卷积神经网络实验报告

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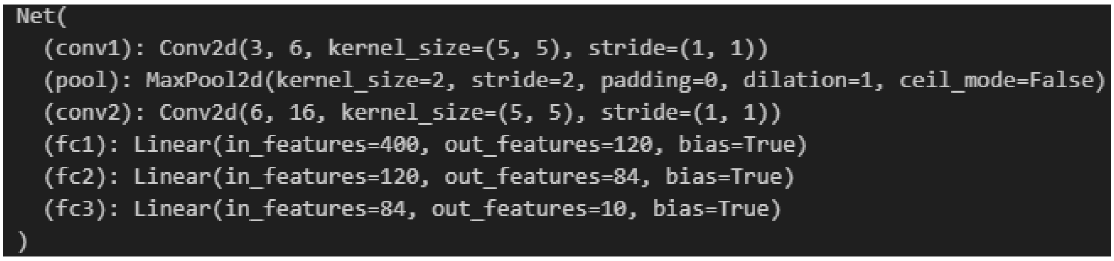
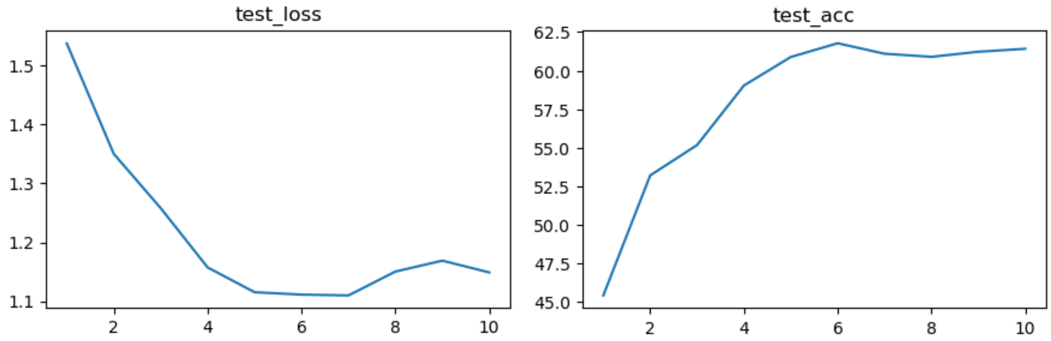
一．原始版本卷积网络

网络结构：



```
Net(
  (conv1): Conv2d(3, 6, kernel_size=(5, 5), stride=(1, 1))
  (pool): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  (conv2): Conv2d(6, 16, kernel_size=(5, 5), stride=(1, 1))
  (fc1): Linear(in_features=400, out_features=120, bias=True)
  (fc2): Linear(in_features=120, out_features=84, bias=True)
  (fc3): Linear(in_features=84, out_features=10, bias=True)
)
```

输出结果：

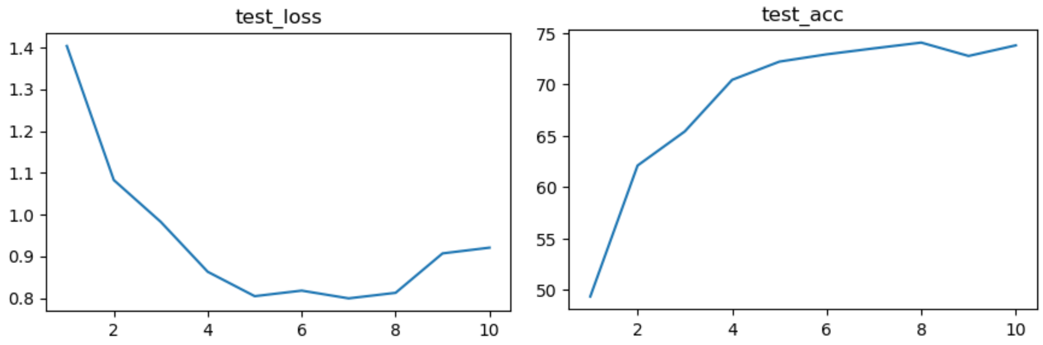


二．使用 Resnet

网络结构：

```
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
    (1): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (layer2): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (layer3): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (layer4): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (avg_pool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=512, out_features=10, bias=True)、
```

