Gurmukhi Digit Classification

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Observations by analyzing the dataset

1. Dataset contains 1000 training and 178 validation images
2. Images belong to 10 classes (1 for each digit)
3. Each image is 32x32 with 3 color channels
4. All 3 channels have the same pixel values thus making the image effectively 1 channel image
5. Pixels are either Black(0) or White(255) : making black digits on white background

Example image of a 5

Link to notebook used for analysing the dataset

Data preprocessing

1. Converted images from RGB (3-channel) to grayscale (1 channel)
2. Rescaled pixels values from 0-255 to 0-1
3. Batched the data into batches of 32 images

Training Neural Network to classify images

notebook used for training : here

Loss Function used for Optimization : **Cross Entropy loss** : $-\sum_{c=1}^{M} y_{o,c} log(p_{o,c})$
where:
M - number of classes
log - the natural log
y - binary indicator (0 or 1) if class label c is the correct classification for observation o
p - predicted probability observation o is of class c

Optimizer used: **Adam (Adaptive Moment Estimation)**
with learning rate = 0.001, $\beta_1 = 0.9$, $\beta_2 = 0.999$, $\epsilon = 1e-07$

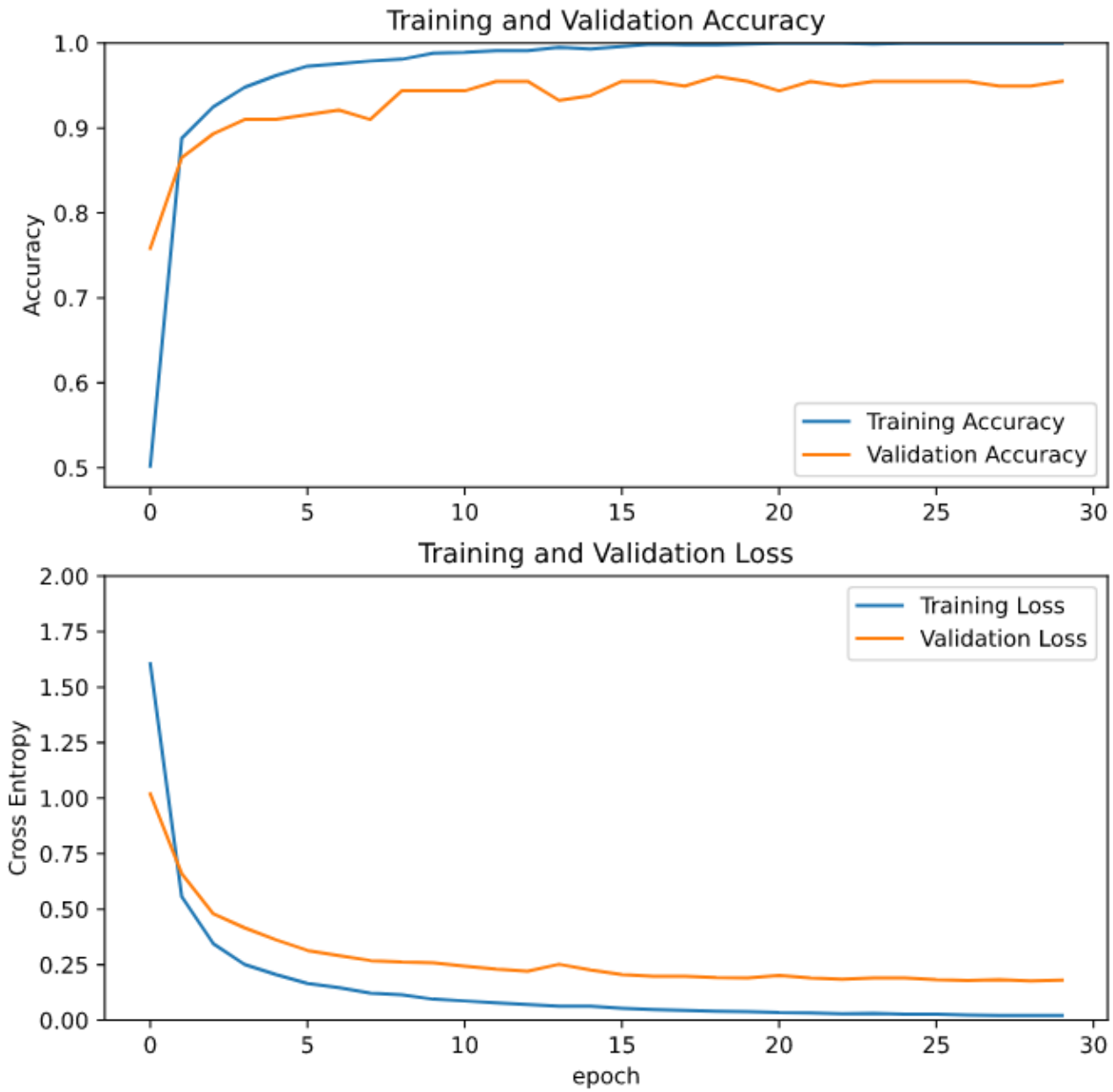
Training 1-layer NN with no hidden layer as baseline

