Deep Learning Assignment II - Report

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https://github.com/LittleFish-Coder/deep-learning-assignment-2

1. Dataset:

Mini-ImageNet is a subset of the ImageNet dataset, which contains 50 classes.

- Training Set: 63325
- Validation Set: 450
- Testing Set: 450

Sample images from the dataset:

n02111277_1207.JPEG	n02112137_7.JPEG	n02112137_112.JPEG

Data Preprocessing

It's worth noting that each image does not have the same size, so we need to standardize the size of all images. Moreover, some images are in RGB format, while others are in grayscale format.

- Image Size: we resize all images to **256x256** pixels.
- Image Channel: we convert all images to **RGB format (3 channels).**

Evaluation Performance

During training, we will evaluate the model using the validation set. Performance metrics such as test accuracy and loss will be discussed in the next 2 sections.

2. Task 1: Designing a Convolution Module for Variable Input Channels

We will discuss the 2 models' performance for dynamic input channels image.

2.1. Hyperparameters

- Epoch: 25
- Learning Rate: 0.001
- Batch Size: 64
- Input Size: (3, 256, 256)
- Optimizer: Adam
- Criterion: CrossEntropyLoss

2.2. Simple CNN

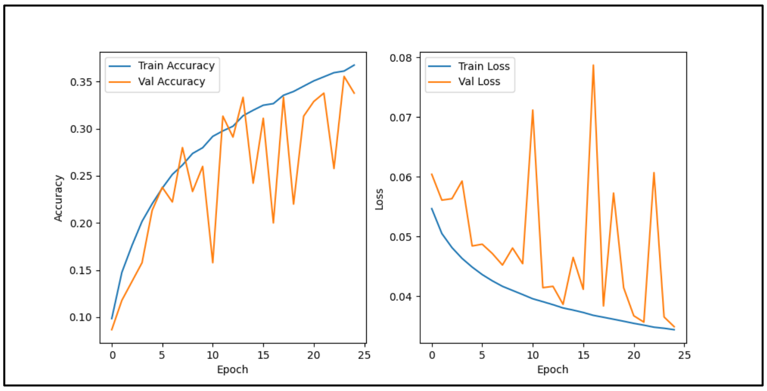
- Model Architecture:

```
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 32, 256, 256]             896
       BatchNorm2d-2         [-1, 32, 256, 256]              64
         MaxPool2d-3         [-1, 32, 128, 128]               0
            Conv2d-4         [-1, 64, 128, 128]          18,496
       BatchNorm2d-5         [-1, 64, 128, 128]             128
         MaxPool2d-6           [-1, 64, 64, 64]               0
            Conv2d-7          [-1, 128, 64, 64]          73,856
       BatchNorm2d-8          [-1, 128, 64, 64]             256
         MaxPool2d-9          [-1, 128, 32, 32]               0
AdaptiveAvgPool2d-10            [-1, 128, 1, 1]               0
           Linear-11                  [-1, 256]          33,024
          Dropout-12                  [-1, 256]               0
           Linear-13                   [-1, 50]          12,850
================================================================
Total params: 139,570
Trainable params: 139,570
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.75
Forward/backward pass size (MB): 63.01
Params size (MB): 0.53
Estimated Total Size (MB): 64.29
----------------------------------------------------------------
```

- **Validation Accuracy & Loss**

  We save the best model based on the validation loss

  - Best Validation Accuracy: 0.3379
  - Best Validation Loss: 0.0349



- **Test Accuracy & Loss**

	RGB	RG	GB	R	G	B
Accuracy	0.3556	0.3111	0.0378	0.0222	0.0222	0.02
Loss	0.0412	0.0479	0.1202	0.2145	0.1152	0.2187

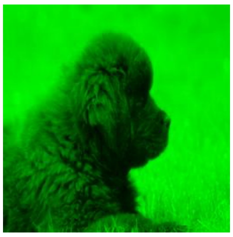
- **Dataset Design**

  We will test the model on 6 downstream tasks, each using different combinations of the RGB channels.

  Since the simple CNN can only process images with 3 channels, we have redesigned the test dataset to accommodate this limitation. When testing different channel combinations, we will first select the desired channels and then copy these channels to a new image. The channels that are not selected will be padded with zeros. This ensures that the image remains in a 3-channel format.

  For example, if the 'RG' combination is selected, we will copy the 'R' and 'G' channels from the raw image. The 'B' channel will be set to zero.

