# National Tsing Hua University
# Fall 2023 11210IPT 553000
# Deep Learning in Biomedical Optical Imaging
# Report

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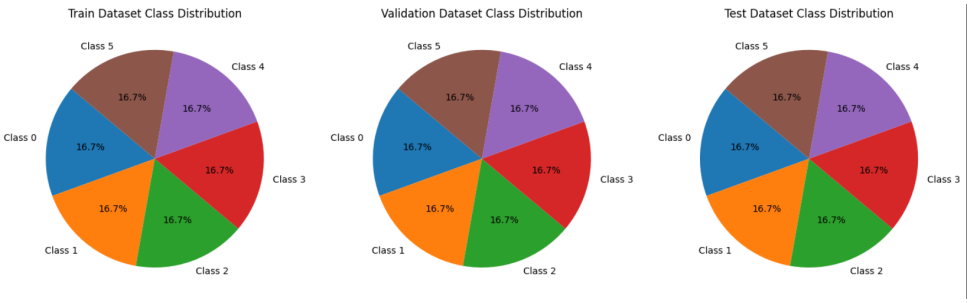
## 1. Cancer Histology Image Classification (100 pts)

### *1.1* 資料平衡

(圖一)為test,validation和train在6類別資料分布上的結果。由此可以看到資料十分平衡。




(圖一) 6 classes distribution in train, test, and validation

### *1.2* 直接訓練

首先我只對圖片做Normalization, 將數值從(0,255)變成(0, 1), 由兩層CNN與一層fully connected layer去做分類, overfitting的問題解決不了, 在train data的accuracy接近99%而validation卻一直非常低且loss極高。

因此後來我還分別嘗試了(1) L2 Regularization (2) Data Augmentation (flip, rotation, colorjitter等等) (3) Batch normalization 與這些參數的組合, 最後還降低模型複雜度, 成功解決overfitting的問題, 但train和validation data卻停在uderfitting, 準確度約為60%上不去。

因此我判斷是模型複雜度的問題, 選擇改用transfer learning。

### *1.2 Transfer Learning - ResNet50*

這部分首先對train, validation和 test data做 data transform, 使圖片條件接近原模型訓練資料, 在Train和Validation的表現上一開始就有極低的Loss和不錯的accuracy, 不過如圖二, 訓練的過程並沒有下降反而是維持在差不多的位置。

```
Epoch 4/10 - Train Loss: 0.4445, Train Acc: 83.84%, Val Loss: 0.3070, Val Acc: 89.17%
Epoch 5/10 - Train Loss: 0.4220, Train Acc: 84.12%, Val Loss: 0.2810, Val Acc: 90.00%
Epoch 6/10 - Train Loss: 0.4428, Train Acc: 83.61%, Val Loss: 0.3352, Val Acc: 88.50%
Epoch 7/10 - Train Loss: 0.4663, Train Acc: 83.25%, Val Loss: 0.3136, Val Acc: 88.17%
Epoch 8/10 - Train Loss: 0.4700, Train Acc: 82.67%, Val Loss: 0.3256, Val Acc: 88.00%
Epoch 9/10 - Train Loss: 0.4311, Train Acc: 84.12%, Val Loss: 0.2929, Val Acc: 89.67%
Epoch 10/10 - Train Loss: 0.4472, Train Acc: 84.20%, Val Loss: 0.3036, Val Acc: 88.67%
```

(圖二) ResNet50 training process

透過test data可以看到歲然模型在train和validation上表現良好，但是卻在test data上出現了極差的預測結果(如圖三)。接著我試著在模型中加入Regularization等等卻也都有相同的結果，同時檢查train, validation和test並沒有不平衡的問題，因此這邊我認為是模型複雜度太高導致overfitting，應使用複雜度較低的模型。

```
Test Loss: 0.1700, Test Accuracy: 18.17%
```

(圖三) ResNet50 test data accuracy and loss

於是我轉往使用ResNet18，相較於ResNet50(50 layer, 25.6m parameter)，ResNet18具有較淺的深度與廣度(18 layer, 11.7m parameter)，希望能透過降低複雜度來解決先前遇到的問題，然而卻發生相同的狀況，雖然在train和validation隨著訊驗的過程有出現loss下降、accuracy增加的情況，不過即使train和validation的accuracy大約在70%，test data的準確度仍只有23.33%(圖四)。


(圖四) ResNet18  test data accuracy and loss

於是重複上述步驟，首先我加入了Data Augmentation(圖五，最後使用Horizontal, Vertical flip, ColorJitter)，此時就已經出現比較正常的訓練曲線，不過仍有overfitting的問題，因此我更進一步加入Dropout(0.5), L2 Regularization 並調weight decay。

```python
def resnet_transform(is_train=True):
    if is_train:
        return transforms.Compose([
            transforms.ToPILImage(),
            transforms.RandomResizedCrop(224),
            transforms.RandomHorizontalFlip(),
            transforms.ColorJitter(brightness=0.1, contrast=0.1, saturation=0.1, hue=0.1),
            transforms.RandomRotation(15),
            transforms.ToTensor(),
            transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225])
        ])
    else:
        return transforms.Compose([
            transforms.ToPILImage(),
            transforms.Resize(256),
            transforms.CenterCrop(224),
            transforms.ToTensor(),
            transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225])
        ])
```

