4, 5] and other perceptual processing[5]. Second, it is becoming clear that temporal dynamics are important in neural processing. Thus the system employs the spiking neural model of Worgotter and Koch[6], an integrate-and-fire-like neuron augmented with separate excitatory and inhibitory channels.

The benchmark application involves detection of a closed contour amongst a field of distractors. The difficulty traditional computer vision algorithms have with such a task, versus the ease with which a human can detect such 'pop-out' targets, typifies the gap that the PetaVision project is trying to close.

3 Methods and Results

The neural connectivity patterns suggest a natural implementation on a grid of parallel processing nodes. Designed with this target platform in mind, the code scales using both shared-memory multiprocessing and MPI, running efficiently on commodity multicore PCs and on the 12,000-processor Roadrunner. The idiosyncratic hybrid architecture of Roadrunner[7] presents significant programming challenges, but the layered, columnar structure of visual cortex has an obvious topographic mapping.

Initial experiments utilize a 64x64 monochrome image and more than 100,000 neurons, with simulations corresponding to 300-500 milliseconds of neural response. Using standard spike analysis techniques, cortical activity is post-processed and object detection is implicated in self-organized temporal correlations in the spike train data.

References

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