MSBD 6000B Deep Learning

Project 2

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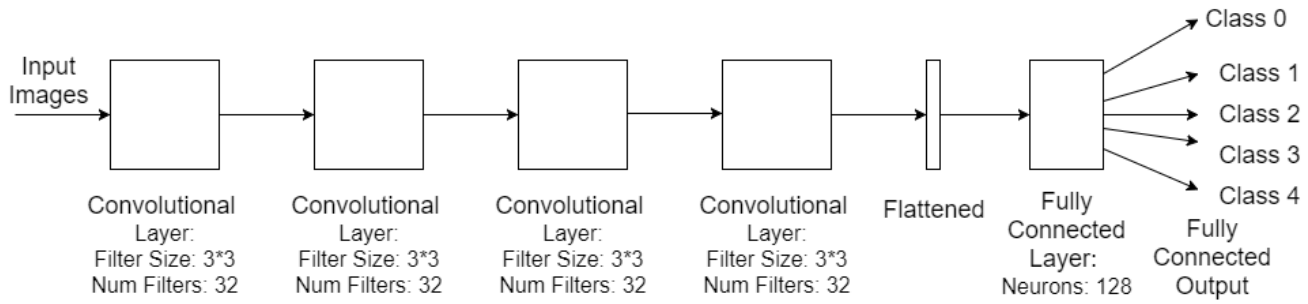
1. Data Load

I read the images' paths and labels from train.txt and val.txt. For paths, I read the target images and store them into a list of tensors. For labels, I predefine an all zeros list for each image with the length of classes and set the #label content as 1. Each label list for image contains the probabilities that this image should be classified into this class. For example, [0, 0, 1, 0, 0] means this image has 100% probability to be classified into class No.2.

2. CNN model

I choose CNN with tensorflow to build the model for this project.