训练结果：



三．使用 DenseNet

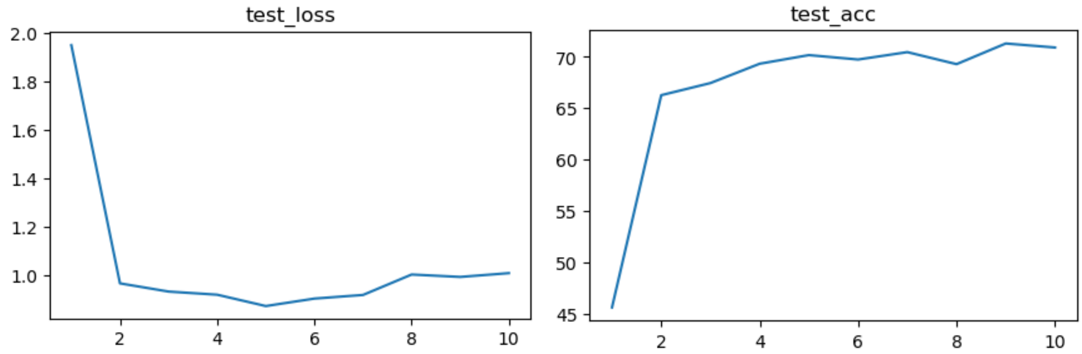
网络结构：

```
DenseNet(
  (conv): Conv2d(3, 32, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3))
```

```
(bn1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
(max_pool): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
(relu): ReLU()
(denseblock1): DenseBlock(
  (denseblock): Sequential(
    (0): DenseBasic(
      (layer): Sequential(
        (0): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (1): ReLU()
        (2): Conv2d(32, 128, kernel_size=(1, 1), stride=(1, 1))
        (3): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (4): ReLU()
        (5): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      )
    )
    (1): DenseBasic(
      (layer): Sequential(
        (0): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (1): ReLU()
        (2): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1))
        (3): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (4): ReLU()
        (5): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      )
    )
    (2): DenseBasic(
      (layer): Sequential(
        (0): BatchNorm2d(96, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (1): ReLU()
        (2): Conv2d(96, 128, kernel_size=(1, 1), stride=(1, 1))
        (3): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (4): ReLU()
        (5): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      )
    )
    (3): DenseBasic(
      (layer): Sequential(
        (0): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (1): ReLU()
        (2): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1))
        (3): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (4): ReLU()
        (5): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      )
      )
      (4): DenseBasic(
        (layer): Sequential(
          (0): BatchNorm2d(160, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (1): ReLU()
          (2): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1))
          (3): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (4): ReLU()
          (5): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        )
      )
      (5): DenseBasic(
        (layer): Sequential(
          (0): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (1): ReLU()
          (2): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1))
          (3): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (4): ReLU()
          (5): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        )
      )
    )
  )
  (bn2): BatchNorm2d(224, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (conv1): Conv2d(224, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  (avg1): AvgPool2d(kernel_size=2, stride=2, padding=0)
  (denseblock2): DenseBlock(
    (denseblock): Sequential(
      (0): DenseBasic(
        (layer): Sequential(
          (0): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (1): ReLU()
          (2): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1))
          (3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (4): ReLU()
          (5): Conv2d(256, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        )
      )
      (1): DenseBasic(
        (layer): Sequential(
          (0): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (1): ReLU()
          (2): Conv2d(128, 256, kernel_size=(1, 1), stride=(1, 1))
          (3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (4): ReLU()
    (5): Conv2d(256, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  )
)
(2): DenseBasic(
  (layer): Sequential(
    (0): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (1): ReLU()
    (2): Conv2d(192, 256, kernel_size=(1, 1), stride=(1, 1))
    (3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (4): ReLU()
    (5): Conv2d(256, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  )
)
(3): DenseBasic(
  (layer): Sequential(
    (0): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (1): ReLU()
    (2): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1))
    (3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (4): ReLU()
    (5): Conv2d(256, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  )
)
(4): DenseBasic(
  (layer): Sequential(
    (0): BatchNorm2d(320, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (1): ReLU()
    (2): Conv2d(320, 256, kernel_size=(1, 1), stride=(1, 1))
    (3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (4): ReLU()
    (5): Conv2d(256, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  )
)
(5): DenseBasic(
  (layer): Sequential(
    (0): BatchNorm2d(384, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (1): ReLU()
    (2): Conv2d(384, 256, kernel_size=(1, 1), stride=(1, 1))
    (3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (4): ReLU()
    (5): Conv2d(256, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
  )
)
```

```
    )
  )
  (fc1): Linear(in_features=7168, out_features=10, bias=True)
)
```

