# 심층학습
# [실습04] 심층신경망 훈련

SW융합학부 양희경

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- 포트폴리오 작성법 익힘(미래의 나의 재산)
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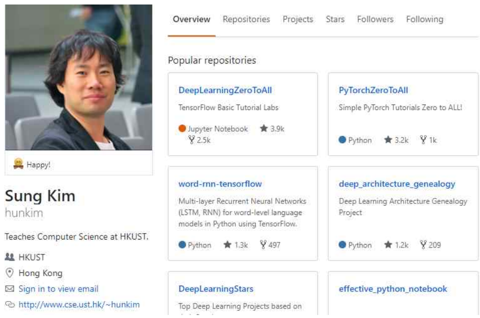
- 참고 GitHub
  - https://github.com/hunkim
  - https://github.com/hwalsuklee
  - https://github.com/sjchoi86



Happy!

Sung Kim
hunkim

Teaches Computer Science at HKUST.

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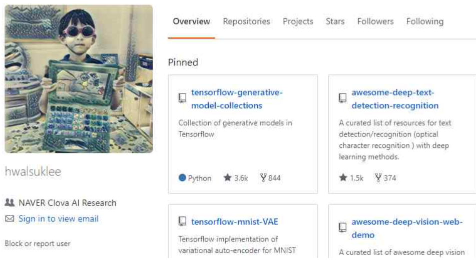

hwalsuklee

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Collection of generative models in Tensorflow
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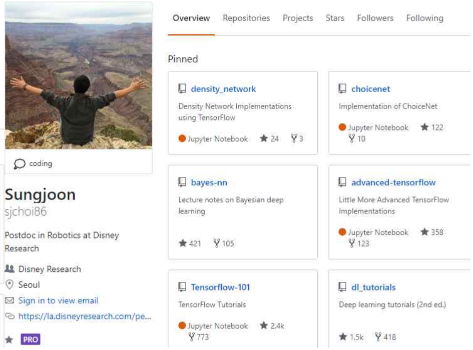
★ 1.5k 374

tensorflow-mnist-VAE
Tensorflow implementation of variational auto-encoder for MNIST