2.1



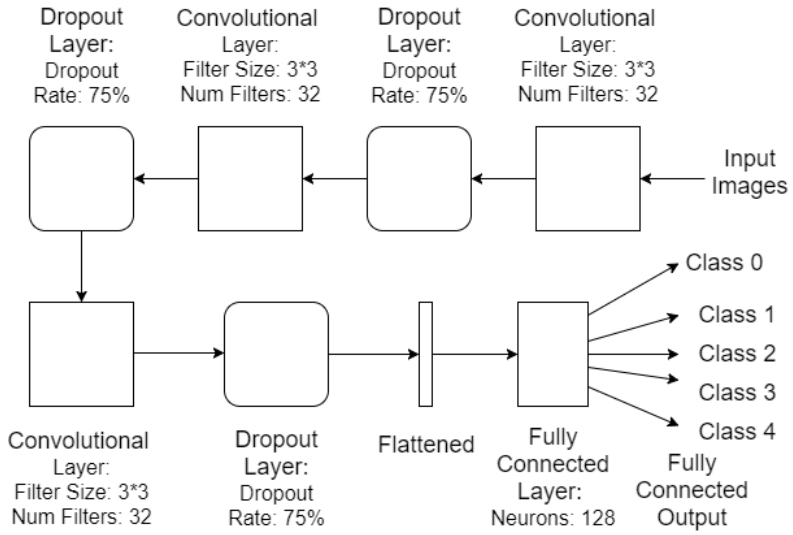
In this CNN model, there exists overfitting problem. In the later epochs, the training accuracies are around 100%, while the validation accuracy is around 60%.

```
Training Epoch 1---Training Accuracy:  29.0%, Validation Accuracy:  34.4%, Validation Loss: 0.317
Training Epoch 2---Training Accuracy:  43.9%, Validation Accuracy:  44.2%, Validation Loss: 0.270
Training Epoch 3---Training Accuracy:  52.2%, Validation Accuracy:  51.2%, Validation Loss: 0.254
Training Epoch 4---Training Accuracy:  56.9%, Validation Accuracy:  54.9%, Validation Loss: 0.242
Training Epoch 5---Training Accuracy:  61.2%, Validation Accuracy:  55.3%, Validation Loss: 0.245
Training Epoch 6---Training Accuracy:  65.2%, Validation Accuracy:  59.7%, Validation Loss: 0.238
Training Epoch 7---Training Accuracy:  68.4%, Validation Accuracy:  61.2%, Validation Loss: 0.235
Training Epoch 8---Training Accuracy:  72.1%, Validation Accuracy:  60.6%, Validation Loss: 0.244
Training Epoch 9---Training Accuracy:  75.2%, Validation Accuracy:  62.8%, Validation Loss: 0.251
Training Epoch 10---Training Accuracy:  77.6%, Validation Accuracy:  61.6%, Validation Loss: 0.282
Training Epoch 11---Training Accuracy:  80.3%, Validation Accuracy:  59.7%, Validation Loss: 0.307
Training Epoch 12---Training Accuracy:  82.2%, Validation Accuracy:  60.6%, Validation Loss: 0.263
Training Epoch 13---Training Accuracy:  84.3%, Validation Accuracy:  61.1%, Validation Loss: 0.291
Training Epoch 14---Training Accuracy:  85.1%, Validation Accuracy:  60.1%, Validation Loss: 0.288
Training Epoch 15---Training Accuracy:  89.4%, Validation Accuracy:  58.8%, Validation Loss: 0.371
Training Epoch 16---Training Accuracy:  90.8%, Validation Accuracy:  58.9%, Validation Loss: 0.458
Training Epoch 17---Training Accuracy:  90.6%, Validation Accuracy:  59.5%, Validation Loss: 0.403
Training Epoch 18---Training Accuracy:  91.2%, Validation Accuracy:  60.5%, Validation Loss: 0.444
Training Epoch 19---Training Accuracy:  95.0%, Validation Accuracy:  61.2%, Validation Loss: 0.424
Training Epoch 20---Training Accuracy:  96.0%, Validation Accuracy:  61.1%, Validation Loss: 0.469
Training Epoch 21---Training Accuracy:  97.5%, Validation Accuracy:  61.3%, Validation Loss: 0.532
Training Epoch 22---Training Accuracy:  98.0%, Validation Accuracy:  58.9%, Validation Loss: 0.604
Training Epoch 23---Training Accuracy:  97.1%, Validation Accuracy:  59.2%, Validation Loss: 0.543
Training Epoch 24---Training Accuracy:  97.9%, Validation Accuracy:  58.0%, Validation Loss: 0.615
Training Epoch 25---Training Accuracy:  98.3%, Validation Accuracy:  58.2%, Validation Loss: 0.582
