Improved Generalizability and Performance on Small Datasets Using Hyper-Connected Neural Architectures, C. elegans-Inspired Networks, and Evolutionary Modeling

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Neural networks are fundamentally flawed. In even the most trivial tasks like digit recognition, they require tens of thousands of training examples to achieve near-human accuracy. In contrast, toddlers can identify digits with only about a hundred examples. The generalizability problem has troubling implications for AI. Slight, almost imperceptible alterations to test cases can cause fine-tuned networks to generate absurd conclusions, which is disastrous in critical applications like self-driving and medicine. This project incorporates biological structures to increase the inductive performance of neural networks on outliers and small datasets. We create a novel class of neural networks termed the mesh neural network (MNN), modeled after the visual cortex. The MNN contains recursive feedback mechanisms, in which neurons can communicate with itself and other neurons in any layer. Since conventional training methods are infeasible, we train the MNN using a genetic algorithm as a search heuristic that evolves the network's parameters and connections across multiple generations. As a proof of concept, we test the MNN's generalizability and performance on the MNIST database, with a trainset of just 100 digits. Three networks were incorporated into the MNN as 'seeds' to be evolved by the genetic algorithm: a feedforward DNN, a C. elegans inspired network, and a Bernoulli randomized network. The network achieved 91% test set accuracy with the C. elegans seed. The best neural configuration outperformed state-of-the-art models on accuracy by 29%, F1 Score by 11%, AUROC by 8%, and AUPRC by 14%. The success of the MNIST test case is very promising for future small data applications—from classifying social media posts to analyzing genome sequences.

Awards Won:
Second Award of $2,000
Air Force Research Laboratory on behalf of the United States Air Force: Glass trophy and USAF medal for each recipient
Air Force Research Laboratory on behalf of the United States Air Force: First Award of $750 in each Regeneron ISEF Category, FOR 2023 ONLY: EBED WILL HAVE TWO
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