Trained a NN with only one input layer and one output layer. No hidden layers used. Model looked like this

Image (32x32)
↓
Input Layer (1024 units)
↓
Output Layer (10 units with softmax activation)

Results obtained : for best weights saved during training using early stopping strategy:
Validation loss: 0.2166 and **Validation accuracy: 96.07%**

Progress of loss and accuracy during training is shown below :



Observation noted for 1-layer NN

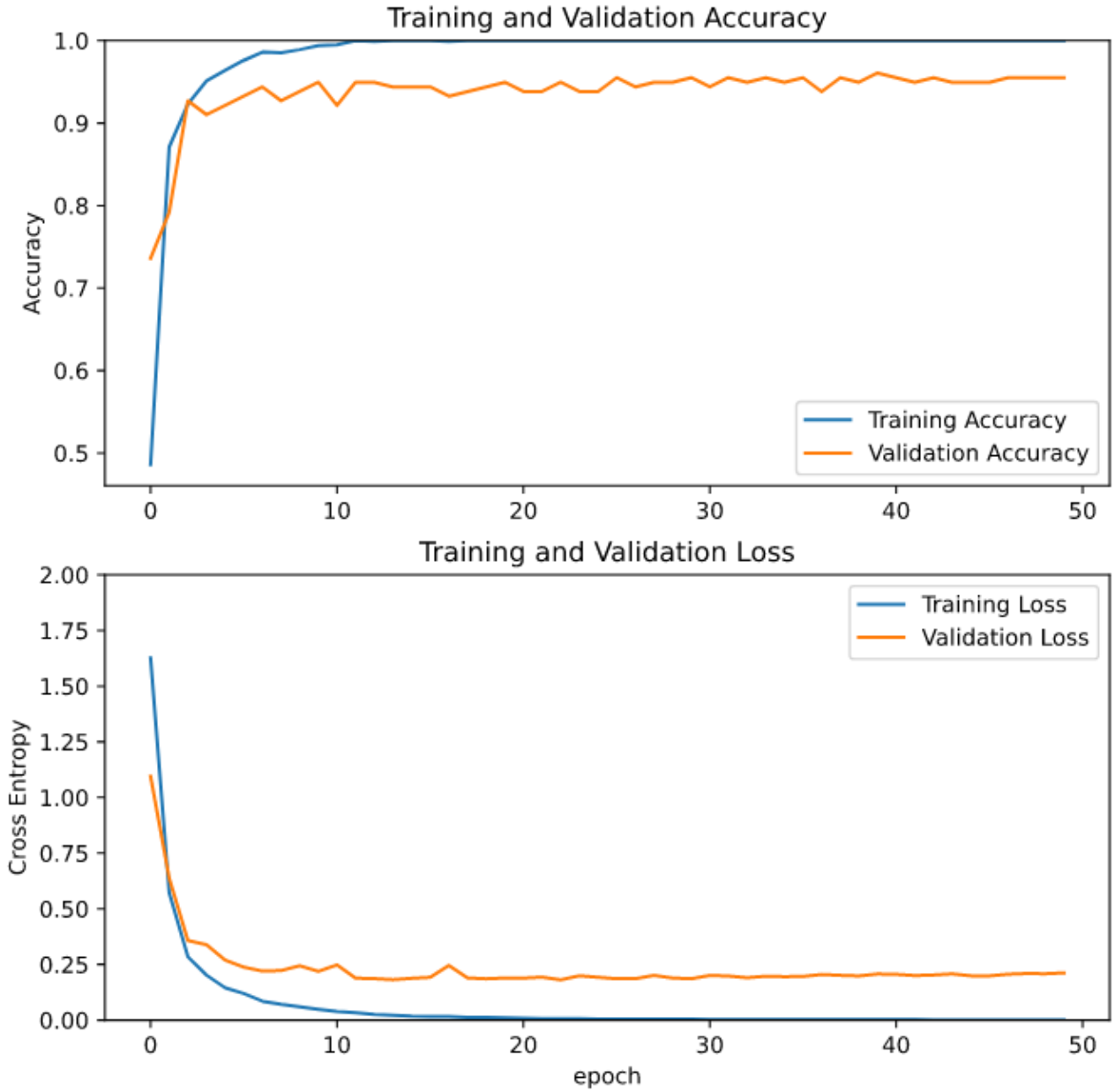
1. Starts overfitting just after training for 2-4 epochs
2. Training accuracy reaches 100% accuracy in 12-15 epochs while validation accuracy hovers around 94% during later epochs : indicating clear overfitting
3. Training loss keeps on decreasing while training for larger number of epochs while validation loss reaches its minimum in 15-20 epochs of training : again showing clear overfitting