Training Epoch 26---Training Accuracy:  99.0%, Validation Accuracy:  56.8%, Validation Loss: 0.662
```

```
Training Epoch 26---Training Accuracy:  99.0%, Validation Accuracy:  56.8%, Validation Loss: 0.662
Training Epoch 27---Training Accuracy:  99.2%, Validation Accuracy:  56.9%, Validation Loss: 0.702
Training Epoch 28---Training Accuracy:  99.7%, Validation Accuracy:  57.9%, Validation Loss: 0.781
Training Epoch 29---Training Accuracy:  99.7%, Validation Accuracy:  59.0%, Validation Loss: 0.817
Training Epoch 30---Training Accuracy:  99.9%, Validation Accuracy:  60.1%, Validation Loss: 0.832
Training Epoch 31---Training Accuracy:  99.9%, Validation Accuracy:  59.7%, Validation Loss: 0.881
Training Epoch 32---Training Accuracy: 100.0%, Validation Accuracy:  59.2%, Validation Loss: 0.954
Training Epoch 33---Training Accuracy: 100.0%, Validation Accuracy:  58.1%, Validation Loss: 0.971
Training Epoch 34---Training Accuracy: 100.0%, Validation Accuracy:  60.1%, Validation Loss: 0.981
Training Epoch 35---Training Accuracy: 100.0%, Validation Accuracy:  60.3%, Validation Loss: 1.014
Training Epoch 36---Training Accuracy: 100.0%, Validation Accuracy:  59.7%, Validation Loss: 1.009
Training Epoch 37---Training Accuracy: 100.0%, Validation Accuracy:  60.9%, Validation Loss: 0.990
Training Epoch 38---Training Accuracy: 100.0%, Validation Accuracy:  59.3%, Validation Loss: 0.994
Training Epoch 39---Training Accuracy: 100.0%, Validation Accuracy:  57.4%, Validation Loss: 1.293
Training Epoch 40---Training Accuracy:  99.4%, Validation Accuracy:  59.6%, Validation Loss: 0.821
Training Epoch 41---Training Accuracy:  99.8%, Validation Accuracy:  59.7%, Validation Loss: 0.878
Training Epoch 42---Training Accuracy:  99.7%, Validation Accuracy:  59.4%, Validation Loss: 0.799
Training Epoch 43---Training Accuracy:  99.6%, Validation Accuracy:  59.6%, Validation Loss: 0.801
Training Epoch 44---Training Accuracy:  99.9%, Validation Accuracy:  61.2%, Validation Loss: 0.776
Training Epoch 45---Training Accuracy:  99.8%, Validation Accuracy:  61.1%, Validation Loss: 0.813
Training Epoch 46---Training Accuracy:  99.9%, Validation Accuracy:  60.5%, Validation Loss: 0.930
Training Epoch 47---Training Accuracy:  99.8%, Validation Accuracy:  57.8%, Validation Loss: 0.853
Training Epoch 48---Training Accuracy: 100.0%, Validation Accuracy:  57.4%, Validation Loss: 0.897
Training Epoch 49---Training Accuracy: 100.0%, Validation Accuracy:  60.3%, Validation Loss: 0.913
Training Epoch 50---Training Accuracy:  99.9%, Validation Accuracy:  59.0%, Validation Loss: 0.968
```

