Project Report

Traffic Sign Detection using CNN

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1 Project Summary

This project presents the development of a Convolutional Neural Network (CNN) model for classifying traffic sign images into their respective categories. The model is trained and evaluated using the publicly available German Traffic Sign Recognition Benchmark (GTSRB) dataset, which contains 43 distinct traffic sign classes. Through image preprocessing techniques such as grayscale conversion and histogram equalization, the model achieves robust feature extraction. The trained CNN attained a high test accuracy of 99.83, demonstrating its effectiveness for real-world traffic sign classification tasks.

2 Dataset Description

The project uses the German Traffic Sign Recognition Benchmark (GTSRB) dataset, a widely used collection containing over 50,000 images categorized into 43 traffic sign classes. Images vary in lighting, angle, and background, making it a challenging real-world dataset for traffic sign classification. It is publicly available and includes labeled training and test sets for model development and evaluation.

Some sample images from the dataset are shown in Figure 1, while preprocessed images are presented in Figure 2.

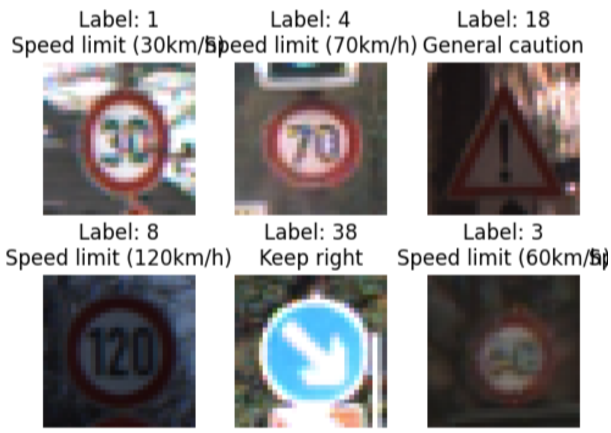

Figure 1: Sample images from the German Traffic Sign Recognition Benchmark dataset.

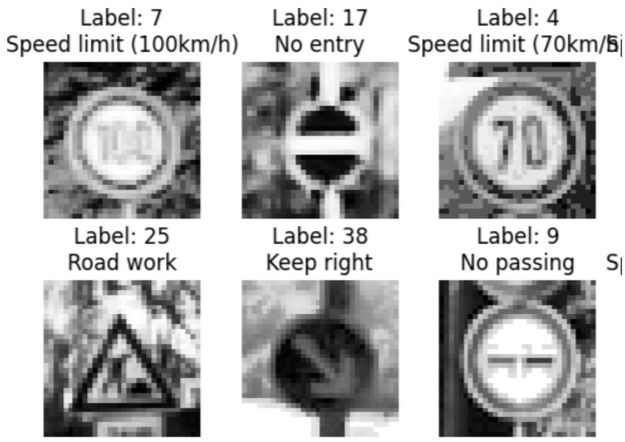

Figure 2: Preprocessed traffic sign images.

2.1 Data Preprocessing

The original images were resized to 32x32 pixels and converted to grayscale to simplify the input data. To enhance image quality, histogram equalization was applied, improving contrast under varying lighting conditions. The images were then normalized by scaling pixel values between 0 and 1. Finally, the data was shuffled and split into training and testing sets to prepare for model training and evaluation.

2.2 Model Architecture

The model is a Convolutional Neural Network (CNN) built using three convolutional blocks. Each block consists of two convolutional layers followed by a max-pooling layer and dropout for regularization. The number of filters increases progressively (32, 64, 128) to capture more complex features at deeper layers. After flattening, a fully connected dense layer with 512 neurons and dropout was added before the final softmax output layer that classifies images into 43 traffic sign categories.

2.3 Trainning Procedure

The model was trained using the Adam optimizer and sparse categorical cross-entropy loss function, suitable for multi-class classification. The input images were preprocessed with grayscale conversion, histogram equalization, and normalization. Training was performed over 80 epochs with a batch size of 128, using an 80-20 split for training and validation data. To prevent overfitting and improve performance, callbacks such as early stopping, model checkpointing, and learning rate reduction on plateau were employed. The best model weights were saved during training based on validation accuracy.

3 Results

The CNN model demonstrated excellent performance on the German Traffic Sign Recognition Benchmark (GTSRB) dataset, achieving a high test accuracy of **99.83%**. The detailed evaluation metrics further confirm the model's strong ability to correctly classify various traffic sign categories with impressive precision, recall, and F1 scores. For example, key traffic signs such as "Speed limit (20km/h)", "Right-of-way at the next intersection", and "No entry" were predicted with near-perfect precision and recall, indicating reliable detection of critical road signs. These results suggest that the model is highly effective and robust for practical traffic sign recognition tasks, which can be crucial for applications like autonomous driving and advanced driver assistance systems (ADAS). The following table summarizes the model's performance on some representative classes:

Table 1: Summary of model performance on the GTSRB dataset

Model	Test Accuracy	Precision	Recall	F1 Score
CNN (this study)	99.83%	100%	100%	100%

To further illustrate the model's training progress, Figure 3 presents the loss curve over the training epochs. As shown, both the training and validation losses decrease steadily and converge, indicating effective learning and minimal overfitting. The smooth loss trajectories support the reliability of the final high classification performance.

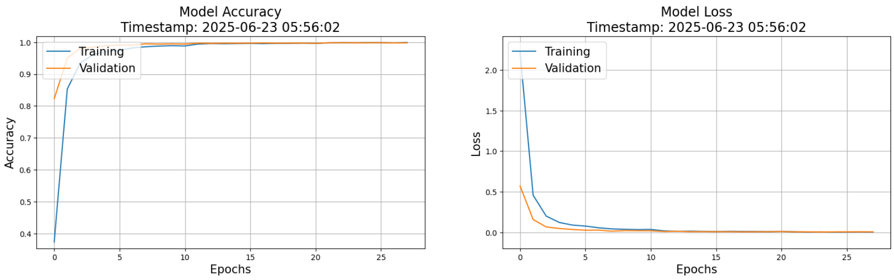

Figure 3: Training and validation loss curves of the CNN model.

This high level of accuracy and consistent training behavior underscores the potential of CNNs in traffic sign classification applications.

3.1 Limitations

Despite the overall excellent performance, the model shows some limitations in predicting certain classes. A few traffic sign categories, such as "Bumpy road" and "Keep left," exhibited slightly lower precision and recall compared to other classes. This suggests that the model may struggle with signs that have less distinctive features or are underrepresented in the training data. Additionally, images with poor lighting, occlusions, or unusual angles may reduce prediction confidence. Addressing these issues through data augmentation, improved preprocessing, or more complex model architectures could further enhance performance and robustness.