



HOMework 4 REPORT

CSCI 677

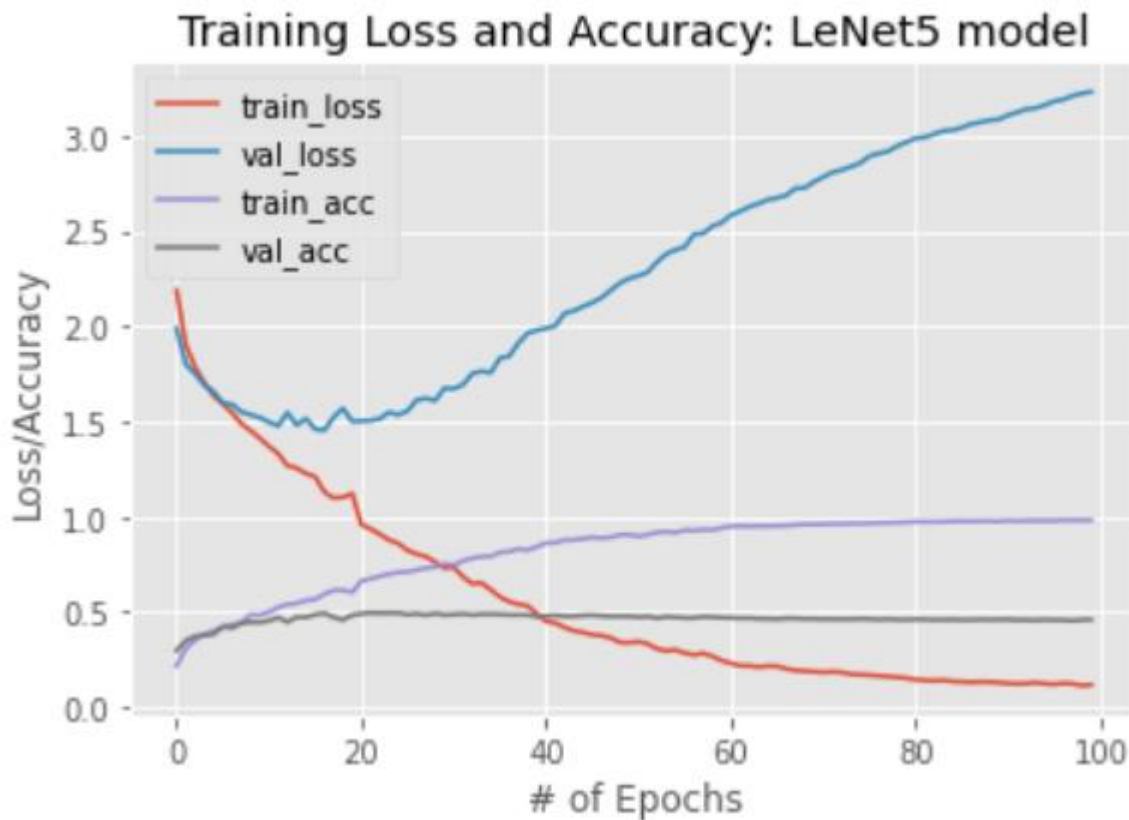
PyTorch, LeNet

Hardik Prajapati

USC ID: 2678294168

| Parameter | Main Experiment | Variation 1- Batch Normalization | Variation 2- L2 regularization |
|-----------------------|-----------------------|------------------------------------|--------------------------------|
| Epochs | 100 | 100 | 100 |
| Initial learning rate | 0.001 | 0.001 | 0.001 |
| Batch size | 128 | 128 | 128 |
| Optimizer | Adam(decay_rate=0) | Adam(decay_rate=0) | Adam(decay_rate=1e-5) |
| Layer1 | Conv—Relu--maxpooling | Conv—batchNorm2d--Relu--maxpooling | Conv—Relu--maxpooling |
| Layer2 | Conv—Relu--maxpooling | Conv—batchNorm2d--Relu--maxpooling | Conv—Relu--maxpooling |
| Layer3 | FC--Relu | FC—batchNorm1d--Relu | FC--Relu |
| Layer4 | FC--Relu | FC—batchNorm1d--Relu | FC--Relu |
| Layer5 | FC-logSoftMax | FC-logSoftMax | FC-logSoftMax |

1) For your main experiment setting, show the evolution of training losses and validation losses with multiple steps.