awesome-deep-vision-web-demo
A curated list of awesome deep vision



coding

Sungjoon
sjchoi86

Postdoc in Robotics at Disney Research

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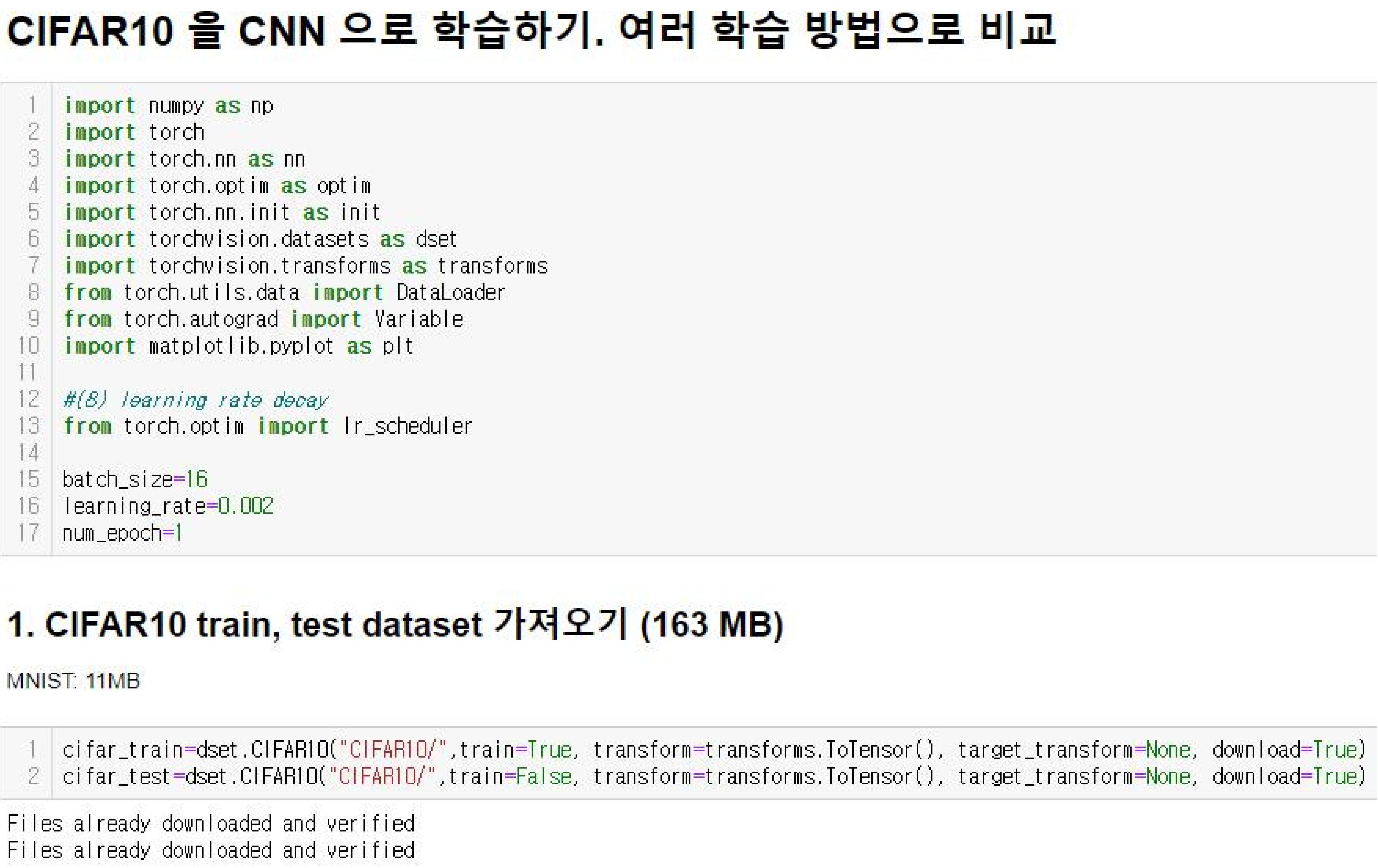


# CIFAR10 을 CNN 으로 학습하기. 여러 학습 방법으로 비교

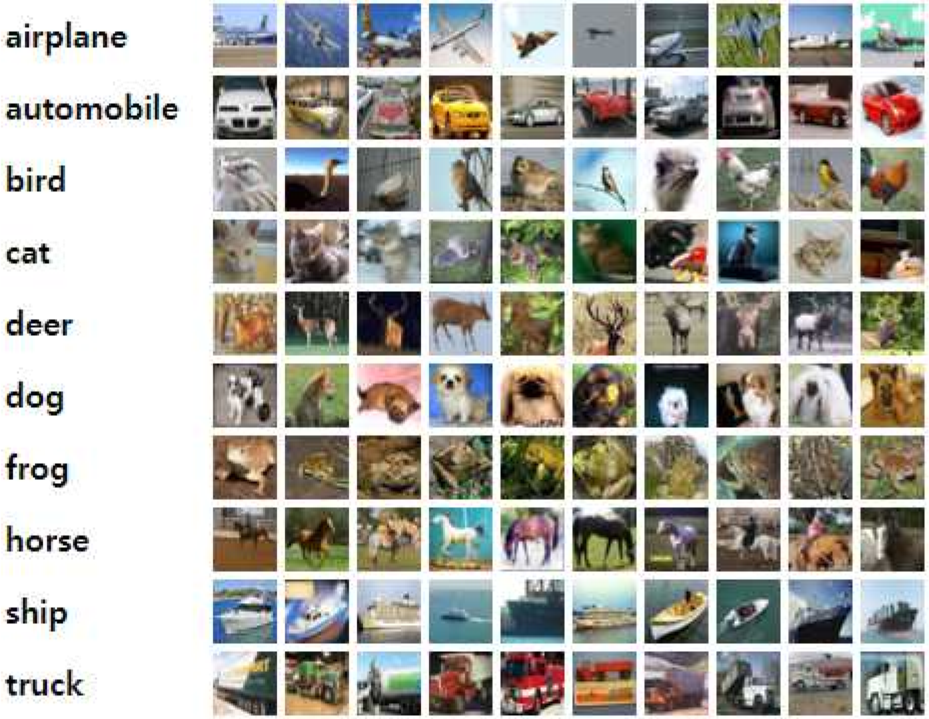
```
import numpy as np
import torch
import torch.nn as nn
import torch.optim as optim
import torch.nn.init as init
import torchvision.datasets as dset
import torchvision.transforms as transforms
from torch.utils.data import DataLoader
from torch.autograd import Variable
import matplotlib.pyplot as plt

#(8) learning rate decay
from torch.optim import lr_scheduler

batch_size=16
learning_rate=0.002
num_epoch=1
```

