Assignment 2 report: The German Traffic Sign Recognition Benchmark — Rev 1

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Honor Statement: By submitting this work, I certify that, with the exception of LaTeX templates and text whose sources I cite, every keystroke in the answers was typed by me.

Instructor: Prof. Rob Fergus.

1 The environment for this assignment

- OS: Windows 10 x64
- CUDA: 10.0
- Python: 3.7.3
- CUDNN: 7
- pytorch: 1.2.0
- GPU: GeForce GTX 1070 (8+8 GB GPU Memory)
- CPU: i7-8750H

P.S. Estimated time to run one batch on this PC: 5 minutes

2 About the dataset

1. The shape of the sample: [*, 3, 32, 32], which means the sample is RBG with 32 x 32 pixel
2. The training dataset has 35339 samples and the validation dataset has 3870 samples.

3 My framework and the hyper-parameters

I used ensemble models which includes 4 GoogLeNets and a Basic CNN Net. 3 GoogLeNets are trained in the same process (Please see the GoogLeNet-Test-3.ipynb) and the another is trained in another process (Please see the GoogLeNet-Test-2.ipynb). I used the same random seed for the two process of training GoogLeNets. However, the result of the two process are actually different.

How do I choose those GoogLeNets?

In GoogLeNet-Test-3.ipynb, by looking at the log and choose those accuracy are local maximum which means not only that epoch has a big validation accuracy but also the near epochs have relatively larger validation accuracy.

