Machine Learning Homework 3 Report

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1. 請說明你實作的 ***CNN*** 模型，其模型架構、訓練參數量和準確率為何？

   optimizer: Adam, learning rate: 0.0001, batchsize: 512, epoch: 300, early stopping patient: 30

	Training accuracy	Training loss	Validation accuracy	Validation loss	Test accuracy
CNN	0.971923	0.000707	0.829697	0.001128	0.85475

Table 1: CNN results

```
----------------------------------------------------------------
       Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 64, 128, 128]           1,792
       BatchNorm2d-2         [-1, 64, 128, 128]             128
              ReLU-3         [-1, 64, 128, 128]               0
            Conv2d-4         [-1, 64, 128, 128]          36,928
       BatchNorm2d-5         [-1, 64, 128, 128]             128
              ReLU-6         [-1, 64, 128, 128]               0
         MaxPool2d-7           [-1, 64, 64, 64]               0
            Conv2d-8          [-1, 128, 64, 64]          73,856
       BatchNorm2d-9          [-1, 128, 64, 64]             256
             ReLU-10          [-1, 128, 64, 64]               0
           Conv2d-11          [-1, 128, 64, 64]         147,584
      BatchNorm2d-12          [-1, 128, 64, 64]             256
             ReLU-13          [-1, 128, 64, 64]               0
        MaxPool2d-14          [-1, 128, 32, 32]               0
           Conv2d-15          [-1, 256, 32, 32]         295,168
      BatchNorm2d-16          [-1, 256, 32, 32]             512
             ReLU-17          [-1, 256, 32, 32]               0
           Conv2d-18          [-1, 256, 32, 32]         590,080
      BatchNorm2d-19          [-1, 256, 32, 32]             512
             ReLU-20          [-1, 256, 32, 32]               0
           Conv2d-21          [-1, 256, 32, 32]         590,080
      BatchNorm2d-22          [-1, 256, 32, 32]             512
             ReLU-23          [-1, 256, 32, 32]               0
        MaxPool2d-24          [-1, 256, 16, 16]               0
           Conv2d-25          [-1, 512, 16, 16]       1,180,160
      BatchNorm2d-26          [-1, 512, 16, 16]           1,024
             ReLU-27          [-1, 512, 16, 16]               0
           Conv2d-28          [-1, 512, 16, 16]       2,359,808
      BatchNorm2d-29          [-1, 512, 16, 16]           1,024
             ReLU-30          [-1, 512, 16, 16]               0
           Conv2d-31          [-1, 512, 16, 16]       2,359,808
      BatchNorm2d-32          [-1, 512, 16, 16]           1,024
             ReLU-33          [-1, 512, 16, 16]               0
        MaxPool2d-34            [-1, 512, 8, 8]               0
           Conv2d-35            [-1, 512, 8, 8]       2,359,808
      BatchNorm2d-36            [-1, 512, 8, 8]           1,024
             ReLU-37            [-1, 512, 8, 8]               0
           Conv2d-38            [-1, 512, 8, 8]       2,359,808
      BatchNorm2d-39            [-1, 512, 8, 8]           1,024
             ReLU-40            [-1, 512, 8, 8]               0
           Conv2d-41            [-1, 512, 8, 8]       2,359,808
      BatchNorm2d-42            [-1, 512, 8, 8]           1,024
             ReLU-43            [-1, 512, 8, 8]               0
        MaxPool2d-44            [-1, 512, 4, 4]               0
           Linear-45                 [-1, 4096]      33,558,528
          Dropout-46                 [-1, 4096]               0
             ReLU-47                 [-1, 4096]               0
           Linear-48                 [-1, 4096]      16,781,312
          Dropout-49                 [-1, 4096]               0
             ReLU-50                 [-1, 4096]               0
           Linear-51                 [-1, 1000]       4,097,000
          Dropout-52                 [-1, 1000]               0
             ReLU-53                 [-1, 1000]               0
           Linear-54                   [-1, 11]          11,011
================================================================
Total params: 69,170,987
Trainable params: 69,170,987
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.19
Forward/backward pass size (MB): 105.27
```

Figure 1: CNN model architecture

2. 請實作與第一題接近的參數量，但 ***CNN*** 深度（***CNN*** 層數）減半的模型，並說明其模型架構、訓練參數量和準確率為何？

optimizer: Adam, learning rate: 0.0001, batchsize: 512, epoch: 300, early stopping patient: 30

	Training accuracy	Training loss	Validation accuracy	Validation loss	Test accuracy
CNN (half layers)	0.758362	0.001420	0.662767	0.002215	–