Below are samples for images with each selected channel combination:

RGB	RG	GB
R	G	B
		

2.3. Dynamic CNN

- **Model Architecture**

```
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1        [-1, 16, 254, 254]             160
              ReLU-2        [-1, 16, 254, 254]               0
            Conv2d-3         [-1, 1, 252, 252]             145
            Conv2d-4        [-1, 16, 254, 254]             160
              ReLU-5        [-1, 16, 254, 254]               0
            Conv2d-6         [-1, 1, 252, 252]             145
PoolChannelAttention-7        [-1, 1, 252, 252]               0
            Conv2d-8        [-1, 32, 252, 252]             320
       BatchNorm2d-9        [-1, 32, 252, 252]              64
        MaxPool2d-10        [-1, 32, 126, 126]               0
           Conv2d-11        [-1, 64, 126, 126]          18,496
      BatchNorm2d-12        [-1, 64, 126, 126]             128
        MaxPool2d-13          [-1, 64, 63, 63]               0
           Conv2d-14         [-1, 128, 63, 63]          73,856
      BatchNorm2d-15         [-1, 128, 63, 63]             256
        MaxPool2d-16         [-1, 128, 31, 31]               0
AdaptiveAvgPool2d-17           [-1, 128, 1, 1]               0
           Linear-18                  [-1, 256]          33,024
          Dropout-19                  [-1, 256]               0
           Linear-20                   [-1, 50]          12,850
              CNN-21                   [-1, 50]               0
================================================================
Total params: 139,604
Trainable params: 139,604
Non-trainable params: 0
```

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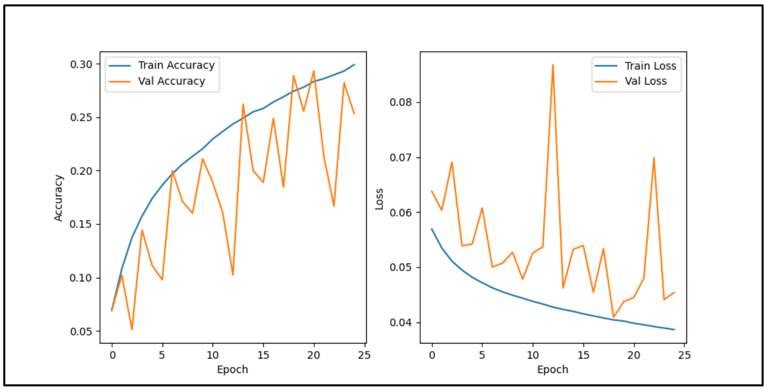
```
----------------------------------------------------------------
Input size (MB): 0.75
Forward/backward pass size (MB): 93.98
Params size (MB): 0.53
Estimated Total Size (MB): 95.26
----------------------------------------------------------------
```

- **Validation Accuracy & Loss**

  We save the best model based on the validation loss

  - Best Validation Accuracy: 0.2889
  - Best Validation Loss: 0.0410



- **Test Accuracy & Loss**

	RGB	RG	GB	R	G	B
Accuracy	0.3044	0.3111	0.2911	0.3089	0.3089	0.2467
Loss	0.0480	0.0479	0.0483	0.0489	0.0478	0.0526

- **Dataset Design**

  The Dynamic CNN can handle different input channels. Therefore, if 'RG' is selected for testing, we will create a new image containing only the 'RG' channel information from the raw image.

  In this way, we can create images with the following dimensions:

  - (1, height, width) for 'R', 'G', or 'B'
  - (2, height, width) for 'RG' or 'GB'
  - (3, height, width) for 'RGB'

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2.4. Comparison

By comparing the results from the testing phase of these two models, the dynamic CNN outperforms the simple one on the 6 downstream tasks.

3. Task 2: Designing a Two-Layer Network for Image Classification

3.1. Hyperparameters

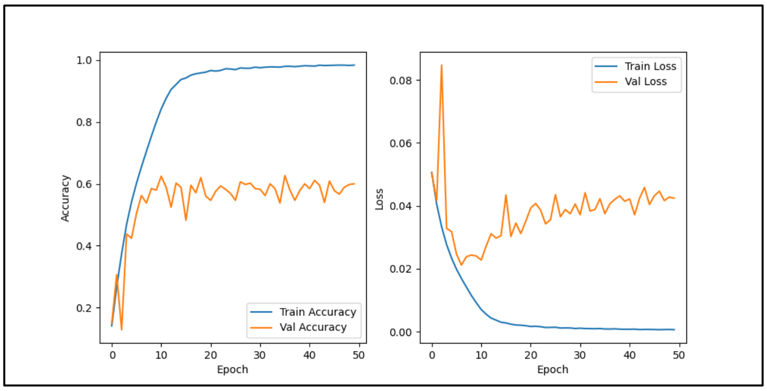
- Epoch: 50
- Learning Rate: 0.001
- Batch Size: 64
- Input Size: (3, 256, 256)
- Optimizer: Adam
- Criterion: CrossEntropyLoss