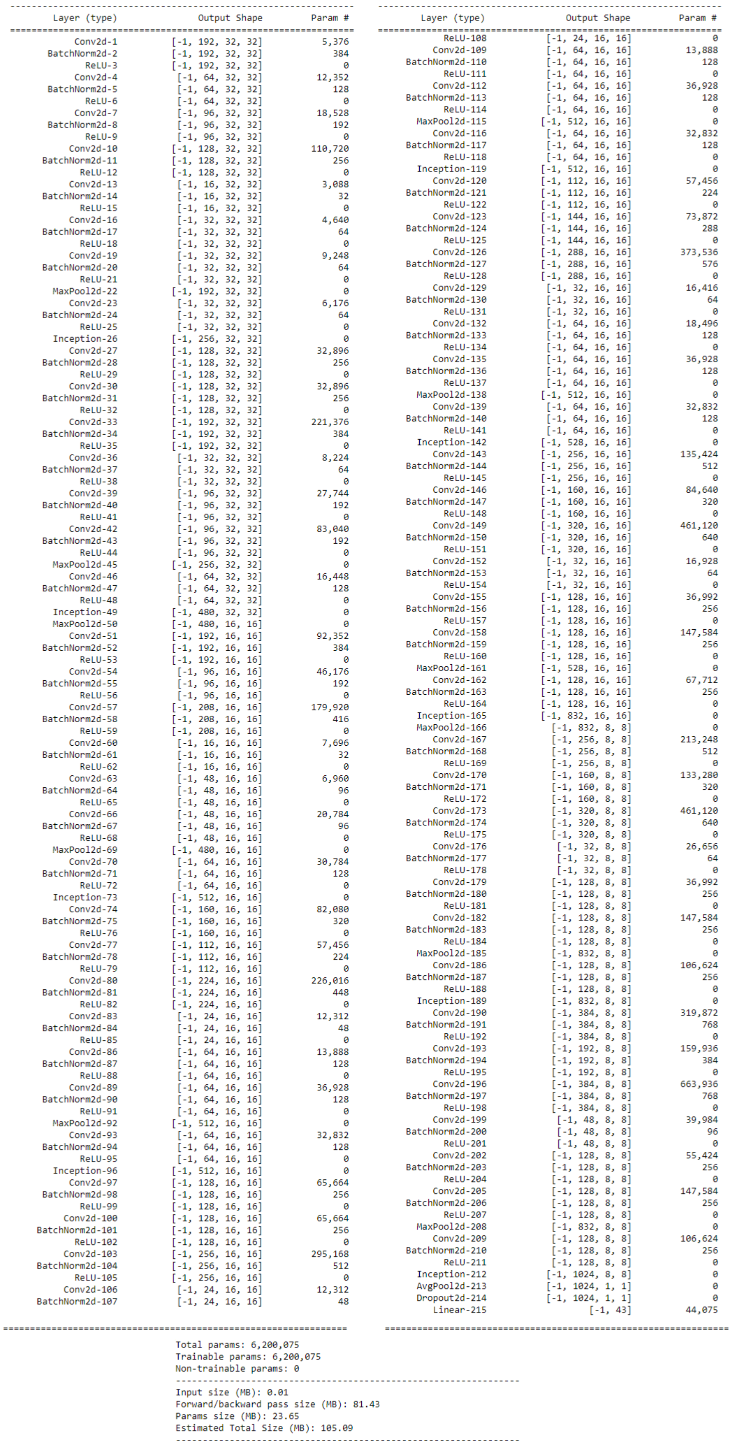
1. GoogLeNet
2. A Basic CNN Net

   I will show the frameworks at the end of this file.

4 How I ensemble these models?

During the process of get the Kaggle files, I got the raw classification scores for each model and take the mean. Then, I use it as the ensemble model result which performs better than any models in the ensemble list.

