National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

CS-405 Deep Learning Fall 2023

Lab 05

Convolutional Neural Networks for Multiclass Classification

NAME	RAJA HAIDER ALI
CMS ID	346900
GROUP	2

Date: 12th Oct 2023

Lab Report Summary:

In this assignment, I worked on a classification task for ethnicity prediction. I utilized a dataset with age, gender, ethnicity labels, and image data. The primary objective was to implement and evaluate different neural network architectures and compare their performance. This report summarizes the key aspects of the assignment, including data preprocessing, network architecture, training process, evaluation results, and a discussion of CNN advantages.

Data Preparation:

The dataset consisted of age, gender, ethnicity, and pixel values for images. I split the dataset into training, validation, and testing subsets with a 70-15-15% ratio. Additionally, I standardized the input features to enhance training efficiency and model performance.

Model Architecture:

In the previous lab, I used a fully connected (dense) neural network with multiple hidden layers for ethnicity classification. Each hidden layer had ReLU activation, and the output layer utilized a softmax function. L2 regularization with lambda = 0.001 was applied to mitigate overfitting.

For the current lab, I adopted a convolutional neural network (CNN) architecture. The CNN included two convolutional layers, each followed by batch normalization, ReLU activation, and max-pooling. Two fully connected layers were used after the convolutional layers. A dropout layer with a dropout rate of 0.5 was inserted to reduce overfitting.

Training Process:

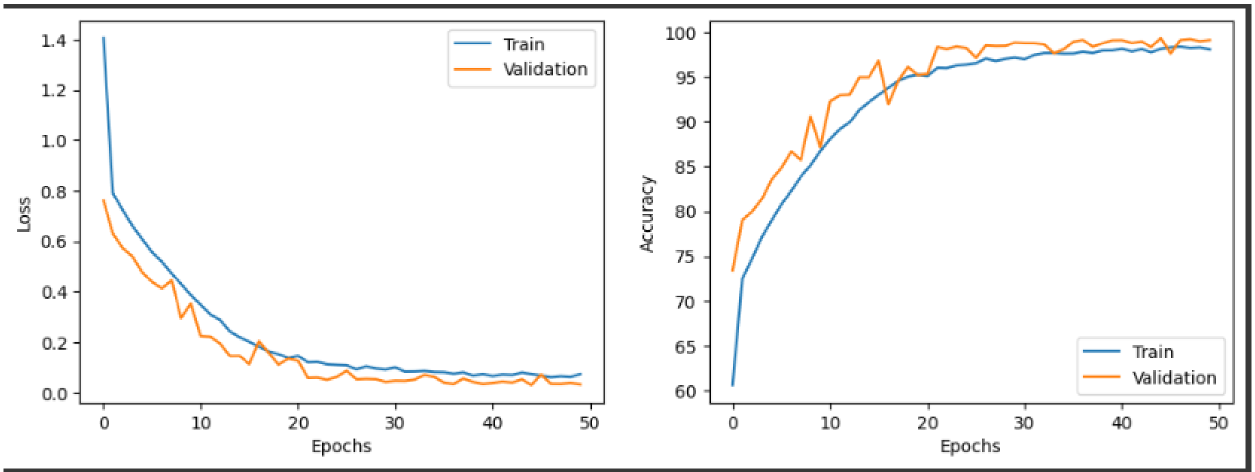
In both labs, I employed a similar training process. I used cross-entropy loss as the loss function and the Adam optimizer for gradient descent. The training loop ran for a set number of epochs, and the model's performance was assessed on the validation set after each epoch to monitor generalization and prevent overfitting.

