

### Homework 3 (CIFAR-10)

The goal of this modeling exercise was to predict the class of images from the CIFAR-10 dataset. This dataset comprises 60,000 32x32 color images (50,000 for training and 10,000 for testing) that each belong to one of ten classes. Scaling each pixel by 255 was the only preprocessing performed on the data. Only neural networks were used for this assignment and all models were evaluated using validation classification accuracy.

Exploration of deep learning techniques for this task began with basic convolutional neural network (CNN) models. The first model fit was extremely basic with only one convolutional layer, a max pooling operation, and then a dense output layer. Gradually, deeper and more complex models were explored with variations in the number and size of kernels used. Ultimately, a CNN using three convolutional layers (128, 128, and 32 3x3 kernels) with padding added to the training images was found to be the most effective with a 71.65% validation accuracy. In addition to the CNN structures developed, the pre-defined LeNet-5 model was fit for comparison. The developed models slightly outperformed LeNet-5 and several variations of that framework. Next, pretraining techniques were tested using the ResNet50 and VGG16 pretrained models available in Keras. While the ResNet50 pretrained model performed distinctly poorly on the CIFAR-10 dataset, the VGG16 model performed strongly. Two layers from VGG16 were chosen to be trained to fine-tune the model to the CIFAR-10 dataset and a dense layer (64 neurons) was added before the output layer. This fine-tuned pretrained model achieved a validation accuracy of 76.94%. Finally, data augmentation was performed using random rotations, zooms, and flips. Surprisingly, models using augmented data performed drastically worse than models using raw data. This could be because the resolution of the images is already so low that distortions make them nearly uninterpretable.

The CNN with three convolutional layers and the fine-tuned VGG16 model were chosen for further investigation and test set prediction. The CNN, after 21 epochs, achieved a test accuracy of 71.78%. The VGG16 model, being much deeper and having been trained in a more sophisticated manner was hypothesized to outperform the CNN. This was found to be true as the VGG16 model achieved a test accuracy of 75.87%. Finally, more advanced fine-tuning methods were applied to the VGG16 base including additional hidden layers, normalizing penalties, a dropout layer (rate of 0.1), and 100 epochs of training. This model impressively achieved 78.09% test accuracy and was chosen for final submission to Kaggle. Given more time, this analysis would have designed and trained deeper CNN models using the HPC and would have further investigated the detrimental effects of data augmentation in the context of the CIFAR-10 dataset.