Please also see the training loss graph and accuracy graph in the end of this doc



```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 192, 32, 32]           5,376
       BatchNorm2d-2         [-1, 192, 32, 32]             384
              ReLU-3         [-1, 192, 32, 32]               0
            Conv2d-4          [-1, 64, 32, 32]          12,352
       BatchNorm2d-5          [-1, 64, 32, 32]             128
              ReLU-6          [-1, 64, 32, 32]               0
            Conv2d-7          [-1, 96, 32, 32]          18,528
       BatchNorm2d-8          [-1, 96, 32, 32]             192
              ReLU-9          [-1, 96, 32, 32]               0
           Conv2d-10         [-1, 128, 32, 32]         110,720
      BatchNorm2d-11         [-1, 128, 32, 32]             256
             ReLU-12         [-1, 128, 32, 32]               0
           Conv2d-13          [-1, 16, 32, 32]           3,088
      BatchNorm2d-14          [-1, 16, 32, 32]              32
             ReLU-15          [-1, 16, 32, 32]               0
           Conv2d-16          [-1, 32, 32, 32]           4,640
      BatchNorm2d-17          [-1, 32, 32, 32]              64
             ReLU-18          [-1, 32, 32, 32]               0
           Conv2d-19          [-1, 32, 32, 32]           9,248
      BatchNorm2d-20          [-1, 32, 32, 32]              64
             ReLU-21          [-1, 32, 32, 32]               0
        MaxPool2d-22         [-1, 192, 32, 32]               0
           Conv2d-23          [-1, 32, 32, 32]           6,176
      BatchNorm2d-24          [-1, 32, 32, 32]              64
             ReLU-25          [-1, 32, 32, 32]               0
        Inception-26         [-1, 256, 32, 32]               0
           Conv2d-27         [-1, 128, 32, 32]          32,896
      BatchNorm2d-28         [-1, 128, 32, 32]             256
             ReLU-29         [-1, 128, 32, 32]               0
           Conv2d-30         [-1, 128, 32, 32]          32,896
      BatchNorm2d-31         [-1, 128, 32, 32]             256
             ReLU-32         [-1, 128, 32, 32]               0
           Conv2d-33         [-1, 192, 32, 32]         221,376
      BatchNorm2d-34         [-1, 192, 32, 32]             384
             ReLU-35         [-1, 192, 32, 32]               0
           Conv2d-36          [-1, 32, 32, 32]           8,224
      BatchNorm2d-37          [-1, 32, 32, 32]              64
             ReLU-38          [-1, 32, 32, 32]               0
           Conv2d-39          [-1, 96, 32, 32]          27,744
      BatchNorm2d-40          [-1, 96, 32, 32]             192
             ReLU-41          [-1, 96, 32, 32]               0
           Conv2d-42          [-1, 96, 32, 32]          83,040
      BatchNorm2d-43          [-1, 96, 32, 32]             192
             ReLU-44          [-1, 96, 32, 32]               0
        MaxPool2d-45         [-1, 256, 32, 32]               0
           Conv2d-46          [-1, 64, 32, 32]          16,448
      BatchNorm2d-47          [-1, 64, 32, 32]             128
             ReLU-48          [-1, 64, 32, 32]               0
        Inception-49         [-1, 480, 32, 32]               0
        MaxPool2d-50         [-1, 480, 16, 16]               0
           Conv2d-51         [-1, 192, 16, 16]          92,352
      BatchNorm2d-52         [-1, 192, 16, 16]             384
             ReLU-53         [-1, 192, 16, 16]               0
           Conv2d-54          [-1, 96, 16, 16]          46,176
      BatchNorm2d-55          [-1, 96, 16, 16]             192
             ReLU-56          [-1, 96, 16, 16]               0
           Conv2d-57         [-1, 208, 16, 16]         179,920
      BatchNorm2d-58         [-1, 208, 16, 16]             416
             ReLU-59         [-1, 208, 16, 16]               0
           Conv2d-60          [-1, 16, 16, 16]           7,696
      BatchNorm2d-61          [-1, 16, 16, 16]              32
             ReLU-62          [-1, 16, 16, 16]               0
           Conv2d-63          [-1, 48, 16, 16]           6,960
      BatchNorm2d-64          [-1, 48, 16, 16]              96
             ReLU-65          [-1, 48, 16, 16]               0
           Conv2d-66          [-1, 48, 16, 16]          20,784
      BatchNorm2d-67          [-1, 48, 16, 16]              96
             ReLU-68          [-1, 48, 16, 16]               0
        MaxPool2d-69         [-1, 480, 16, 16]               0
           Conv2d-70          [-1, 64, 16, 16]          30,784
      BatchNorm2d-71          [-1, 64, 16, 16]             128
             ReLU-72          [-1, 64, 16, 16]               0
        Inception-73         [-1, 512, 16, 16]               0
           Conv2d-74         [-1, 160, 16, 16]          82,080