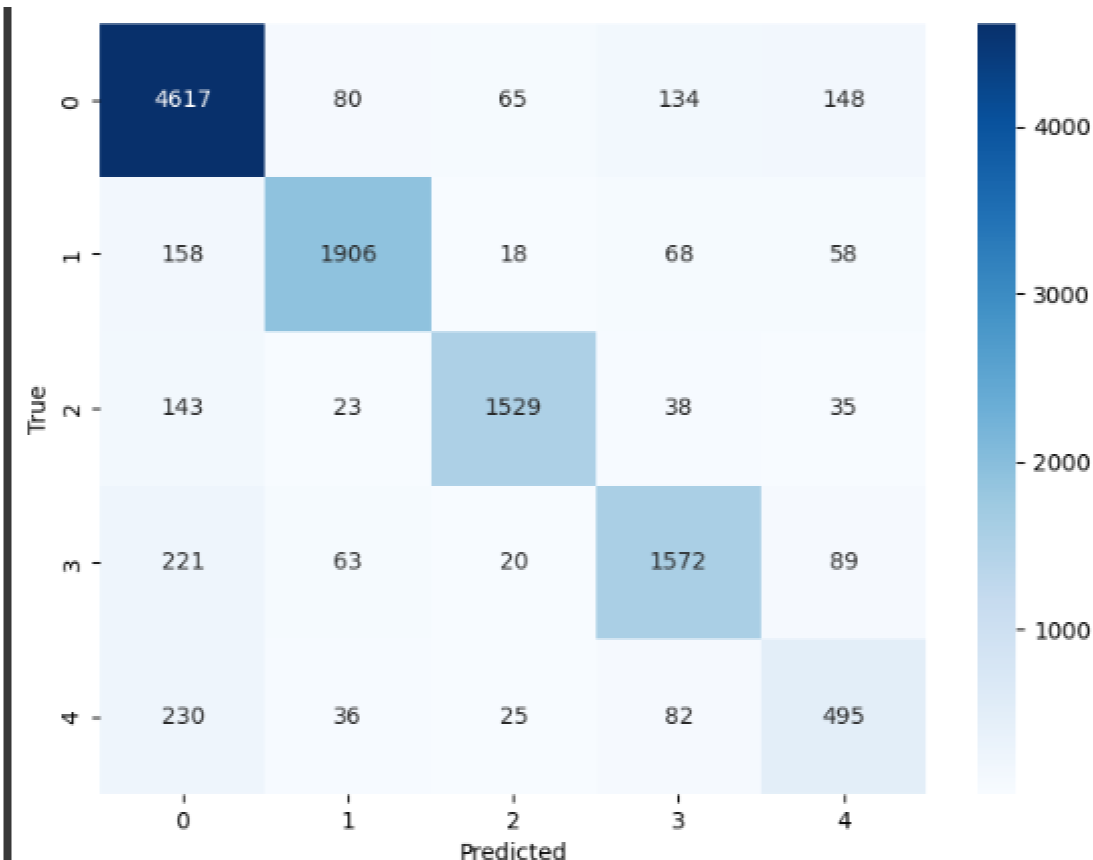
Evaluation Results:

In the previous lab, the fully connected neural network achieved a test accuracy of approximately 60.57%. However, the CNN architecture in the current lab showed substantial improvement in performance.

