An Evolutionary Autonomous Agent with Visual Cortex and Recurrent Spiking Columnar Neural Network

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Abstract. Spiking neural networks are computationally more powerful than conventional artificial neural networks [1]. Although this fact should make them especially desirable for use in evolutionary autonomous agent research, several factors have limited their application. This work demonstrates an evolutionary agent with a sizeable recurrent spiking neural network containing a biologically motivated columnar visual cortex. This model is instantiated in spiking neural network simulation software and challenged with a dynamic image recognition and memory task. We use a genetic algorithm to evolve generations of this brain model that instinctively perform progressively better on the task. This early work builds a foundation for determining which features of biological neural networks are important for evolving capable dynamic cognitive agents.

1 Introduction

We describe an evolutionary autonomous agent experiment designed to explore the computational power of certain biological features, such as *spiking* neural networks and *cortical-columnar* organization, in dynamic cognitive tasks. For these experiments, the agents are recurrent column-structured spiking neural networks with about 14000 total neurons and about ten times that many synapses. The model is divided into several areas that roughly mimic some of what is known of early mammalian visual processing, connected to "motor" output areas where the response of the model is interpreted as a rate-coded output. All learning occurs between generations, on an evolutionary time scale; each model is only given one chance to perform the challenge task in its own lifetime.

Because our long term goal is to replicate features of biological cognition, the task we have chosen to challenge our neural agents is modeled after a dynamic psychological recognition and memory test rather than a more typical artifical neural net mapping task such as static image recognition. Though important in other respects, we believe such mapping tasks are not interesting areas for the investigation of biological cognition in part because they are not dynamic (having no time constraints on response) and they are readily implemented in

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non-biological, non-spiking feedforward networks. In contrast, many explorations of human and animal visual working memory involve a delayed matching task [2]. In our variant an image is presented to the test subject momentarily and then removed. A short time later, a second test image is presented and the agent must decide if that image was the same as or different than the first image. To make the test more difficult, a "distractor" image is interposed between the test images. To succeed on the task, the evolved neural agents must actively *remember* some representation of the first image during the presentation of the distractor and then later *compare* this remembered representation with the second test image.

2 Results and Discussion

Little is known about the design and behavior of recurrent spiking neural networks, making prediction of their capabilities difficult and, we suspected, success unlikely. After considerable experimentation with model architecture and parameters—generally simplifications—we were able to consistently evolve agents to correctly perform our delayed matching task (figure 1). Any fitness value over 16 indicates that the agent got all four responses correct. Higher fitness values indicate an improved *ratio* of spikes in the correct vs. incorrect motor output regions. Generalization of the task and investigation of which model features are important for successful evolution of dynamic cognitive agents will follow.

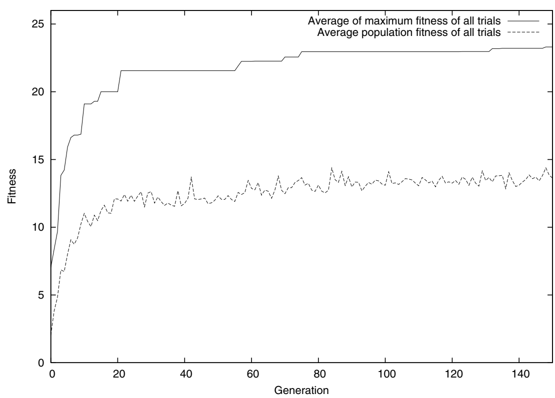

Fig. 1. Avg. of max. fitness, and avg. of pop. fitness, over 5 trials. Pop. size: 16

References

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