      BatchNorm2d-75         [-1, 160, 16, 16]             320
             ReLU-76         [-1, 160, 16, 16]               0
           Conv2d-77         [-1, 112, 16, 16]          57,456
      BatchNorm2d-78         [-1, 112, 16, 16]             224
             ReLU-79         [-1, 112, 16, 16]               0
           Conv2d-80         [-1, 224, 16, 16]         226,016
      BatchNorm2d-81         [-1, 224, 16, 16]             448
             ReLU-82         [-1, 224, 16, 16]               0
           Conv2d-83          [-1, 24, 16, 16]          12,312
      BatchNorm2d-84          [-1, 24, 16, 16]              48
             ReLU-85          [-1, 24, 16, 16]               0
           Conv2d-86          [-1, 64, 16, 16]          13,888
      BatchNorm2d-87          [-1, 64, 16, 16]             128
             ReLU-88          [-1, 64, 16, 16]               0
           Conv2d-89          [-1, 64, 16, 16]          36,928
      BatchNorm2d-90          [-1, 64, 16, 16]             128
             ReLU-91          [-1, 64, 16, 16]               0
        MaxPool2d-92         [-1, 512, 16, 16]               0
           Conv2d-93          [-1, 64, 16, 16]          32,832
      BatchNorm2d-94          [-1, 64, 16, 16]             128
             ReLU-95          [-1, 64, 16, 16]               0
        Inception-96         [-1, 512, 16, 16]               0
           Conv2d-97         [-1, 128, 16, 16]          65,664
      BatchNorm2d-98         [-1, 128, 16, 16]             256
             ReLU-99         [-1, 128, 16, 16]               0
          Conv2d-100         [-1, 128, 16, 16]          65,664
     BatchNorm2d-101         [-1, 128, 16, 16]             256
            ReLU-102         [-1, 128, 16, 16]               0
          Conv2d-103         [-1, 256, 16, 16]         295,168
     BatchNorm2d-104         [-1, 256, 16, 16]             512
            ReLU-105         [-1, 256, 16, 16]               0
          Conv2d-106          [-1, 24, 16, 16]          12,312
     BatchNorm2d-107          [-1, 24, 16, 16]              48
================================================================
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----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            ReLU-108          [-1, 24, 16, 16]               0
          Conv2d-109          [-1, 64, 16, 16]          13,888
     BatchNorm2d-110          [-1, 64, 16, 16]             128
            ReLU-111          [-1, 64, 16, 16]               0
          Conv2d-112          [-1, 64, 16, 16]          36,928
     BatchNorm2d-113          [-1, 64, 16, 16]             128
            ReLU-114          [-1, 64, 16, 16]               0
       MaxPool2d-115         [-1, 512, 16, 16]               0
          Conv2d-116          [-1, 64, 16, 16]          32,832
     BatchNorm2d-117          [-1, 64, 16, 16]             128
            ReLU-118          [-1, 64, 16, 16]               0
       Inception-119         [-1, 512, 16, 16]               0
          Conv2d-120         [-1, 112, 16, 16]          57,456
     BatchNorm2d-121         [-1, 112, 16, 16]             224
            ReLU-122         [-1, 112, 16, 16]               0
          Conv2d-123         [-1, 144, 16, 16]          73,872
     BatchNorm2d-124         [-1, 144, 16, 16]             288
            ReLU-125         [-1, 144, 16, 16]               0
          Conv2d-126         [-1, 288, 16, 16]         373,536
     BatchNorm2d-127         [-1, 288, 16, 16]             576
            ReLU-128         [-1, 288, 16, 16]               0
          Conv2d-129          [-1, 32, 16, 16]          16,416
     BatchNorm2d-130          [-1, 32, 16, 16]              64
            ReLU-131          [-1, 32, 16, 16]               0
          Conv2d-132          [-1, 64, 16, 16]          18,496
     BatchNorm2d-133          [-1, 64, 16, 16]             128
            ReLU-134          [-1, 64, 16, 16]               0
          Conv2d-135          [-1, 64, 16, 16]          36,928
     BatchNorm2d-136          [-1, 64, 16, 16]             128
            ReLU-137          [-1, 64, 16, 16]               0
       MaxPool2d-138         [-1, 512, 16, 16]               0
          Conv2d-139          [-1, 64, 16, 16]          32,832
     BatchNorm2d-140          [-1, 64, 16, 16]             128
            ReLU-141          [-1, 64, 16, 16]               0
       Inception-142         [-1, 528, 16, 16]               0
          Conv2d-143         [-1, 256, 16, 16]         135,424
     BatchNorm2d-144         [-1, 256, 16, 16]             512
            ReLU-145         [-1, 256, 16, 16]               0
          Conv2d-146         [-1, 160, 16, 16]          84,640