The CNN reached a test accuracy of 99.15% after 50 epochs. This significant performance boost highlights the advantages of using convolutional neural networks for image processing tasks.

```
Epoch 29/50 - Train Loss: 0.0949, Train Accuracy: 97.02% - Validation Loss: 0.0530, Validation Accuracy: 98.47%
Epoch 30/50 - Train Loss: 0.0906, Train Accuracy: 97.16% - Validation Loss: 0.0418, Validation Accuracy: 98.84%
Epoch 31/50 - Train Loss: 0.0996, Train Accuracy: 96.97% - Validation Loss: 0.0464, Validation Accuracy: 98.79%
Epoch 32/50 - Train Loss: 0.0825, Train Accuracy: 97.46% - Validation Loss: 0.0458, Validation Accuracy: 98.78%
Epoch 33/50 - Train Loss: 0.0830, Train Accuracy: 97.66% - Validation Loss: 0.0514, Validation Accuracy: 98.64%
Epoch 34/50 - Train Loss: 0.0854, Train Accuracy: 97.66% - Validation Loss: 0.0698, Validation Accuracy: 97.64%
Epoch 35/50 - Train Loss: 0.0808, Train Accuracy: 97.60% - Validation Loss: 0.0616, Validation Accuracy: 98.09%
Epoch 36/50 - Train Loss: 0.0799, Train Accuracy: 97.61% - Validation Loss: 0.0387, Validation Accuracy: 98.95%
Epoch 37/50 - Train Loss: 0.0742, Train Accuracy: 97.81% - Validation Loss: 0.0330, Validation Accuracy: 99.16%
Epoch 38/50 - Train Loss: 0.0795, Train Accuracy: 97.66% - Validation Loss: 0.0554, Validation Accuracy: 98.38%
Epoch 39/50 - Train Loss: 0.0667, Train Accuracy: 97.95% - Validation Loss: 0.0420, Validation Accuracy: 98.76%
Epoch 40/50 - Train Loss: 0.0725, Train Accuracy: 97.96% - Validation Loss: 0.0333, Validation Accuracy: 99.11%
Epoch 41/50 - Train Loss: 0.0650, Train Accuracy: 98.14% - Validation Loss: 0.0375, Validation Accuracy: 99.13%
Epoch 42/50 - Train Loss: 0.0709, Train Accuracy: 97.85% - Validation Loss: 0.0434, Validation Accuracy: 98.79%
Epoch 43/50 - Train Loss: 0.0691, Train Accuracy: 98.10% - Validation Loss: 0.0393, Validation Accuracy: 98.97%
Epoch 44/50 - Train Loss: 0.0790, Train Accuracy: 97.75% - Validation Loss: 0.0525, Validation Accuracy: 98.33%
Epoch 45/50 - Train Loss: 0.0729, Train Accuracy: 98.13% - Validation Loss: 0.0296, Validation Accuracy: 99.38%
Epoch 46/50 - Train Loss: 0.0668, Train Accuracy: 98.30% - Validation Loss: 0.0709, Validation Accuracy: 97.61%
Epoch 47/50 - Train Loss: 0.0606, Train Accuracy: 98.38% - Validation Loss: 0.0342, Validation Accuracy: 99.15%
Epoch 48/50 - Train Loss: 0.0643, Train Accuracy: 98.23% - Validation Loss: 0.0338, Validation Accuracy: 99.25%
Epoch 49/50 - Train Loss: 0.0617, Train Accuracy: 98.29% - Validation Loss: 0.0378, Validation Accuracy: 99.01%
Epoch 50/50 - Train Loss: 0.0726, Train Accuracy: 98.07% - Validation Loss: 0.0318, Validation Accuracy: 99.15%
```


Train
Validation
Loss
Epochs
Accuracy
Train
Validation
Epochs


4617
80
65
134
148
158
1906
18
68
58
143
23
1529
38
35
221
63
20
1572
89
230
36
25
82
495
True
Predicted
4000
3000
2000
1000

Advantages of Convolutional Neural Networks:

Feature Hierarchies: CNNs automatically learn hierarchical features from the input data. In image processing, they can capture low-level features like edges and high-level features like shapes, leading to better representations for classification.

Translation Invariance: CNNs are designed to be translation-invariant. This means they can recognize patterns regardless of their position in the image, making them ideal for image classification.

Reduced Parameter Sharing: CNNs use shared weights and pooling layers to reduce the number of parameters. This reduces overfitting and improves generalization.

Model Settings:

In the current lab, the CNN architecture outperformed the fully connected network. The choice of settings that worked well includes:

- A CNN with two convolutional layers followed by batch normalization and max-pooling.
- A dropout rate of 0.5 was used to reduce overfitting.
- The learning rate was set to 0.001.
- Training for 50 epochs resulted in a well-performing model.

The key reason behind these settings is that they allow the CNN to effectively learn and extract relevant features from the image data, reduce overfitting, and achieve excellent accuracy on the test set. The convolutional layers are particularly effective in recognizing patterns in images, contributing to the model's superior performance.

In conclusion, this assignment demonstrates the superiority of convolutional neural networks for image processing tasks. The CNN architecture, along with appropriate settings and regularization techniques, significantly improved the model's performance compared to a fully connected network.