2.2

To solve overfitting problem, I reduce the number of convolutional layers and add some dropout layer.



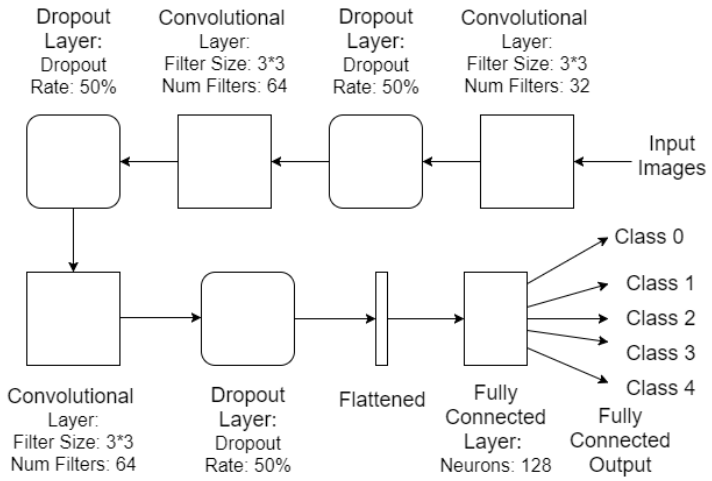
This kind of change cannot obviously improve the validation accuracy although it seems that the overfitting problem is partially solved.

```
Training Epoch 1---Training Accuracy:  26.5%, Validation Accuracy:  35.2%, Validation Loss: 0.342
Training Epoch 2---Training Accuracy:  42.8%, Validation Accuracy:  43.6%, Validation Loss: 0.274
Training Epoch 3---Training Accuracy:  52.5%, Validation Accuracy:  49.8%, Validation Loss: 0.257
Training Epoch 4---Training Accuracy:  57.2%, Validation Accuracy:  50.5%, Validation Loss: 0.254
Training Epoch 5---Training Accuracy:  61.0%, Validation Accuracy:  54.9%, Validation Loss: 0.242
Training Epoch 6---Training Accuracy:  64.8%, Validation Accuracy:  56.1%, Validation Loss: 0.238
Training Epoch 7---Training Accuracy:  67.8%, Validation Accuracy:  59.8%, Validation Loss: 0.234
Training Epoch 8---Training Accuracy:  70.3%, Validation Accuracy:  59.2%, Validation Loss: 0.240
Training Epoch 9---Training Accuracy:  73.6%, Validation Accuracy:  60.6%, Validation Loss: 0.238
Training Epoch 10---Training Accuracy:  76.3%, Validation Accuracy:  60.6%, Validation Loss: 0.250
Training Epoch 11---Training Accuracy:  79.8%, Validation Accuracy:  60.0%, Validation Loss: 0.256
Training Epoch 12---Training Accuracy:  82.1%, Validation Accuracy:  60.3%, Validation Loss: 0.273
Training Epoch 13---Training Accuracy:  83.5%, Validation Accuracy:  59.0%, Validation Loss: 0.285
Training Epoch 14---Training Accuracy:  85.3%, Validation Accuracy:  61.6%, Validation Loss: 0.263
Training Epoch 15---Training Accuracy:  85.7%, Validation Accuracy:  57.4%, Validation Loss: 0.332
Training Epoch 16---Training Accuracy:  89.3%, Validation Accuracy:  58.8%, Validation Loss: 0.355
Training Epoch 17---Training Accuracy:  90.7%, Validation Accuracy:  56.7%, Validation Loss: 0.394
Training Epoch 18---Training Accuracy:  91.7%, Validation Accuracy:  53.1%, Validation Loss: 0.472
Training Epoch 19---Training Accuracy:  92.0%, Validation Accuracy:  60.0%, Validation Loss: 0.412
Training Epoch 20---Training Accuracy:  91.9%, Validation Accuracy:  59.0%, Validation Loss: 0.374
Training Epoch 21---Training Accuracy:  93.4%, Validation Accuracy:  60.8%, Validation Loss: 0.360
Training Epoch 22---Training Accuracy:  94.1%, Validation Accuracy:  63.2%, Validation Loss: 0.377
Training Epoch 23---Training Accuracy:  95.6%, Validation Accuracy:  61.7%, Validation Loss: 0.382
Training Epoch 24---Training Accuracy:  96.8%, Validation Accuracy:  61.5%, Validation Loss: 0.398
Training Epoch 25---Training Accuracy:  97.2%, Validation Accuracy:  58.0%, Validation Loss: 0.444
Training Epoch 26---Training Accuracy:  97.6%, Validation Accuracy:  60.5%, Validation Loss: 0.415