Training NN with one or more hidden layers

Models looked like this

Image (32x32)
↓
Input Layer (1024 units)
↓
One or more Hidden Layer (5 to 128 units with relu activation)
↓
Output Layer (10 units with softmax activation)

Progress of loss and accuracy during training of NN with hidden layers :



Observation noted for NN with one or more hidden layers

1. Starts overfitting just after training for 2 epochs of training
2. Training accuracy reaches 100% accuracy in 10-12 epochs of training while validation accuracy hovers around 94% during later epochs : indicating **more overfitting than the baseline model**
3. Training loss almost vanishes after 15-20 epochs of training while validation loss reaches its minimum in 5-7 epochs of training and ddoes not decrease further : again showing large overfitting
4. **NONE of the NNs with hidden layers could outperform the baseline model with no hidden layer**

Using Image augmentation by adding random distortions in images

Added random **rotation and shear distortions in training images**.

1. Mimicking distortions present hand written digits.
2. Effectively increasing the size of training data.

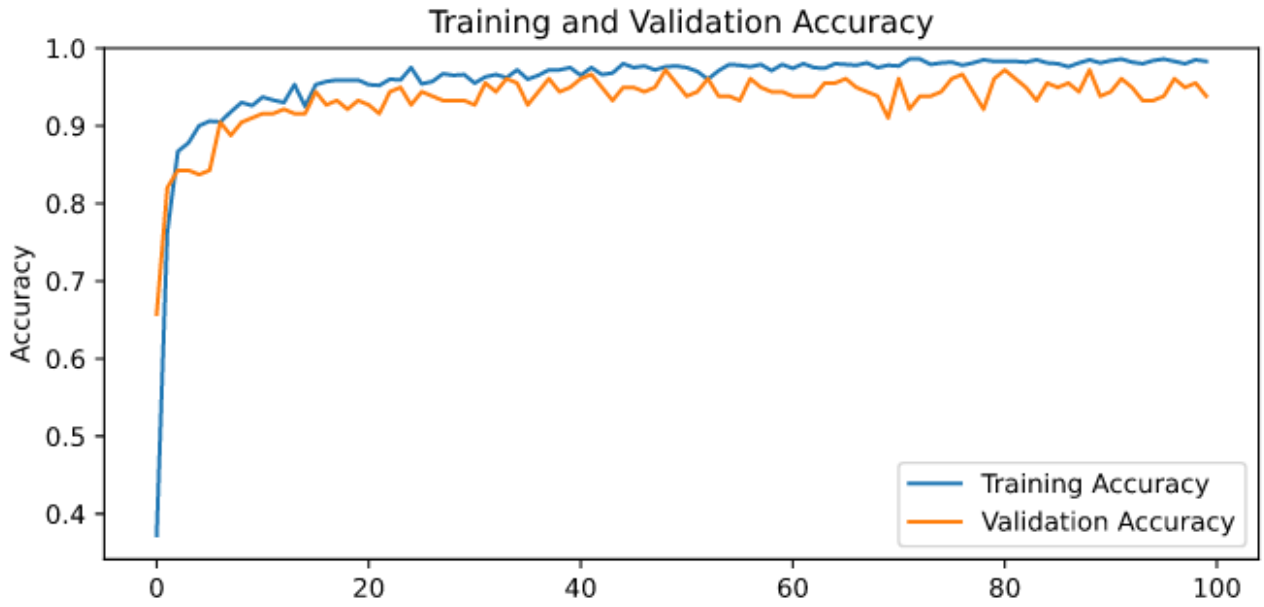
Range of random shear and rotation distortions applied = 0°-15°