     BatchNorm2d-147         [-1, 160, 16, 16]             320
            ReLU-148         [-1, 160, 16, 16]               0
          Conv2d-149         [-1, 320, 16, 16]         461,120
     BatchNorm2d-150         [-1, 320, 16, 16]             640
            ReLU-151         [-1, 320, 16, 16]               0
          Conv2d-152          [-1, 32, 16, 16]          16,928
     BatchNorm2d-153          [-1, 32, 16, 16]              64
            ReLU-154          [-1, 32, 16, 16]               0
          Conv2d-155         [-1, 128, 16, 16]          36,992
     BatchNorm2d-156         [-1, 128, 16, 16]             256
            ReLU-157         [-1, 128, 16, 16]               0
          Conv2d-158         [-1, 128, 16, 16]         147,584
     BatchNorm2d-159         [-1, 128, 16, 16]             256
            ReLU-160         [-1, 128, 16, 16]               0
       MaxPool2d-161         [-1, 528, 16, 16]               0
          Conv2d-162         [-1, 128, 16, 16]          67,712
     BatchNorm2d-163         [-1, 128, 16, 16]             256
            ReLU-164         [-1, 128, 16, 16]               0
       Inception-165         [-1, 832, 16, 16]               0
       MaxPool2d-166           [-1, 832, 8, 8]               0
          Conv2d-167           [-1, 256, 8, 8]         213,248
     BatchNorm2d-168           [-1, 256, 8, 8]             512
            ReLU-169           [-1, 256, 8, 8]               0
          Conv2d-170           [-1, 160, 8, 8]         133,280
     BatchNorm2d-171           [-1, 160, 8, 8]             320
            ReLU-172           [-1, 160, 8, 8]               0
          Conv2d-173           [-1, 320, 8, 8]         461,120
     BatchNorm2d-174           [-1, 320, 8, 8]             640
            ReLU-175           [-1, 320, 8, 8]               0
          Conv2d-176            [-1, 32, 8, 8]          26,656
     BatchNorm2d-177            [-1, 32, 8, 8]              64
            ReLU-178            [-1, 32, 8, 8]               0
          Conv2d-179           [-1, 128, 8, 8]          36,992
     BatchNorm2d-180           [-1, 128, 8, 8]             256
            ReLU-181           [-1, 128, 8, 8]               0
          Conv2d-182           [-1, 128, 8, 8]         147,584
     BatchNorm2d-183           [-1, 128, 8, 8]             256
            ReLU-184           [-1, 128, 8, 8]               0
       MaxPool2d-185           [-1, 832, 8, 8]               0
          Conv2d-186           [-1, 128, 8, 8]         106,624
     BatchNorm2d-187           [-1, 128, 8, 8]             256
            ReLU-188           [-1, 128, 8, 8]               0
       Inception-189           [-1, 832, 8, 8]               0
          Conv2d-190           [-1, 384, 8, 8]         319,872
     BatchNorm2d-191           [-1, 384, 8, 8]             768
            ReLU-192           [-1, 384, 8, 8]               0
          Conv2d-193           [-1, 192, 8, 8]         159,936
     BatchNorm2d-194           [-1, 192, 8, 8]             384
            ReLU-195           [-1, 192, 8, 8]               0
          Conv2d-196           [-1, 384, 8, 8]         663,936
     BatchNorm2d-197           [-1, 384, 8, 8]             768
            ReLU-198           [-1, 384, 8, 8]               0
          Conv2d-199            [-1, 48, 8, 8]          39,984
     BatchNorm2d-200            [-1, 48, 8, 8]              96
            ReLU-201            [-1, 48, 8, 8]               0
          Conv2d-202           [-1, 128, 8, 8]          55,424
     BatchNorm2d-203           [-1, 128, 8, 8]             256
            ReLU-204           [-1, 128, 8, 8]               0
          Conv2d-205           [-1, 128, 8, 8]         147,584
     BatchNorm2d-206           [-1, 128, 8, 8]             256
            ReLU-207           [-1, 128, 8, 8]               0
       MaxPool2d-208           [-1, 832, 8, 8]               0
          Conv2d-209           [-1, 128, 8, 8]         106,624
     BatchNorm2d-210           [-1, 128, 8, 8]             256
            ReLU-211           [-1, 128, 8, 8]               0
       Inception-212          [-1, 1024, 8, 8]               0
       AvgPool2d-213          [-1, 1024, 1, 1]               0
       Dropout2d-214          [-1, 1024, 1, 1]               0
          Linear-215                  [-1, 43]          44,075
================================================================
```
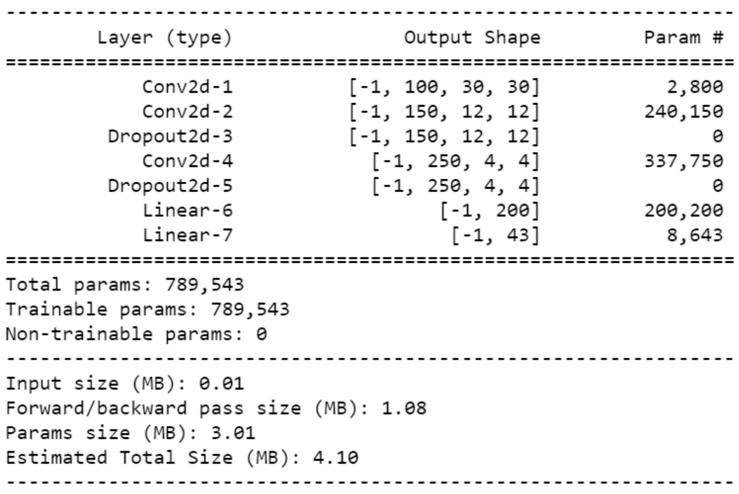
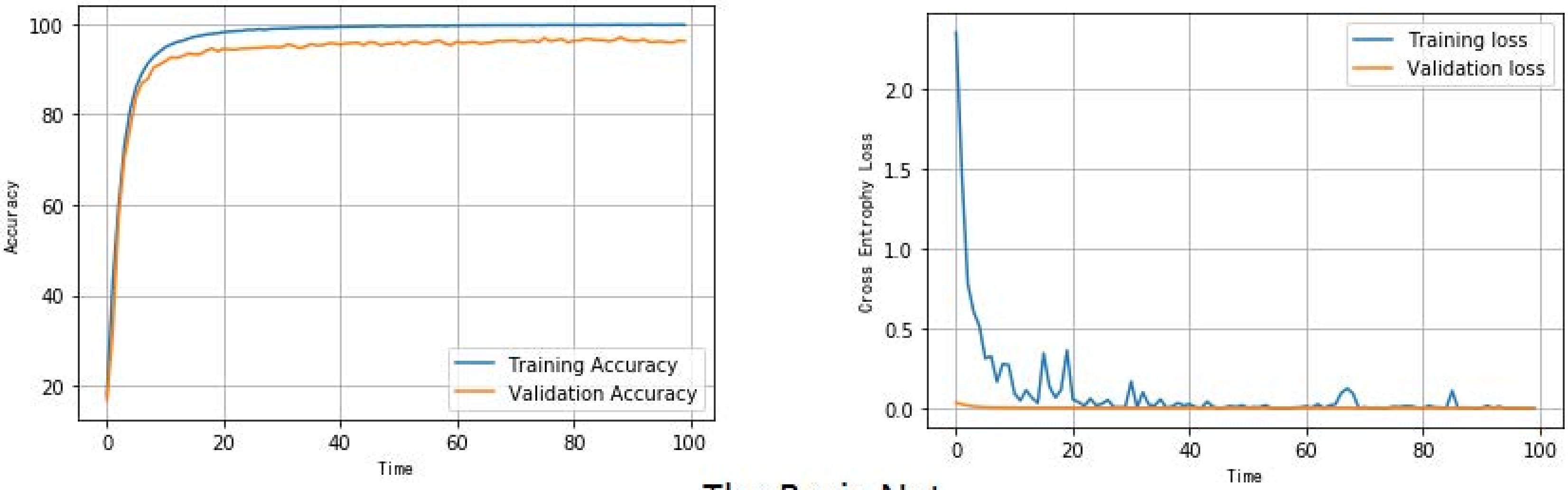

```
Total params: 6,200,075
Trainable params: 6,200,075
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.01
Forward/backward pass size (MB): 81.43
Params size (MB): 23.65
Estimated Total Size (MB): 105.09
----------------------------------------------------------------
```