## 1. CIFAR10 train, test dataset 가져오기 (163 MB)

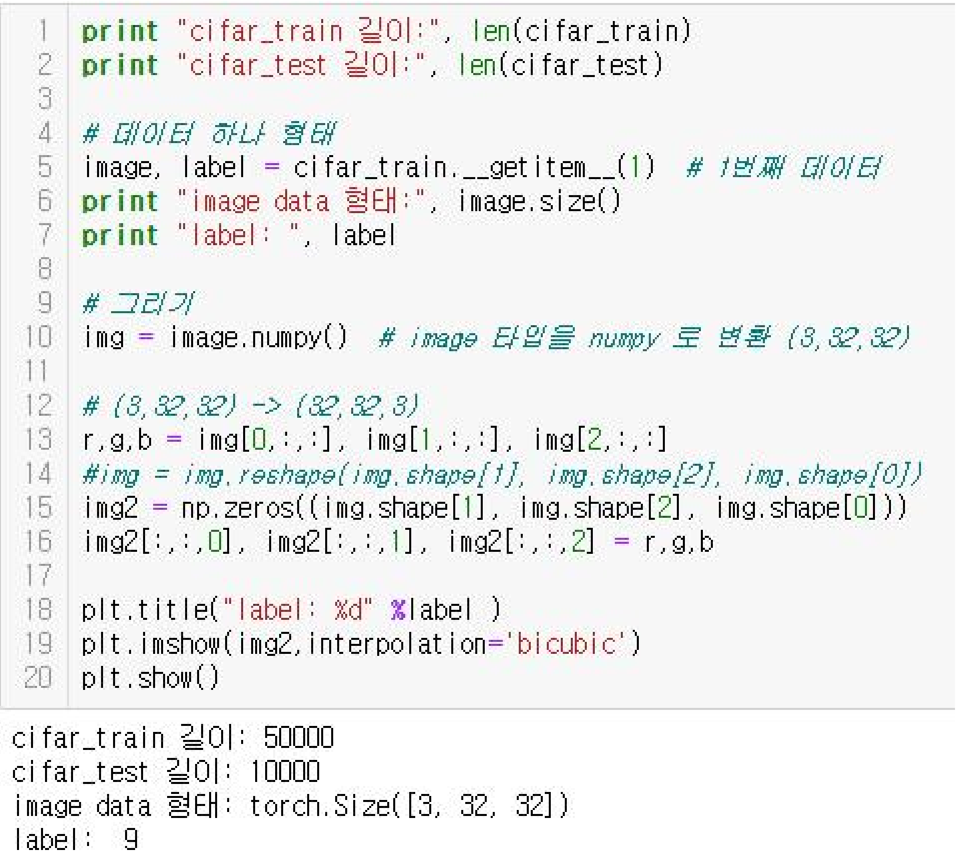
MNIST: 11MB

```
cifar_train=dset.CIFAR10("CIFAR10/",train=True, transform=transforms.ToTensor(), target_transform=None, download=True)
cifar_test=dset.CIFAR10("CIFAR10/",train=False, transform=transforms.ToTensor(), target_transform=None, download=True)
```

```
Files already downloaded and verified
Files already downloaded and verified
```