Table 2: CNN (half layers) results

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 16, 128, 128]             448
       BatchNorm2d-2         [-1, 16, 128, 128]              32
              ReLU-3         [-1, 16, 128, 128]               0
            Conv2d-4         [-1, 16, 128, 128]           2,320
       BatchNorm2d-5         [-1, 16, 128, 128]              32
              ReLU-6         [-1, 16, 128, 128]               0
         MaxPool2d-7           [-1, 16, 64, 64]               0
            Conv2d-8           [-1, 32, 64, 64]           4,640
       BatchNorm2d-9           [-1, 32, 64, 64]              64
             ReLU-10           [-1, 32, 64, 64]               0
           Conv2d-11           [-1, 32, 64, 64]           9,248
      BatchNorm2d-12           [-1, 32, 64, 64]              64
             ReLU-13           [-1, 32, 64, 64]               0
        MaxPool2d-14           [-1, 32, 32, 32]               0
           Conv2d-15           [-1, 64, 32, 32]          18,496
      BatchNorm2d-16           [-1, 64, 32, 32]             128
             ReLU-17           [-1, 64, 32, 32]               0
           Conv2d-18           [-1, 64, 32, 32]          36,928
      BatchNorm2d-19           [-1, 64, 32, 32]             128
             ReLU-20           [-1, 64, 32, 32]               0
        MaxPool2d-21           [-1, 64, 16, 16]               0
           Linear-22                 [-1, 4096]      67,112,960
          Dropout-23                 [-1, 4096]               0
             ReLU-24                 [-1, 4096]               0
           Linear-25                 [-1, 4096]      16,781,312
          Dropout-26                 [-1, 4096]               0
             ReLU-27                 [-1, 4096]               0
           Linear-28                 [-1, 1000]       4,097,000
          Dropout-29                 [-1, 1000]               0
             ReLU-30                 [-1, 1000]               0
           Linear-31                   [-1, 11]          11,011
================================================================
Total params: 88,074,811
Trainable params: 88,074,811
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.19
Forward/backward pass size (MB): 22.09
Params size (MB): 335.98
Estimated Total Size (MB): 358.25
----------------------------------------------------------------
```

Figure 2: CNN model architecture (half layers)

3. 請實作與第一題接近的參數量，簡單的 ***DNN*** 模型，同時也說明其模型架構、訓練參數和準確率為何？

optimizer: Adam, learning rate: 0.0001, batchsize: 256, epoch: 300, early stopping patient: 30

	Training accuracy	Training loss	Validation accuracy	Validation loss	Test accuracy
DNN	0.417784	0.006590	0.390837	0.007002	–

Table 3: DNN results

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Linear-1          [-1, 3, 128, 256]          33,024
           Dropout-2          [-1, 3, 128, 256]               0
              ReLU-3          [-1, 3, 128, 256]               0
            Linear-4          [-1, 3, 128, 512]         131,584
           Dropout-5          [-1, 3, 128, 512]               0
              ReLU-6          [-1, 3, 128, 512]               0
            Linear-7         [-1, 3, 128, 1024]         525,312
           Dropout-8         [-1, 3, 128, 1024]               0
              ReLU-9         [-1, 3, 128, 1024]               0
           Linear-10         [-1, 3, 128, 2048]       2,099,200
          Dropout-11         [-1, 3, 128, 2048]               0
             ReLU-12         [-1, 3, 128, 2048]               0
           Linear-13         [-1, 3, 128, 4096]       8,392,704
          Dropout-14         [-1, 3, 128, 4096]               0
             ReLU-15         [-1, 3, 128, 4096]               0
           Linear-16         [-1, 3, 128, 6120]      25,073,640
          Dropout-17         [-1, 3, 128, 6120]               0
             ReLU-18         [-1, 3, 128, 6120]               0
           Linear-19         [-1, 3, 128, 3072]      18,803,712
          Dropout-20         [-1, 3, 128, 3072]               0
             ReLU-21         [-1, 3, 128, 3072]               0
           Linear-22         [-1, 3, 128, 2048]       6,293,504
          Dropout-23         [-1, 3, 128, 2048]               0
             ReLU-24         [-1, 3, 128, 2048]               0
           Linear-25         [-1, 3, 128, 1024]       2,098,176
          Dropout-26         [-1, 3, 128, 1024]               0
             ReLU-27         [-1, 3, 128, 1024]               0
           Linear-28          [-1, 3, 128, 512]         524,800
          Dropout-29          [-1, 3, 128, 512]               0
             ReLU-30          [-1, 3, 128, 512]               0
           Linear-31          [-1, 3, 128, 256]         131,328
          Dropout-32          [-1, 3, 128, 256]               0
             ReLU-33          [-1, 3, 128, 256]               0
           Linear-34          [-1, 3, 128, 128]          32,896
          Dropout-35          [-1, 3, 128, 128]               0
             ReLU-36          [-1, 3, 128, 128]               0
           Linear-37           [-1, 3, 128, 64]           8,256
          Dropout-38           [-1, 3, 128, 64]               0
             ReLU-39           [-1, 3, 128, 64]               0
           Linear-40           [-1, 3, 128, 32]           2,080
          Dropout-41           [-1, 3, 128, 32]               0
             ReLU-42           [-1, 3, 128, 32]               0
           Linear-43           [-1, 3, 128, 16]             528
          Dropout-44           [-1, 3, 128, 16]               0
             ReLU-45           [-1, 3, 128, 16]               0
           Linear-46            [-1, 3, 128, 8]             136
          Dropout-47            [-1, 3, 128, 8]               0
             ReLU-48            [-1, 3, 128, 8]               0
          Flatten-49                 [-1, 3072]               0
           Linear-50                  [-1, 384]       1,180,032
          Dropout-51                  [-1, 384]               0
             ReLU-52                  [-1, 384]               0
           Linear-53                   [-1, 48]          18,480
          Dropout-54                   [-1, 48]               0
             ReLU-55                   [-1, 48]               0
           Linear-56                   [-1, 11]             539
================================================================
Total params: 65,349,931
Trainable params: 65,349,931
Non-trainable params: 0
----------------------------------------------------------------
```