Figure 1: Model summary for GoogLeNet

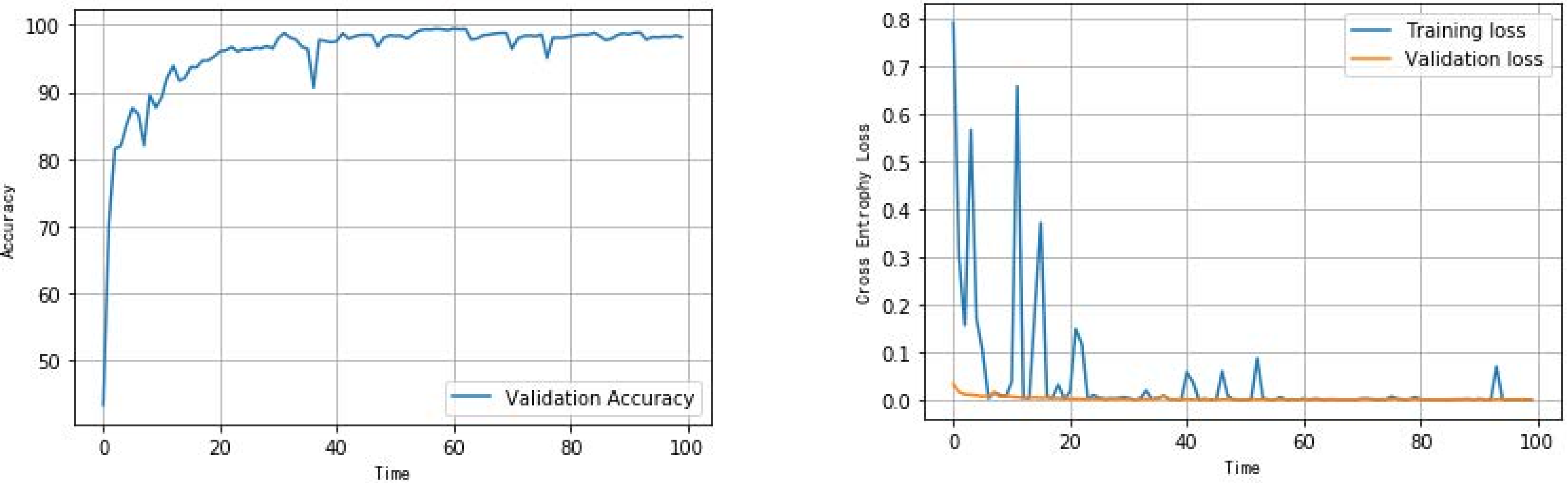


```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 100, 30, 30]           2,800
            Conv2d-2         [-1, 150, 12, 12]         240,150
         Dropout2d-3         [-1, 150, 12, 12]               0
            Conv2d-4           [-1, 250, 4, 4]         337,750
         Dropout2d-5           [-1, 250, 4, 4]               0
            Linear-6                 [-1, 200]         200,200
            Linear-7                  [-1, 43]           8,643
================================================================
Total params: 789,543
Trainable params: 789,543
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.01
Forward/backward pass size (MB): 1.08
Params size (MB): 3.01
Estimated Total Size (MB): 4.10
----------------------------------------------------------------
```