Training Epoch 27---Training Accuracy:  98.1%, Validation Accuracy:  59.5%, Validation Loss: 0.517
Training Epoch 28---Training Accuracy:  97.4%, Validation Accuracy:  59.8%, Validation Loss: 0.509
```

```
Training Epoch 25---Training Accuracy:  97.2%, Validation Accuracy:  58.0%, Validation Loss: 0.444
Training Epoch 26---Training Accuracy:  97.6%, Validation Accuracy:  60.5%, Validation Loss: 0.415
Training Epoch 27---Training Accuracy:  98.1%, Validation Accuracy:  59.5%, Validation Loss: 0.517
Training Epoch 28---Training Accuracy:  97.4%, Validation Accuracy:  59.8%, Validation Loss: 0.509
Training Epoch 29---Training Accuracy:  97.6%, Validation Accuracy:  58.9%, Validation Loss: 0.559
Training Epoch 30---Training Accuracy:  97.5%, Validation Accuracy:  58.9%, Validation Loss: 0.549
Training Epoch 31---Training Accuracy:  98.6%, Validation Accuracy:  61.7%, Validation Loss: 0.525
Training Epoch 32---Training Accuracy:  98.5%, Validation Accuracy:  63.6%, Validation Loss: 0.527
Training Epoch 33---Training Accuracy:  98.4%, Validation Accuracy:  62.6%, Validation Loss: 0.551
Training Epoch 34---Training Accuracy:  98.2%, Validation Accuracy:  61.7%, Validation Loss: 0.551
Training Epoch 35---Training Accuracy:  98.2%, Validation Accuracy:  61.0%, Validation Loss: 0.528
Training Epoch 36---Training Accuracy:  97.5%, Validation Accuracy:  59.9%, Validation Loss: 0.569
Training Epoch 37---Training Accuracy:  98.5%, Validation Accuracy:  63.0%, Validation Loss: 0.576
Training Epoch 38---Training Accuracy:  98.8%, Validation Accuracy:  58.9%, Validation Loss: 0.629
Training Epoch 39---Training Accuracy:  98.4%, Validation Accuracy:  62.9%, Validation Loss: 0.546
Training Epoch 40---Training Accuracy:  99.0%, Validation Accuracy:  61.2%, Validation Loss: 0.576
Training Epoch 41---Training Accuracy:  99.2%, Validation Accuracy:  62.8%, Validation Loss: 0.635
Training Epoch 42---Training Accuracy:  99.2%, Validation Accuracy:  61.2%, Validation Loss: 0.634
Training Epoch 43---Training Accuracy:  98.8%, Validation Accuracy:  63.6%, Validation Loss: 0.620
Training Epoch 44---Training Accuracy:  99.2%, Validation Accuracy:  62.7%, Validation Loss: 0.601
Training Epoch 45---Training Accuracy:  99.3%, Validation Accuracy:  61.9%, Validation Loss: 0.604
Training Epoch 46---Training Accuracy:  99.7%, Validation Accuracy:  62.5%, Validation Loss: 0.631
Training Epoch 47---Training Accuracy:  98.9%, Validation Accuracy:  59.8%, Validation Loss: 0.633
Training Epoch 48---Training Accuracy:  99.0%, Validation Accuracy:  62.6%, Validation Loss: 0.662
Training Epoch 49---Training Accuracy:  99.3%, Validation Accuracy:  60.4%, Validation Loss: 0.682
Training Epoch 50---Training Accuracy:  99.1%, Validation Accuracy:  61.4%, Validation Loss: 0.667
```