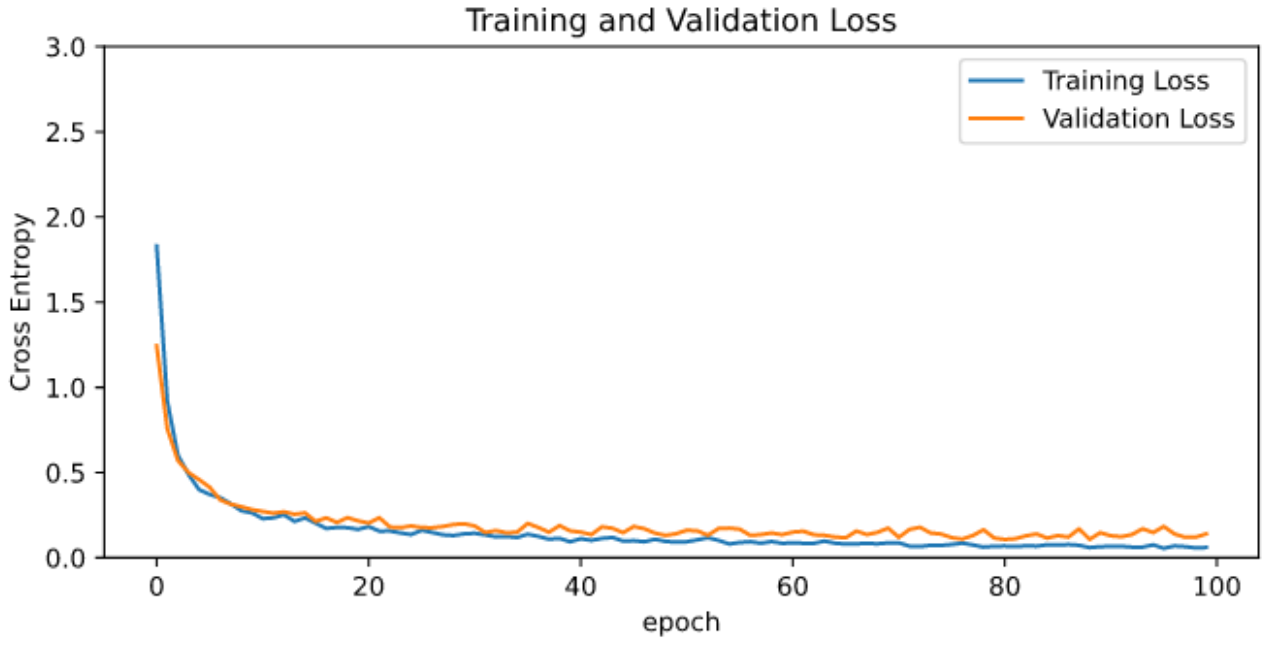
Training 1-layer NN with no hidden layer with augmented data

Model looked like this

Image (32x32)
↓
Adding random distortions to image (only for training set)
↓
Input Layer (1024 units)
↓
Output Layer (10 units with softmax activation)

Progress of loss and accuracy during training is shown below :





Observations noted for 1-layer NN

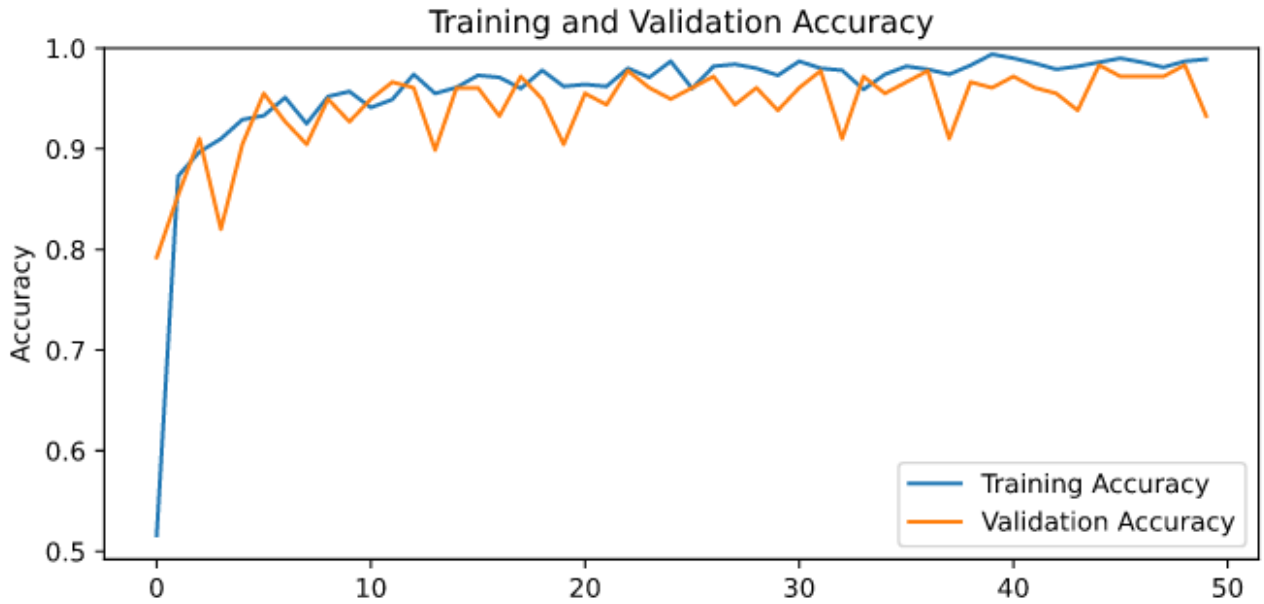
1. Significantly less overfitting than the one without image augmentation
2. Improved loss and accuracy (97.19%) for validation set than the one without image augmentation.
3. OVERALL : **adding random distortions improved the baseline 1-layer model**.