Figure 3: DNN model architecture

4. 請說明由 ***1*** $\sim$ ***3*** 題的實驗中你觀察到了什麼？

We use data normalization, data augmentation and early stopping in the above $1 \sim 3$. All of them are stopped before 300 epochs.

5. 請嘗試 ***data normalization*** 及 ***data augmentation***，說明實作方法並且說明實行前後對準確率有什麼樣的影響？

(a) Data normalizatin:

Calculate the batch mean and standard deviation of training set, then apply this mean and standard deviation to validation set and testing set.

Usage:

torchvision.transforms.Normalize(mean, std)

(b) Data augmentation:

Input size: $3 \times 128 \times 128$

(i) We resized to the size $3 \times 150 \times 150$, then randomly crop center by the size $3 \times 128 \times 128$.

(ii) Randomly horizontal flip.

(iii) Randomly rotation by degree 15.

(iv) Double the original dataset by augmentation.

Usage:

(i) *torchvision.transforms.Resize(150),*

torchvision.transforms.RandomResizedCrop(128)

(ii) *torchvision.transforms.RandomHorizontalFlip()*

(iii) *transforms.RandomRotation(15)*

(c) Comparison table:

	Training accuracy	Training loss	Validation accuracy	Validation loss	Test accuracy
original cnn	0.995231	0.000439	0.761623	–	0.78720
augmentation	0.928874	0.000812	0.776205	–	0.79438
augmentation + normalization	0.971923	0.000707	0.829697	0.001128	0.85475

Table 4: Results comparison table

6. 觀察答錯的圖片中，哪些 ***class*** 彼此間容易用混？

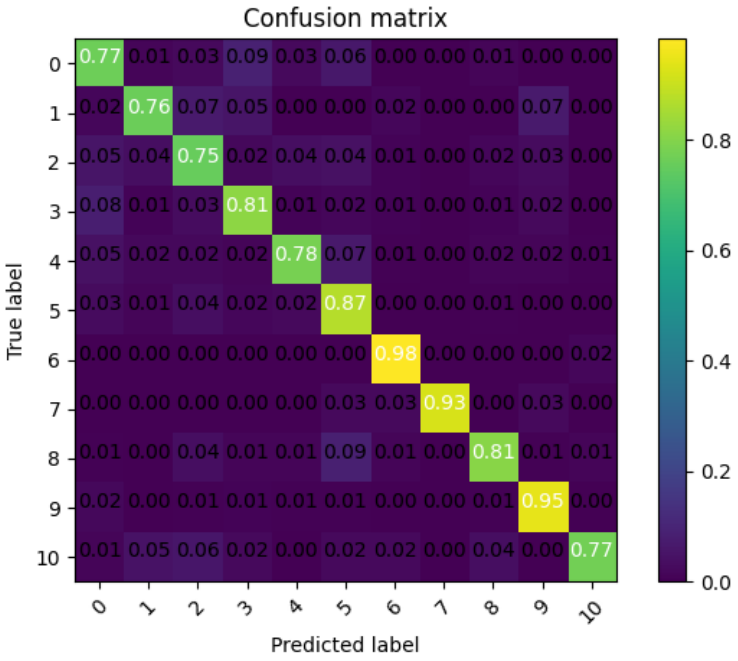
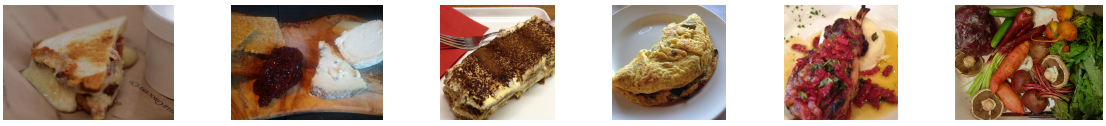


Figure 4: Confusion matrix



(a) Class 0 (b) Class 1 (c) Class 2 (d) Class 3 (e) Class 5 (f) Class 10

Figure 5: Confused classes