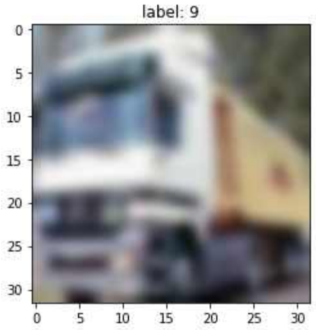

airplane
automobile
bird
cat
deer
dog
frog
horse
ship
truck

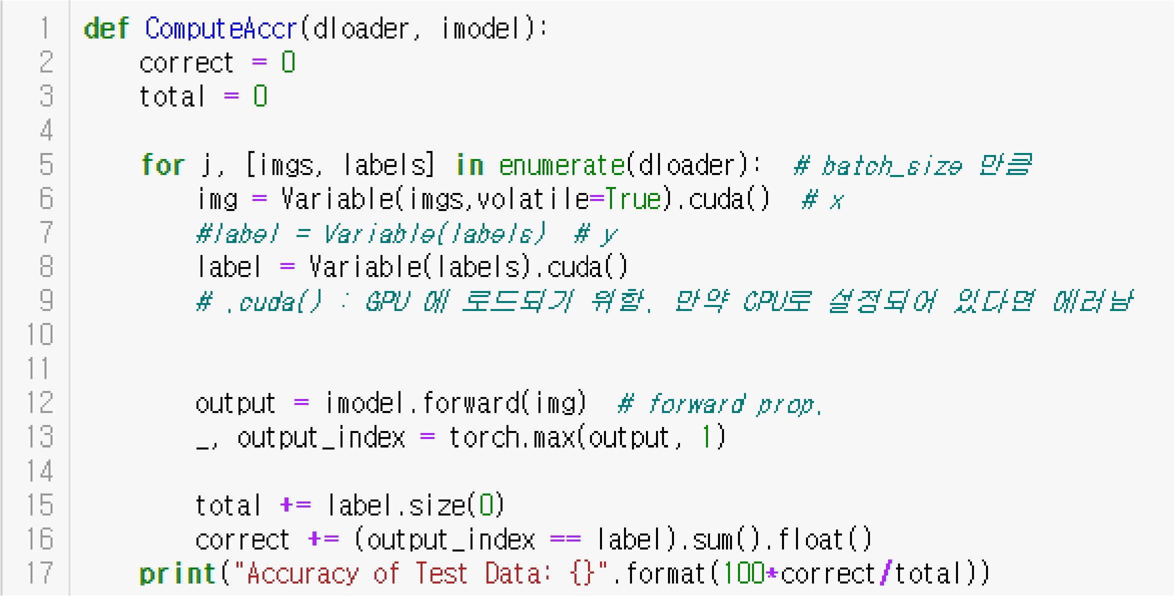
## 2. 대략적인 데이터 형태



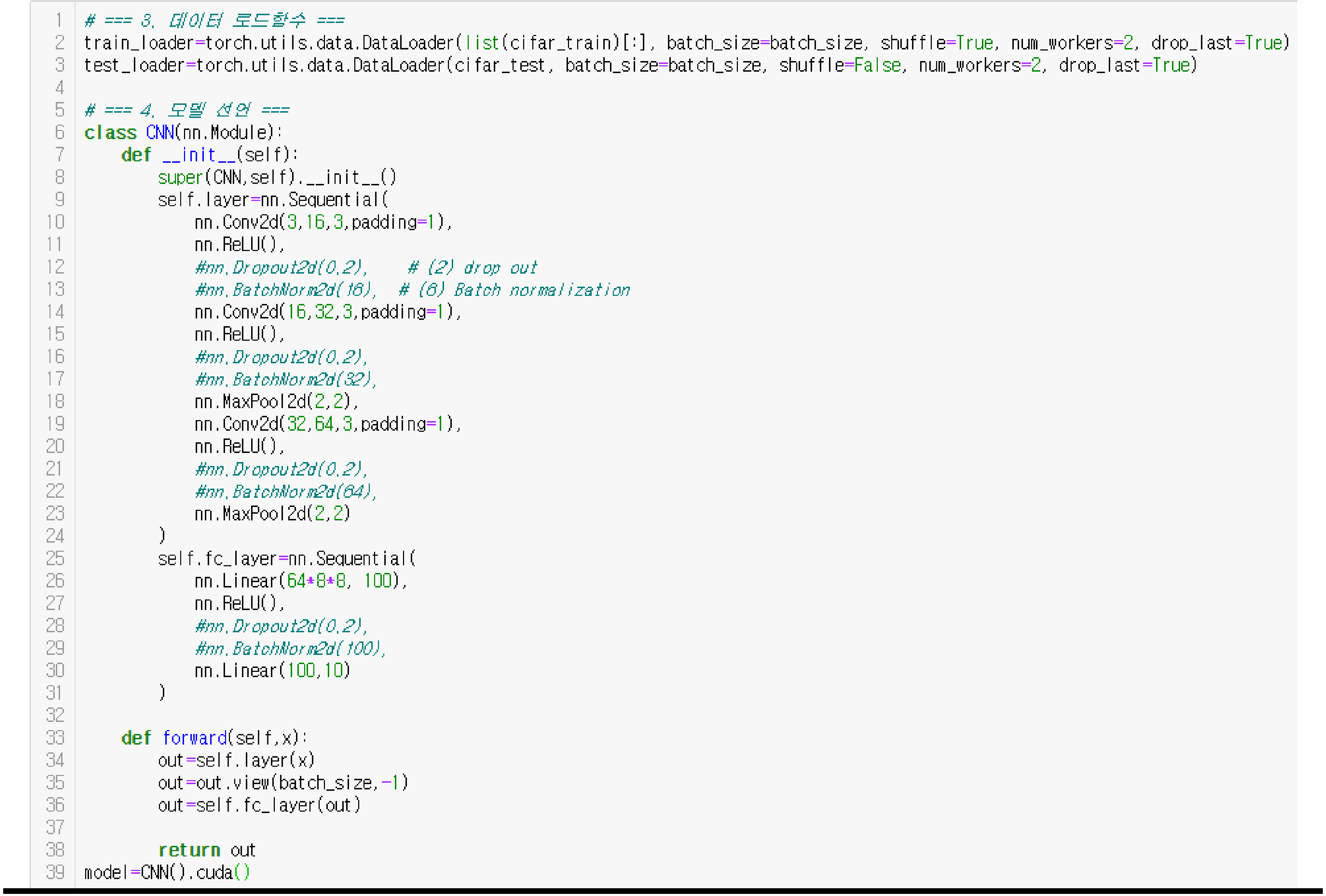
```
print "cifar_train 길이:", len(cifar_train)
print "cifar_test 길이:", len(cifar_test)

# 데이터 하나 형태
image, label = cifar_train.__getitem__(1)  # 1번째 데이터
print "image data 형태:", image.size()
print "label: ", label

# 그리기
img = image.numpy()  # image 타입을 numpy 로 변환 (3,32,32)

# (3,32,32) -> (32,32,3)
r,g,b = img[0,:,:], img[1,:,:], img[2,:,:]
#img = img.reshape(img.shape[1], img.shape[2], img.shape[0])
img2 = np.zeros((img.shape[1], img.shape[2], img.shape[0]))
img2[:,:,0], img2[:,:,1], img2[:,:,2] = r,g,b

plt.title("label: %d" %label )
plt.imshow(img2,interpolation='bicubic')
plt.show()
```

```
cifar_train 길이: 50000
cifar_test 길이: 10000
image data 형태: torch.Size([3, 32, 32])
label:  9
```