2) Show the confusion matrix and per-class classification accuracy for this setting.

```
//...Confusion Matrix...//
[[323 35 17 18 11 22 10 3 8 53]
 [ 35 264 12 78 10 8 13 9 12 59]
 [ 26 10 167 9 72 62 45 23 76 10]
 [ 24 96 16 273 17 9 8 6 8 43]
 [ 9 13 56 10 162 55 64 38 78 15]
 [ 12 7 57 4 56 212 48 48 53 3]
 [ 10 5 55 4 81 57 130 60 94 4]
 [ 4 14 30 3 33 50 85 240 40 1]
 [ 9 7 65 2 72 40 73 49 180 3]
 [ 56 43 5 24 18 12 4 1 4 333]]
```

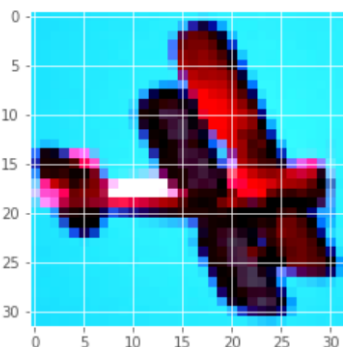
| Class | Per-class classification accuracy |
|----------|-----------------------------------|
| Airplane | 0.646 |
| truck | 0.528 |
| bird | 0.334 |
| car | 0.546 |
| cat | 0.324 |
| deer | 0.424 |
| dog | 0.26 |
| horse | 0.48 |
| monkey | 0.36 |
| ship | 0.666 |

Classification Report:

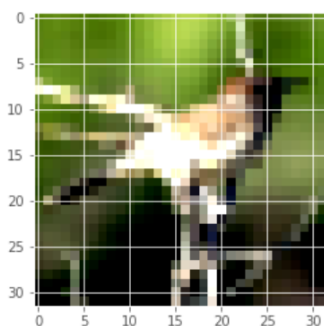
| | precision | recall | f1-score | support |
|--------------|-----------|--------|----------|---------|
| airplane | 0.64 | 0.65 | 0.64 | 500 |
| truck | 0.53 | 0.53 | 0.53 | 500 |
| bird | 0.35 | 0.33 | 0.34 | 500 |
| car | 0.64 | 0.55 | 0.59 | 500 |
| cat | 0.30 | 0.32 | 0.31 | 500 |
| deer | 0.40 | 0.42 | 0.41 | 500 |
| dog | 0.27 | 0.26 | 0.27 | 500 |
| horse | 0.50 | 0.48 | 0.49 | 500 |
| monkey | 0.33 | 0.36 | 0.34 | 500 |
| ship | 0.64 | 0.67 | 0.65 | 500 |
| accuracy | | | 0.46 | 5000 |
| macro avg | 0.46 | 0.46 | 0.46 | 5000 |
| weighted avg | 0.46 | 0.46 | 0.46 | 5000 |

3) Show some examples of failed cases, with some analysis if feasible.

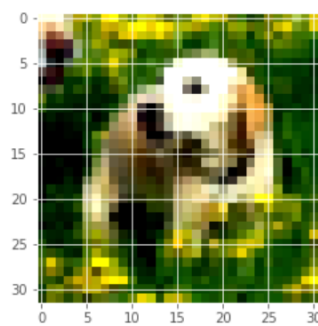
ground truth label: 1, predicted label: 4



