Deep Learning in Biological and Artificial Neuronal Networks
Assignment 4

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1 Synaptic Intelligence

1.1 Working Principles

Artificial Neural Networks (ANNs), unlike the Biological Neural Networks (BNNs) in our brain, are prone to catastrophic forgetting, where they completely forget previously learned task upon acquiring and learning a new task. While the exact underlying mechanism in the brain that allows biological agents to learn from non-stationary data in a continual manner remains unclear, the author hypothesises that the relative simplicity of synapses (weights) in ANNs compared to those of BNNs could be a contributing factor to their vulnerability to catastrophic forgetting.

In this paper, the authors introduce *intelligent synapses*. These synapses, unlike the vanilla ANN synapses that have a single scalar quantity, are represented by a three-dimensional state-space model in which a surrogate loss, parameterized by the past and current synapse parameters and an online importance of individual synapse, is introduced to prevent the synapses that were important for solving previous tasks from changing when future tasks are encountered. They demonstrate the effectiveness of this online computation of per-synapse consolidation strength on a number of different tasks, including Split MNIST, Permuted MNIST and Split CIFAR-10/CIFAR-100 datasets.

1.2 Biological Plausibility

The approach introduced in this paper is strongly influenced by the complex internal dynamics of biological neurons that drives memory consolidation and thus, alleviating catastrophic forgetting. Biological neurons do not have separate phase for learning on a task and consolidating their synaptic strengths. Their importance to the task is learned on-the-fly and along the entire learning phase. By allowing individual neurons to learn their own importance weight in a local and online fashion, the authors seek to more closely mimic the complexity and the characteristics of biological neurons in the brain. Nonetheless, the paper ultimately relies on biologically implausible learning rules to back-propagate the errors and update the synaptic weights so it is unlikely that the biological neurons follow the exact same approach as intelligent synapses for tackling catastrophic forgetting.

2 Results

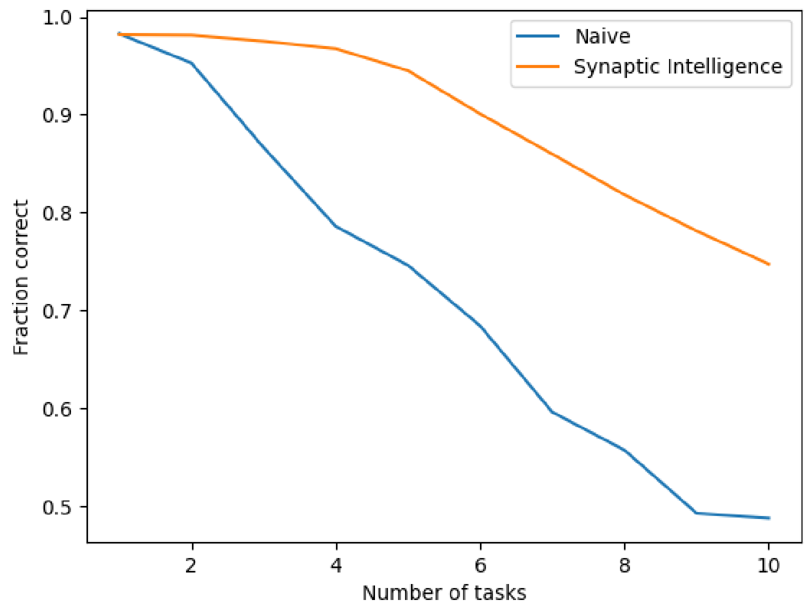

Figure 1: The average accuracy across all tasks in the Permuted MNIST dataset that had been encountered so far for Synaptic Intelligence (SI) and Naive approach

We trained a Multi-Layer Perceptron (MLP) model with 2 hidden layers of 2000 units on the Permuted MNISt dataset for 20 epochs on each task using SI and a simple "Naive" retraining strategy as shown in Figure 1. From Figure 1, we can clearly see that the model trained using Synaptic Intelligence maintains a relatively high accuracy as the number of tasks increase compared to the Naive baseline. SI achieves the final average accuracy of 74.8% as compared to 48.8% for the baseline.