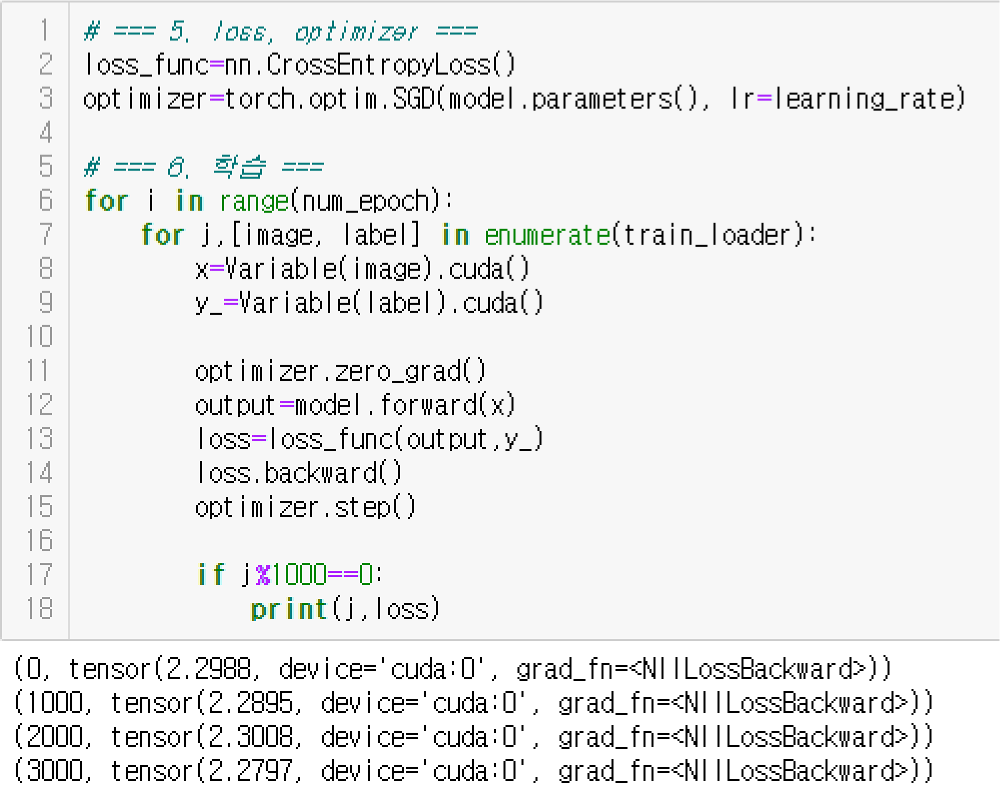




```python
def ComputeAccr(dloader, imodel):
    correct = 0
    total = 0

    for j, [imgs, labels] in enumerate(dloader):  # batch_size 만큼
        img = Variable(imgs,volatile=True).cuda()  # x
        #label = Variable(labels)  # y
        label = Variable(labels).cuda()
        # .cuda() : GPU 에 로드되기 위함. 만약 CPU로 설정되어 있다면 에러남


        output = imodel.forward(img)  # forward prop.
        _, output_index = torch.max(output, 1)

        total += label.size(0)
        correct += (output_index == label).sum().float()
    print("Accuracy of Test Data: {}".format(100*correct/total))
```

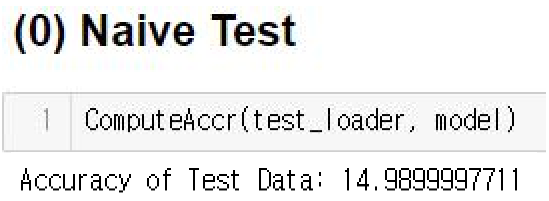


```
# === 3. 데이터 로드함수 ===
train_loader=torch.utils.data.DataLoader(list(cifar_train)[:], batch_size=batch_size, shuffle=True, num_workers=2, drop_last=True)
test_loader=torch.utils.data.DataLoader(cifar_test, batch_size=batch_size, shuffle=False, num_workers=2, drop_last=True)

# === 4. 모델 선언 ===
class CNN(nn.Module):
    def __init__(self):
        super(CNN,self).__init__()
        self.layer=nn.Sequential(
            nn.Conv2d(3,16,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),     # (2) drop out
            #nn.BatchNorm2d(16),  # (6) Batch normalization
            nn.Conv2d(16,32,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(32),
            nn.MaxPool2d(2,2),
            nn.Conv2d(32,64,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(64),
            nn.MaxPool2d(2,2)
        )
        self.fc_layer=nn.Sequential(
            nn.Linear(64*8*8, 100),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(100),
            nn.Linear(100,10)
        )

    def forward(self,x):
        out=self.layer(x)
        out=out.view(batch_size,-1)
        out=self.fc_layer(out)

        return out
model=CNN().cuda()
```



```
# === 5. loss, optimizer ===
loss_func=nn.CrossEntropyLoss()
optimizer=torch.optim.SGD(model.parameters(), lr=learning_rate)

# === 6. 학습 ===
for i in range(num_epoch):
    for j,[image, label] in enumerate(train_loader):
        x=Variable(image).cuda()
        y_=Variable(label).cuda()

        optimizer.zero_grad()
        output=model.forward(x)
        loss=loss_func(output,y_)
        loss.backward()
        optimizer.step()

        if j%1000==0:
            print(j,loss)
```