Training NN with one or more hidden layers with data augmentation

Models looked like this

Image (32x32)
↓
Adding random distortions to image(only for training set)
↓
Input Layer (1024 units)
↓
One or more Hidden Layer (5 to 2048 units with relu activation)
↓
Output Layer (10 units with softmax activation)

Progress of loss and accuracy during training of NN with hidden layers :



Observation noted for NN with one or more hidden layers with image distortions

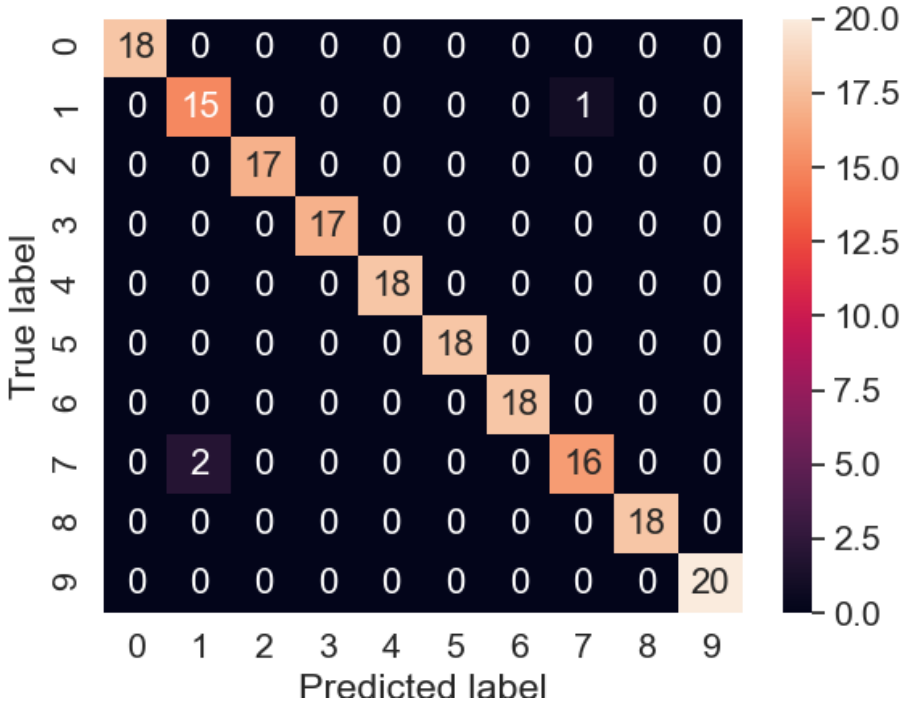
1. Very less (negligible) overfitting
2. Perform very well with $> 98\%$ accuracy on validation data.
3. Only 2-3 images out of 178 images in validation set are misclassified

Best model and its performance on validation data

With 2 hidden layers having 1024 units each with relu activation. Looked like this :

Image (32x32)
↓
Adding random distortions to image(only for training set)
↓
Input Layer (1024 units)
↓
Hidden Layer : 1024 units with relu activation
↓
Hidden Layer : 1024 units with relu activation
↓
Output Layer (10 units with softmax activation)

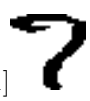
Result :Accuracy on validation data = 98.31%, Only 3 images misclassified



Confusion Matrix

Observation from confusion matrix

Model finds it hard to differentiate between 1 and 7. Maybe because they look similar

[Example image of a 1]  [Example image of a 7] 

1 and 7 look similar

Code used :

(also containing more details of experiments done) :

- For analysing the dataset
- For classification w/o image distortions
- For classification with image distortions
- To test and plot confusion matrix