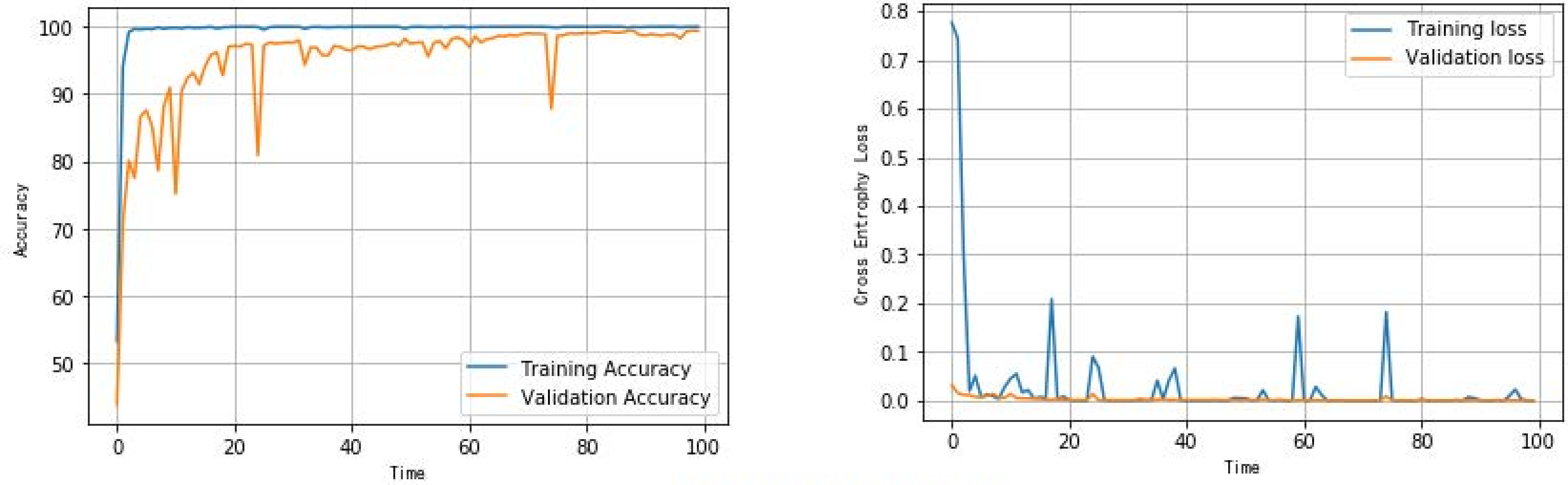
Figure 2: Model summary for A Basic CNN Net



The Basic Net



GooaLeNet-test-2



GoogLeNet-test-3