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Tangled Program Graphs as Possible Models of Human Brain

Project Description

An essential question that computational neuroscientists attempt to answer is how to computationally model the human brain and, consequently, build computer models that solve cognitive tasks as efficiently. Commonly, the brain has been modeled as a deep neural network, often convolutional neural networks for computer vision tasks. Although this has led to many promising discoveries, such models fail to model a few important characteristics of the brain. First, there is evidence that each node (neuron) in the brain can perform its own local computations. Second, the brain's network is capable of performing many different kinds of tasks at high efficiency and accuracy. Lastly, the anatomical structure of the brain regions that are best modeled by modern convolutional neural networks show important differences from those models. They appear less deep (e.g., the number of synapses through a given brain hierarchy are often fewer than the number of layers in a deep net) and contain more horizontal and feedback connections in contrast to the purely feedforward deep net architectures. Due to these shortcomings, I will be evaluating tangled program graphs (TPG) as a potential model.

Tangled program graphs are a genetic algorithm framework that builds from the Symbiotic Bid-Based algorithm. TPG evolves teams of programs that are interconnected and solve certain tasks. From this algorithm, a policy graph forms through evolution where different programs are connected as parts of teams. The relationships between programs, number of teams, and relationship between teams all emerge as they are evolved during training. This approach has been shown to perform well in multi-task reinforcement learning, where a single network learns to perform multiple tasks simultaneously. The networks they form need not be as deep or as computational intensive as state-of-the-art neural networks.

TPGs appear to address many of the shortcomings of deep neural networks when modeling the brain. Each node in the graph is now a program, which means the smallest computational unit can perform multiple arithmetic operations, similar to neurons in the brain. They can perform multiple tasks at the same time fairly efficiently and are efficient when doing so.

My task is then to explore the nature of the networks formed by TPG, specifically comparing them to networks in the human brain. To do this, I will train the algorithm on 20 different cognitive tasks that are often used in the literature to study the neural basis of cognition in animals and humans. Various deep neural network architectures have been evaluated on these tasks, so this will allow me to compare the performance of the two models. After this, I will try to train the TPG to perform multiple of those tasks. Once this is done, I will investigate the nature of the policy graph that emerges, studying the connectivity of the network and the structural features of the graph.

List of Deliverables

This project is largely exploratory in nature, so it is difficult to pin down the exact tasks that need to completed as this will depend on the results at each stage of the process, so the list below may change entirely. I do plan to spend 7-10 hours per week on this project, hopefully leading to some exciting discoveries about the model.

Task	**Date**
Develop at least 5 (hopefully more) cognitive tasks to train on	Feb 17
Train TPG to perform each task, independently	Mar 6
Train TPG to perform multiple tasks	Mar 30
Analyze TPG graph structure	Rest of semester