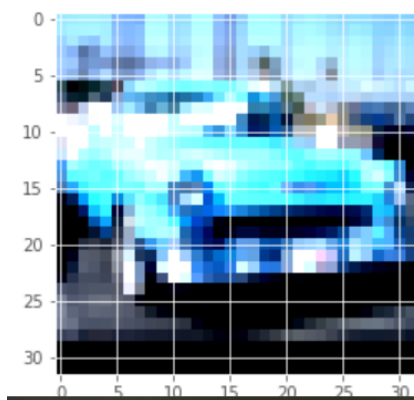
ground truth label: 2, predicted label: 8



ground truth label: 6, predicted label: 7



ground truth label: 3, predicted label: 9



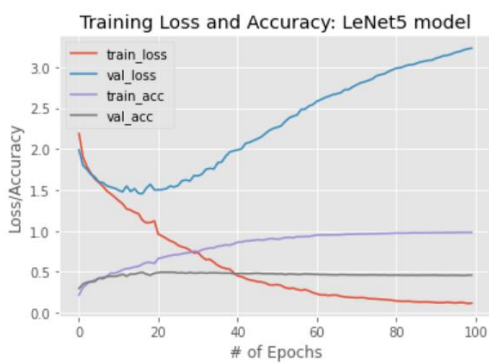
In general, macro accuracy for class prediction is low and hence we are getting wrong predictions in general.

Also We have re-sized from 96*96 to 32*32, hence loosing key features

Some of the background attributes are being learned and wrongly interpreted.

4) Compare your results for the variations with the main experiment setting.

Main Experiment

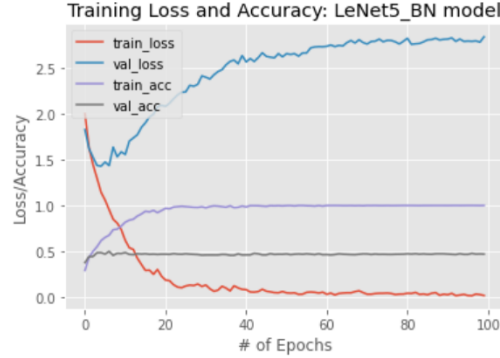


```

//...Confusion Matrix...//
[[323 35 17 18 11 22 10 3 8 53]
 [ 35 264 12 78 10 8 13 9 12 59]
 [ 26 10 167 9 72 62 45 23 76 10]
 [ 24 96 16 273 17 9 8 6 8 43]
 [ 9 13 56 10 162 55 64 38 78 15]
 [ 12 7 57 4 56 212 48 48 53 3]
 [ 10 5 55 4 81 57 130 60 94 4]
 [ 4 14 30 3 33 50 85 240 40 1]
 [ 9 7 65 2 72 40 73 49 180 3]
 [ 56 43 5 24 18 12 4 1 4 333]]
    
```

| | precision | recall | f1-score | support |
|--------------|-----------|--------|----------|---------|
| airplane | 0.64 | 0.65 | 0.64 | 500 |
| truck | 0.53 | 0.53 | 0.53 | 500 |
| bird | 0.35 | 0.33 | 0.34 | 500 |
| car | 0.64 | 0.55 | 0.59 | 500 |
| cat | 0.30 | 0.32 | 0.31 | 500 |
| deer | 0.40 | 0.42 | 0.41 | 500 |
| dog | 0.27 | 0.26 | 0.27 | 500 |
| horse | 0.50 | 0.48 | 0.49 | 500 |
| monkey | 0.33 | 0.36 | 0.34 | 500 |
| ship | 0.64 | 0.67 | 0.65 | 500 |
| accuracy | | | 0.46 | 5000 |
| macro avg | 0.46 | 0.46 | 0.46 | 5000 |
| weighted avg | 0.46 | 0.46 | 0.46 | 5000 |