训练结果：



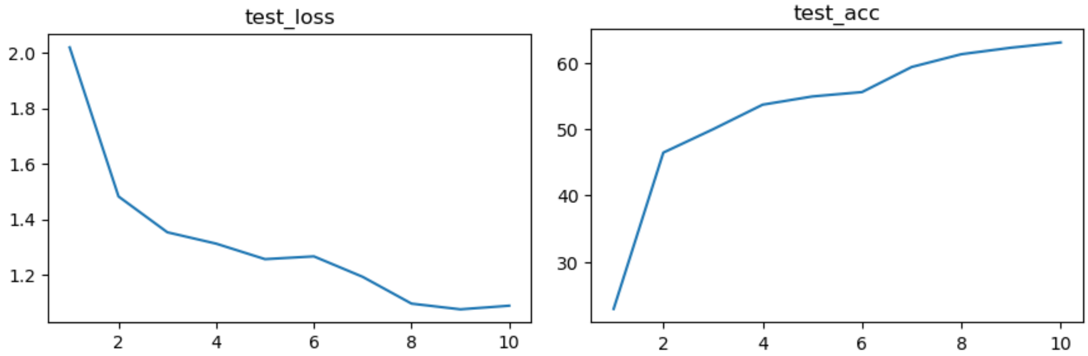
四 ．使用 MobileNet

网络结构:

```
MobleNetV1(
  (conv1): Sequential(
    (0): Conv2d(3, 32, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
    (1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
  )
  (conv_dw1): Sequential(
    (0): Conv2d(32, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=32, bias=False)
    (1): BatchNorm2d(32, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(32, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (4): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU()
  )
  (conv_dw2): Sequential(
    (0): Conv2d(64, 64, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=64, bias=False)
    (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (4): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU()
  )
  (conv_dw3): Sequential(
    (0): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=128, bias=False)
    (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (4): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (5): ReLU()
)
(conv_dw4): Sequential(
  (0): Conv2d(128, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=128, bias=False)
  (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (2): ReLU()
  (3): Conv2d(128, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (4): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (5): ReLU()
)
(conv_dw5): Sequential(
  (0): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=256, bias=False)
  (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (2): ReLU()
  (3): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (4): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (5): ReLU()
)
(conv_dw6): Sequential(
  (0): Conv2d(256, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=256, bias=False)
  (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (2): ReLU()
  (3): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
  (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (5): ReLU()
)
(conv_dw_x5): Sequential(
  (0): Sequential(
    (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=512, bias=False)
    (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU()
  )
  (1): Sequential(
    (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=512, bias=False)
    (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU()
  )
```

```
    (2): Sequential(
      (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=512, bias=False)
      (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (2): ReLU()
      (3): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (5): ReLU()
    )
    (3): Sequential(
      (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=512, bias=False)
      (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (2): ReLU()
      (3): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (5): ReLU()
    )
    (4): Sequential(
      (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=512, bias=False)
      (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (2): ReLU()
      (3): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (5): ReLU()
    )
  )
  (conv_dw7): Sequential(
    (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=512, bias=False)
    (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (4): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU()
  )
  (conv_dw8): Sequential(
    (0): Conv2d(1024, 1024, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1024, bias=False)
    (1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU()
    (3): Conv2d(1024, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (4): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU()
  )
  (avgpool): AvgPool2d(kernel_size=1, stride=1, padding=0)
  (fc): Linear(in_features=1024, out_features=10, bias=True)
)
```

训练结果：



五．实验总结和心得

在这次的卷积神经网络实验中，我分别使用了 ResNet, DenseNet 和 MobileNet 进行了实验，ResNet 通过引入残差块（Residual Block）解决了深层网络训练中的梯度消失问题，使得网络可以更深，能够训练非常深的网络，提高了模型的表现能力，适用于需要训练非常深的网络且对准确率要求高的任务。DenseNet 通过连接每一层到后续的所有层来加强特征的传递和复用，从而减少了参数和计算量，参数效率高，较少的参数可以达到甚至超越传统卷积网络的表现，易于训练，且能较好地缓解梯度消失问题。在此次的实验中的表现最好，初始状态的训练速度最快。MobileNet 采用深度可分离卷积（Depthwise Separable Convolutions），将标准卷积分解为深度卷积和逐点卷积两部分，显著减少了参数和计算量。在此次的实验中表现也不错，由于我使用的是 cpu 进行训练，只训练了 10 轮，如果继续进行下去可以看出 MobileNet 会有更好的表现。