3.2. ResNet34

- **Model Architecture**

```
----------------------------------------------------------------
Total params: 21,310,322
Trainable params: 21,310,322
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.75
Forward/backward pass size (MB): 125.75
Params size (MB): 81.29
Estimated Total Size (MB): 207.80
----------------------------------------------------------------
```

- **Validation Accuracy & Loss:**
  - Best Validation Accuracy: 0.5622
  - Best Validation Loss: 0.0212



- **Test Accuracy & Loss**
  - Test Accuracy: 0.5978
  - Test Loss: 0.0221

3.3. Attention CNN

- **Model Architecture**

```
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 32, 256, 256]             896
       BatchNorm2d-2         [-1, 32, 256, 256]              64
              ReLU-3         [-1, 32, 256, 256]               0
            Conv2d-4         [-1, 32, 256, 256]             128
       BatchNorm2d-5         [-1, 32, 256, 256]              64
              ReLU-6         [-1, 32, 256, 256]               0
             Block-7         [-1, 32, 256, 256]               0
         MaxPool2d-8         [-1, 32, 128, 128]               0
            Conv2d-9         [-1, 64, 128, 128]          18,496
      BatchNorm2d-10         [-1, 64, 128, 128]             128
             ReLU-11         [-1, 64, 128, 128]               0
           Conv2d-12         [-1, 64, 128, 128]           2,112
      BatchNorm2d-13         [-1, 64, 128, 128]             128
             ReLU-14         [-1, 64, 128, 128]               0
            Block-15         [-1, 64, 128, 128]               0
        MaxPool2d-16           [-1, 64, 64, 64]               0
           Conv2d-17          [-1, 128, 64, 64]          73,856
      BatchNorm2d-18          [-1, 128, 64, 64]             256
             ReLU-19          [-1, 128, 64, 64]               0
           Conv2d-20          [-1, 128, 64, 64]           8,320
      BatchNorm2d-21          [-1, 128, 64, 64]             256
             ReLU-22          [-1, 128, 64, 64]               0
            Block-23          [-1, 128, 64, 64]               0
        MaxPool2d-24          [-1, 128, 32, 32]               0
           Conv2d-25          [-1, 256, 32, 32]         295,168
      BatchNorm2d-26          [-1, 256, 32, 32]             512
             ReLU-27          [-1, 256, 32, 32]               0
           Conv2d-28          [-1, 256, 32, 32]          33,024
      BatchNorm2d-29          [-1, 256, 32, 32]             512
             ReLU-30          [-1, 256, 32, 32]               0
            Block-31          [-1, 256, 32, 32]               0
        MaxPool2d-32          [-1, 256, 16, 16]               0
           Conv2d-33            [-1, 1, 16, 16]              98
          Sigmoid-34            [-1, 1, 16, 16]               0
 SpatialAttention-35            [-1, 1, 16, 16]               0
          Dropout-36          [-1, 256, 16, 16]               0
AdaptiveAvgPool2d-37            [-1, 256, 1, 1]               0
           Linear-38                   [-1, 50]          12,850
================================================================
```

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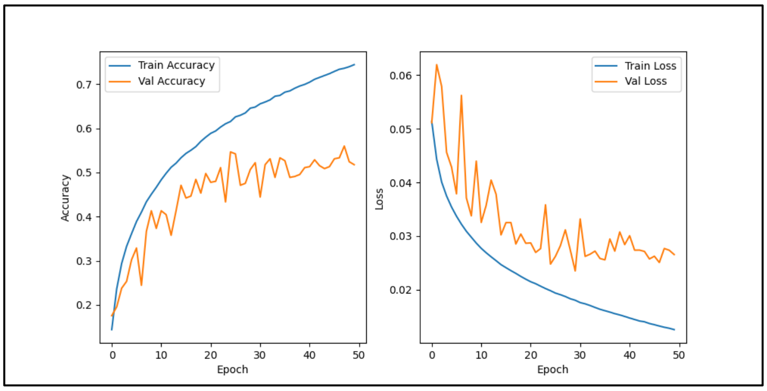
```
Total params: 446,868
Trainable params: 446,868
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.75
Forward/backward pass size (MB): 218.01
Params size (MB): 1.70
Estimated Total Size (MB): 220.46
```

- **Validation Accuracy & Loss**
  - Best Validation Accuracy: 0.5222
  - Best Validation Loss: 0.0235



- **Test Accuracy & Loss**
  - Test Accuracy: 0.5911
  - Test Loss: 0.0239

3.4. Comparison

By adding a Spatial Attention module to a simple CNN with some residual blocks, we are able to rival the ResNet34 model.

	ResNet34	Attention CNN
Test Accuracy	0.5978	0.5911
Test Loss	0.0221	0.0239
Total params	21,310,322	446,868

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