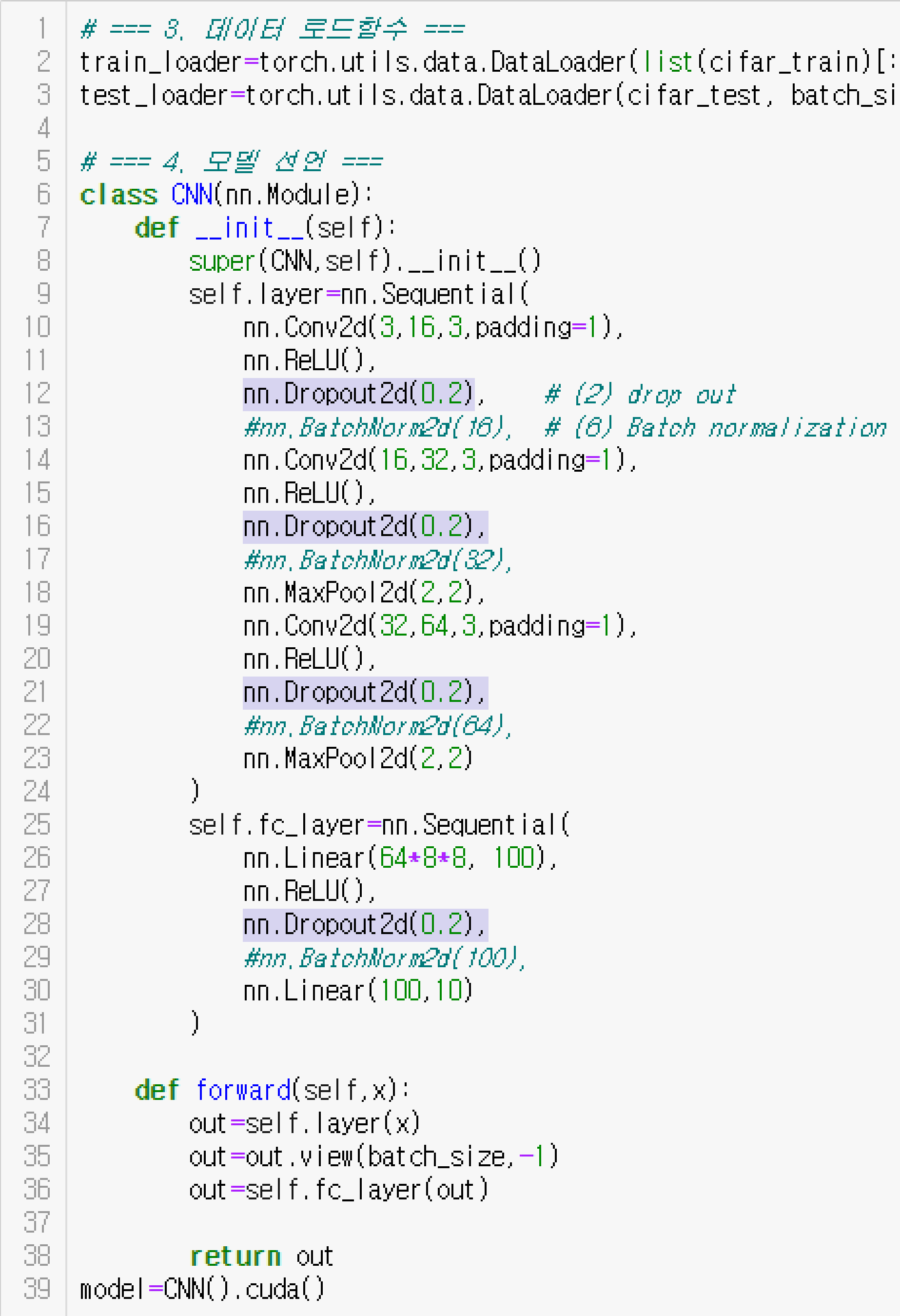
```
(0, tensor(2.2988, device='cuda:0', grad_fn=<NllLossBackward>))
(1000, tensor(2.2895, device='cuda:0', grad_fn=<NllLossBackward>))
(2000, tensor(2.3008, device='cuda:0', grad_fn=<NllLossBackward>))
(3000, tensor(2.2797, device='cuda:0', grad_fn=<NllLossBackward>))
```



