Student Name : Amro Eid
Student NO: 12217562

CNN for CIFAR-10 Image Classification

Introduction

This report evaluates a CNN for CIFAR-10 (60,000 32x32 color images, 10 classes). A baseline model was developed, followed by enhanced and best models with modifications to improve accuracy and address overfitting.

Data and Preprocessing

CIFAR-10 was loaded via Keras, with pixel values normalized to [0, 1] and labels one-hot encoded. Training data was split (80% train, 20% validation) using stratified sampling. Data augmentation (rotation 15°, shifts 0.1, flips, zoom 0.1) was used for enhanced and best models.

Model Development and Results

- **Baseline**: Two Conv2D layers (64, 128 filters, 3x3, ReLU), MaxPooling (2x2), Dense (128, ReLU), Dense (10, softmax). Total parameters: 1,125,642. Trained 10 epochs, batch size 32, Adam (lr=0.001), no augmentation. Test accuracy: 0.6968, test loss: 1.1486.
- **Enhanced**: Six Conv2D layers (32, 32, 64, 64, 128, 128 filters, 3x3), BatchNormalization, Dropout (0.25, 0.25, 0.25, 0.5), Dense (256), Dense (10, softmax). Total parameters: 816,938. Trained 50 epochs, batch size 64, with augmentation, EarlyStopping, ReduceLROnPlateau. Test accuracy: 0.8709, test loss: 0.3979.
- **Best Model**: Six Conv2D layers (64, 64, 128, 128, 128, 128 filters, 4x4), BatchNormalization, Dropout (0.2, 0.25, 0.35, 0.5), Dense (256), Dense (10, softmax). Total parameters: 1,517,450. Trained 50 epochs, batch size 64, with augmentation, EarlyStopping, ReduceLROnPlateau. Test accuracy: 0.8861, test loss: 0.3588.

MODEL	TRAINING ACCURACY	TRAINING LOSS	VALIDAITON ACCRACY	VALIDATION LOSS	TEST ACCURACY	TEST LOSS
BASELINE	0.8998	0.2877	0.6888	1.1573	0.6968	1.1486
ENHANCED	0.8637	0.3984	0.8740	0.3662	0.8709	0.3979
BEST MODEL	0.9101	0.2620	0.8949	0.3242	0.8861	0.3588

Figure 1: Analysis and results

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Chart Description

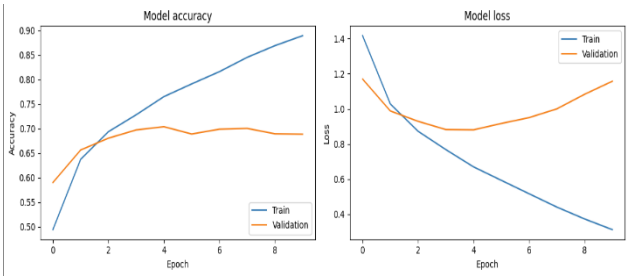

Figure 3: BaseLine Accuracy and Loss

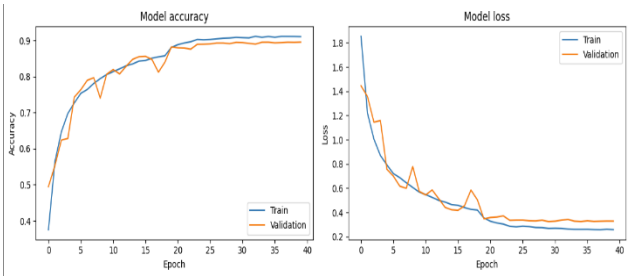

Figure 4: Best Model Accuracy and Loss

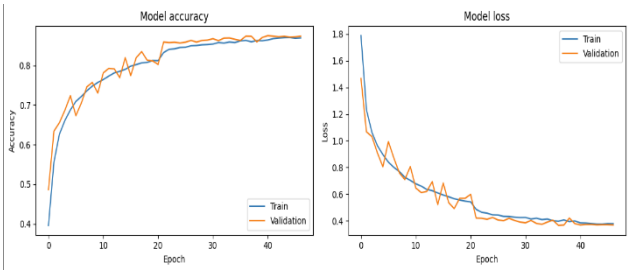

Figure 2: Enhanced Model Accuracy and Loss

Modifications and Impact

- **Increased Depth**: Enhanced and best models used 6 conv layers (vs. 2), improving accuracy (0.6968 to 0.8709, 0.8861) by capturing more features.
- **BatchNormalization**: Added in enhanced/best models, stabilizing training (loss reduced to 0.3979, 0.3588).
- **Dropout**: Applied in enhanced (0.25, 0.5) and best (0.2 to 0.5), reducing overfitting (validation accuracy stabilized at 0.8740, 0.8949).
- **Larger Filters (4x4)**: Best model used 4x4 filters, boosting accuracy to 0.8861 (vs. 0.8709) by enhancing feature extraction.
- **Data Augmentation**: Used in enhanced/best models, increasing accuracy (0.8709, 0.8861 vs. 0.6968).
- **Callbacks**: EarlyStopping and ReduceLROnPlateau in enhanced/best models optimized training, halting at optimal epochs (37, 30).

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Challenges

- **Overfitting**: Baseline validation accuracy dropped after Epoch 5; mitigated with Dropout and callbacks in later models.
- **Training Time**: Augmentation increased training time (42s/epoch for best vs. 12s for baseline); batch size 50 and callbacks helped.

Conclusion

The baseline achieved 69.68% accuracy, while enhanced (87.09%) and best (88.61%) models excelled due to deeper architectures, regularization, and augmentation. Future work could explore hyperparameter tuning.