(圖五) ResNet18 transform

最後終於在test, train和 validation上都得到了接近的準確度(都約80%), (圖七)可以看見test data準確度為84.17%, 這邊我看到loss訓練曲線仍有在持續下降因此我將epochs調整成40讓他訓練更多次, 看看是不是會找到更好的解, 不過結果並不如預期, 仍得到類似的結果。

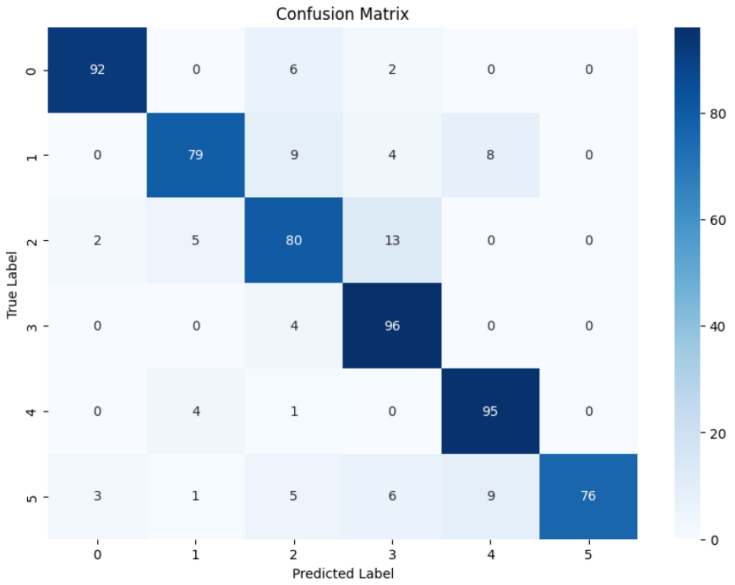
```
Epoch 1/20 - Train Loss: 1.0815, Train Acc: 61.49%, Val Loss: 0.6551, Val Acc: 74.83%
Epoch 2/20 - Train Loss: 0.8243, Train Acc: 70.47%, Val Loss: 0.6711, Val Acc: 78.83%
Epoch 3/20 - Train Loss: 0.7540, Train Acc: 72.39%, Val Loss: 0.4481, Val Acc: 82.33%
Epoch 4/20 - Train Loss: 0.6856, Train Acc: 76.27%, Val Loss: 0.8105, Val Acc: 73.50%
Epoch 5/20 - Train Loss: 0.6650, Train Acc: 76.00%, Val Loss: 0.6904, Val Acc: 77.17%
Epoch 6/20 - Train Loss: 0.5977, Train Acc: 77.76%, Val Loss: 0.4586, Val Acc: 82.33%
Epoch 7/20 - Train Loss: 0.5993, Train Acc: 78.63%, Val Loss: 0.5962, Val Acc: 78.33%
Epoch 8/20 - Train Loss: 0.5941, Train Acc: 78.12%, Val Loss: 0.3929, Val Acc: 85.17%
Epoch 9/20 - Train Loss: 0.5738, Train Acc: 79.57%, Val Loss: 0.4986, Val Acc: 82.67%
Epoch 10/20 - Train Loss: 0.5572, Train Acc: 79.76%, Val Loss: 0.3645, Val Acc: 86.83%
Epoch 11/20 - Train Loss: 0.5546, Train Acc: 79.69%, Val Loss: 0.4653, Val Acc: 83.00%
Epoch 12/20 - Train Loss: 0.5227, Train Acc: 80.78%, Val Loss: 0.3604, Val Acc: 86.17%
Epoch 13/20 - Train Loss: 0.5251, Train Acc: 81.53%, Val Loss: 0.4279, Val Acc: 84.33%
Epoch 14/20 - Train Loss: 0.5559, Train Acc: 80.55%, Val Loss: 0.5724, Val Acc: 79.50%
Epoch 15/20 - Train Loss: 0.4630, Train Acc: 82.75%, Val Loss: 1.4205, Val Acc: 67.67%
Epoch 16/20 - Train Loss: 0.5674, Train Acc: 80.00%, Val Loss: 0.3740, Val Acc: 86.00%
Epoch 17/20 - Train Loss: 0.4890, Train Acc: 81.69%, Val Loss: 0.4450, Val Acc: 83.00%
Epoch 18/20 - Train Loss: 0.5147, Train Acc: 81.65%, Val Loss: 0.3128, Val Acc: 88.67%
Epoch 19/20 - Train Loss: 0.4835, Train Acc: 82.24%, Val Loss: 0.3055, Val Acc: 90.00%
Epoch 20/20 - Train Loss: 0.5045, Train Acc: 82.27%, Val Loss: 0.4337, Val Acc: 84.50%
```

(圖六) ResNet18 + Regularization

```
Test Loss: 0.0124, Test Accuracy: 86.33%
```

(圖七) ResNet18 + Regularization, test data accuracy and loss

這部份則是在test data 上的confusion matrix，6 classes分別為Tumor, Stroma, Complex, Lympho, Debris, Mucosa，可以看到明顯Complex被誤判為Lympho的次數最多。



(圖八) Confusion Matrix in Test Data