Variation 1-Batch Normalization

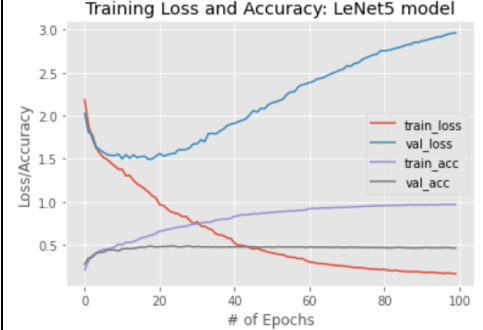


```

//...Confusion Matrix...//
[[353 25 15 17 6 9 10 10 5 50]
 [ 28 224 11 86 23 20 15 16 7 70]
 [ 24 5 154 7 60 63 66 31 73 17]
 [ 16 73 18 313 18 4 13 10 11 24]
 [ 9 11 42 15 141 82 72 44 72 12]
 [ 11 5 46 4 65 212 40 60 50 7]
 [ 7 10 49 3 74 55 147 82 68 5]
 [ 4 14 30 4 33 31 83 255 44 2]
 [ 6 6 27 3 70 49 112 56 168 3]
 [ 52 46 9 12 13 8 6 7 8 339]]
    
```

| | precision | recall | f1-score | support |
|--------------|-----------|--------|----------|---------|
| airplane | 0.69 | 0.71 | 0.70 | 500 |
| truck | 0.53 | 0.45 | 0.49 | 500 |
| bird | 0.38 | 0.31 | 0.34 | 500 |
| car | 0.67 | 0.63 | 0.65 | 500 |
| cat | 0.28 | 0.28 | 0.28 | 500 |
| deer | 0.40 | 0.42 | 0.41 | 500 |
| dog | 0.26 | 0.29 | 0.28 | 500 |
| horse | 0.45 | 0.51 | 0.48 | 500 |
| monkey | 0.33 | 0.34 | 0.33 | 500 |
| ship | 0.64 | 0.68 | 0.66 | 500 |
| accuracy | | | 0.46 | 5000 |
| macro avg | 0.46 | 0.46 | 0.46 | 5000 |
| weighted avg | 0.46 | 0.46 | 0.46 | 5000 |

Variation 2- L2 regularization



```

//...Confusion Matrix...//
[[331 33 20 23 5 18 10 7 3 50]
 [ 26 261 16 97 16 7 5 10 7 55]
 [ 28 5 185 21 59 57 45 23 68 9]
 [ 26 105 8 303 9 8 6 5 7 23]
 [ 4 20 48 8 139 59 85 36 83 18]
 [ 15 8 67 11 64 173 55 52 46 9]
 [ 5 6 57 7 86 44 142 73 75 5]
 [ 4 12 38 4 34 35 85 246 41 1]
 [ 2 4 67 11 66 39 76 51 181 3]
 [ 65 67 9 28 14 7 6 6 3 295]]
    
```

| | precision | recall | f1-score | support |
|--------------|-----------|--------|----------|---------|
| airplane | 0.65 | 0.66 | 0.66 | 500 |
| truck | 0.50 | 0.52 | 0.51 | 500 |
| bird | 0.36 | 0.37 | 0.36 | 500 |
| car | 0.59 | 0.61 | 0.60 | 500 |
| cat | 0.28 | 0.28 | 0.28 | 500 |
| deer | 0.39 | 0.35 | 0.37 | 500 |
| dog | 0.28 | 0.28 | 0.28 | 500 |
| horse | 0.48 | 0.49 | 0.49 | 500 |
| monkey | 0.35 | 0.36 | 0.36 | 500 |
| ship | 0.63 | 0.59 | 0.61 | 500 |
| accuracy | | | 0.45 | 5000 |
| macro avg | 0.45 | 0.45 | 0.45 | 5000 |
| weighted avg | 0.45 | 0.45 | 0.45 | 5000 |

Observations:

- 1) Training time for the network was slightly more for Variation 1
- 2) The model starts overfitting after 18 epochs in Main settings; 10 epochs in Variation-1; 19 epochs in Variation-2
- 3) All the 3 settings perform and learn best for 'Airplane', 'car' and 'ship' classes.
- 4) All the 3 settings perform the worst on 'dog' class.
- 5) It can be easily seen that Batch Normalization speeds up the learning of the network.
- 6) L2-Normalization helps to smoothly settle the validation error until the model starts overfitting.