2.3

In the end, I tried to reduce the dropout rate to 50% which is the so-called the best choice for CNN. From previous CNN model, 40 epochs are enough for training. Meanwhile, I set more filters in some convolutional layer.



The overfitting problem is further solved in this CNN. However, the validation accuracy is still around 62%. It seems that 62% is the maximum accuracy for CNN models in this project. Thus, I choose to use this CNN model to predict test images.

```
Training Epoch 1---Training Accuracy:  24.1%, Validation Accuracy:  22.6%, Validation Loss: 0.354
Training Epoch 2---Training Accuracy:  28.0%, Validation Accuracy:  33.3%, Validation Loss: 0.336
Training Epoch 3---Training Accuracy:  40.3%, Validation Accuracy:  39.7%, Validation Loss: 0.293
Training Epoch 4---Training Accuracy:  50.5%, Validation Accuracy:  46.8%, Validation Loss: 0.273
Training Epoch 5---Training Accuracy:  56.0%, Validation Accuracy:  53.3%, Validation Loss: 0.249
Training Epoch 6---Training Accuracy:  58.4%, Validation Accuracy:  54.1%, Validation Loss: 0.247
Training Epoch 7---Training Accuracy:  60.9%, Validation Accuracy:  53.9%, Validation Loss: 0.264
Training Epoch 8---Training Accuracy:  62.6%, Validation Accuracy:  56.5%, Validation Loss: 0.248
Training Epoch 9---Training Accuracy:  65.0%, Validation Accuracy:  57.6%, Validation Loss: 0.249
Training Epoch 10---Training Accuracy:  66.8%, Validation Accuracy:  56.1%, Validation Loss: 0.241
Training Epoch 11---Training Accuracy:  69.4%, Validation Accuracy:  59.9%, Validation Loss: 0.240
Training Epoch 12---Training Accuracy:  71.3%, Validation Accuracy:  58.9%, Validation Loss: 0.241
Training Epoch 13---Training Accuracy:  73.9%, Validation Accuracy:  57.8%, Validation Loss: 0.241
Training Epoch 14---Training Accuracy:  75.6%, Validation Accuracy:  58.0%, Validation Loss: 0.259
Training Epoch 15---Training Accuracy:  76.9%, Validation Accuracy:  62.2%, Validation Loss: 0.252
Training Epoch 16---Training Accuracy:  77.9%, Validation Accuracy:  59.2%, Validation Loss: 0.268
Training Epoch 17---Training Accuracy:  80.9%, Validation Accuracy:  58.8%, Validation Loss: 0.277
Training Epoch 18---Training Accuracy:  83.1%, Validation Accuracy:  58.9%, Validation Loss: 0.273
Training Epoch 19---Training Accuracy:  83.9%, Validation Accuracy:  58.1%, Validation Loss: 0.311
Training Epoch 20---Training Accuracy:  85.1%, Validation Accuracy:  59.1%, Validation Loss: 0.329
Training Epoch 21---Training Accuracy:  86.1%, Validation Accuracy:  58.8%, Validation Loss: 0.358
Training Epoch 22---Training Accuracy:  87.8%, Validation Accuracy:  60.8%, Validation Loss: 0.371
Training Epoch 23---Training Accuracy:  88.4%, Validation Accuracy:  60.3%, Validation Loss: 0.380
Training Epoch 24---Training Accuracy:  90.1%, Validation Accuracy:  64.0%, Validation Loss: 0.357
Training Epoch 25---Training Accuracy:  91.1%, Validation Accuracy:  60.5%, Validation Loss: 0.371
Training Epoch 26---Training Accuracy:  92.1%, Validation Accuracy:  64.1%, Validation Loss: 0.392
Training Epoch 27---Training Accuracy:  92.1%, Validation Accuracy:  62.8%, Validation Loss: 0.401
Training Epoch 28---Training Accuracy:  93.3%, Validation Accuracy:  59.3%, Validation Loss: 0.400
Training Epoch 29---Training Accuracy:  93.9%, Validation Accuracy:  61.7%, Validation Loss: 0.410
Training Epoch 30---Training Accuracy:  94.6%, Validation Accuracy:  61.5%, Validation Loss: 0.413
Training Epoch 31---Training Accuracy:  95.2%, Validation Accuracy:  60.7%, Validation Loss: 0.407
Training Epoch 32---Training Accuracy:  95.2%, Validation Accuracy:  59.9%, Validation Loss: 0.418
Training Epoch 33---Training Accuracy:  96.8%, Validation Accuracy:  60.1%, Validation Loss: 0.455
Training Epoch 34---Training Accuracy:  96.0%, Validation Accuracy:  62.4%, Validation Loss: 0.468
Training Epoch 35---Training Accuracy:  97.0%, Validation Accuracy:  65.3%, Validation Loss: 0.441
Training Epoch 36---Training Accuracy:  97.3%, Validation Accuracy:  61.4%, Validation Loss: 0.515
Training Epoch 37---Training Accuracy:  97.6%, Validation Accuracy:  62.2%, Validation Loss: 0.459
Training Epoch 38---Training Accuracy:  97.8%, Validation Accuracy:  64.1%, Validation Loss: 0.540
Training Epoch 39---Training Accuracy:  96.4%, Validation Accuracy:  62.4%, Validation Loss: 0.482
Training Epoch 40---Training Accuracy:  97.8%, Validation Accuracy:  61.9%, Validation Loss: 0.512
```

3. Predict test data

In “project2_predict_20459996.py”, I load test images and predict them one-by-one. After predicting, I write the predicted labels into a file: “project2_20459996.txt”.