Traffic Sign Recognition with Deep Learning

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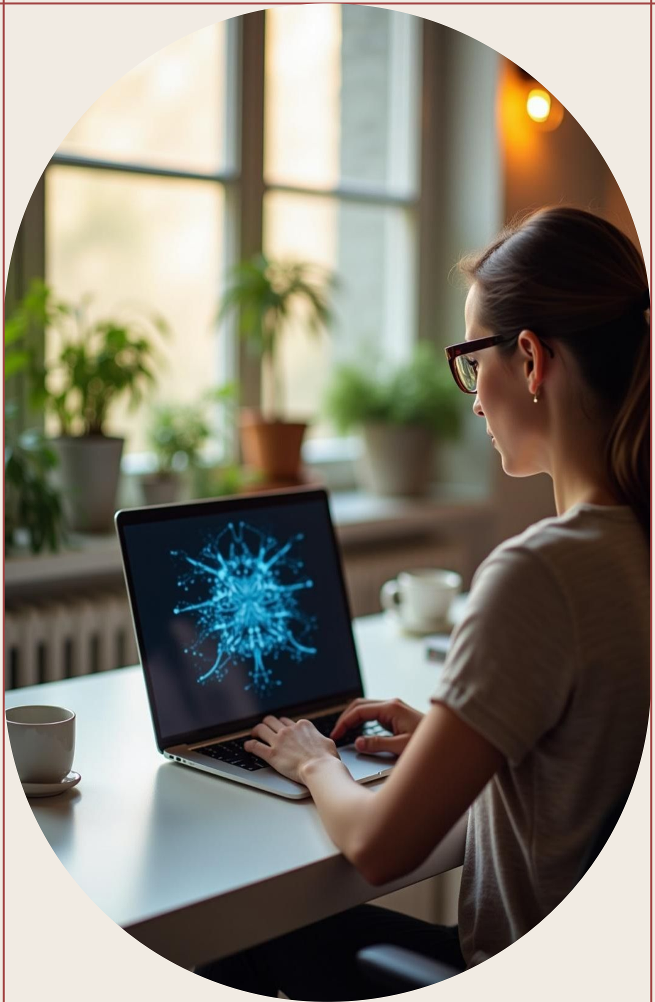
Deep Learning WS 2025

Introduction

- Traffic sign recognition is essential for autonomous driving and advanced systems.
- This project implements a compact CNN model to classify traffic signs with high accuracy.
- Our aim is to demonstrate practical deep learning applications for traffic sign understanding in real-time scenarios.



Dataset Description and Preprocessing


```
traffic_sign_small/
    labels.csv
    traffic_Data/
        DATA/
            0/
            1/
            2/
            ...
```

- The dataset consists of over 50 traffic sign classes, each represented by 32×32 RGB images.
- Data variation includes lighting, blur, and perspective challenges.
- Images are normalized and split into 80% training and 20% validation sets to ensure reliable performance evaluation.

Overview of Convolutional Neural Networks (CNNs)

- **Definition:** A class of deep neural networks specifically designed for processing grid-like data such as images.
- **The "Flashlight" Analogy:** A kernel scans an image like a flashlight in a dark room, noting specific features at each spot to create a "feature map".
- **Spatial Patterns:** CNNs exploit the spatial structure of images to detect local patterns like edges, textures, and shapes.
- **Feature Hierarchy:** Early layers detect simple lines/edges, while deeper layers combine these into complex objects.

Mathematics of CNN

Discrete Convolution: The primary operation involves a learnable kernel W sliding over an input tensor X

Forward Pass Equation:

$$Y_{i,j} = \sigma\left(\sum_{m=0}^{H-1}\sum_{n=0}^{W-1} X_{i+m,j+n} \cdot W_{m,n} + b\right)$$

Activation Function: The Rectified Linear Unit (ReLU), introduces sparsity for deep representation learning.

$$\sigma(x) = \max(0, x),$$

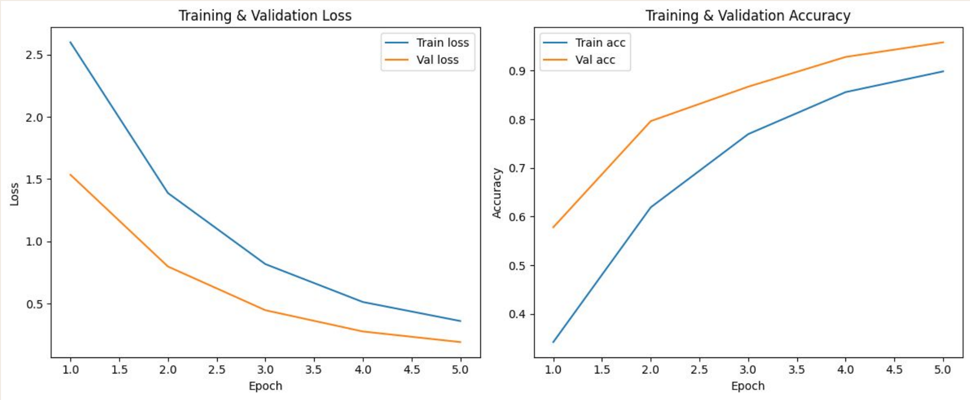
Dimensionality: Output size O is determined by input size N, kernel size K, padding P, and stride S:

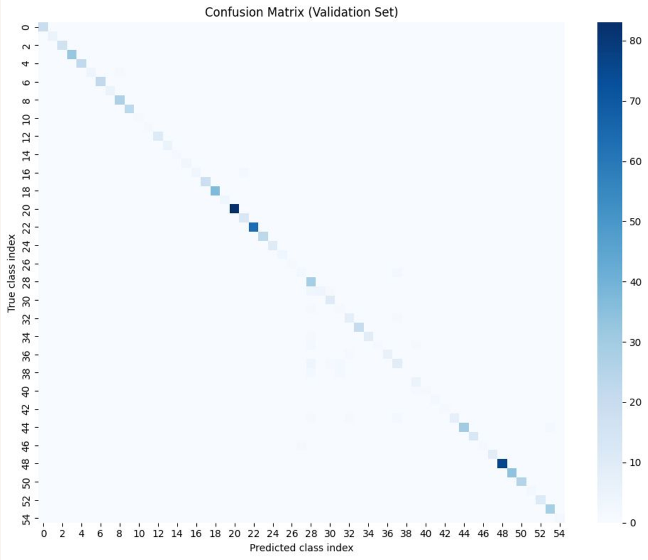
$$O = \lfloor \frac{N-K+2P}{S} \rfloor + 1$$

Implementation Model Architecture

Convolutional Layer: uses small learnable kernels to detect low-level features through a multiplication and summation process
Activation Layer (ReLU): introduces the non-linearity and sparsity necessary for deep representation learning.
Batch Normalization Layer: used to stabilize the training process
Pooling Layer (Max Pooling): reduce computational complexity & introduce translation invariance
Flatten Layer: transforms the feature maps into a single vector to prepare the data for the classification stages.
Fully Connected (Linear) Layer: act as the final classifier, mapping the extracted features to the specific class labels
Dropout Layer: randomly "drops" neurons during training to prevent overfitting and improve generalization.

Results





- The model achieves high accuracy with tightly correlated training and validation metrics
- The confusion matrix reveals accurate classification with only a few confusions for visually similar signs.
- Inference takes approximately 4.51 milliseconds per

Predicted Images

Conclusions

- The compact CNN model effectively classifies traffic sign images
- Limitations include sensitivity to data diversity and lighting changes

THANK YOU

Do you have any questions?

Citations

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