## (0) Naive Test

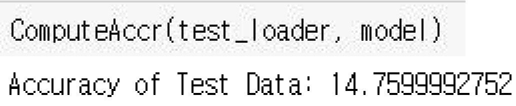
```
ComputeAccr(test_loader, model)
```

```
Accuracy of Test Data: 14.9899997711
```



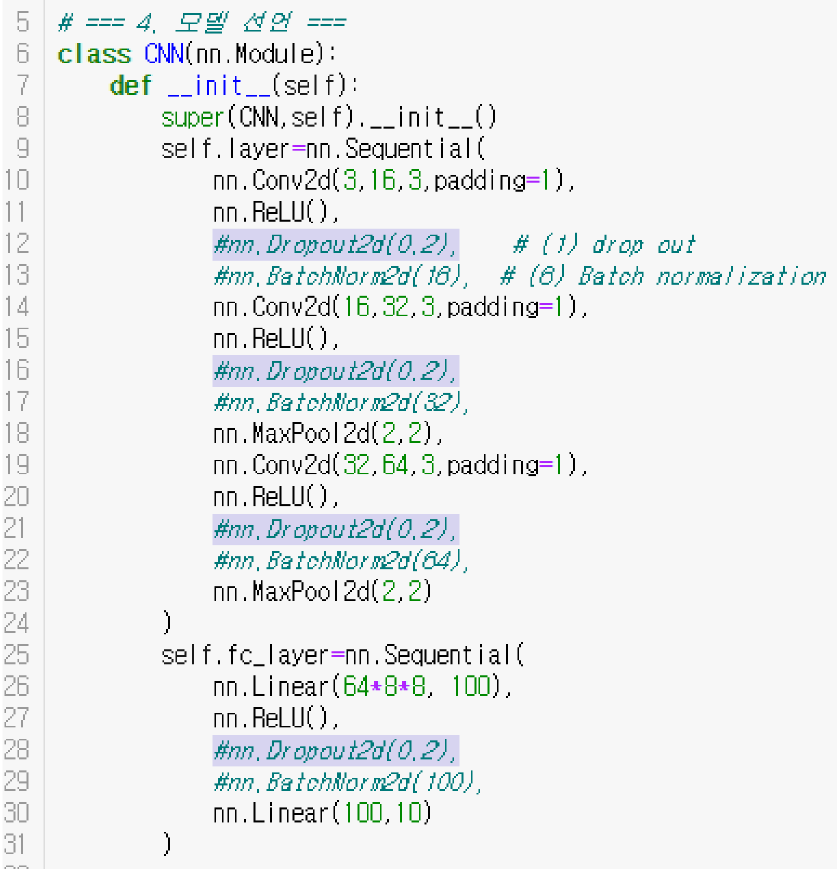
```
# === 3. 데이터 로드함수 ===
train_loader=torch.utils.data.DataLoader(list(cifar_train)[:
test_loader=torch.utils.data.DataLoader(cifar_test, batch_si

# === 4. 모델 선언 ===
class CNN(nn.Module):
    def __init__(self):
        super(CNN,self).__init__()
        self.layer=nn.Sequential(
            nn.Conv2d(3,16,3,padding=1),
            nn.ReLU(),
            nn.Dropout2d(0.2),     # (2) drop out
            #nn.BatchNorm2d(16),   # (6) Batch normalization
            nn.Conv2d(16,32,3,padding=1),
            nn.ReLU(),
            nn.Dropout2d(0.2),
            #nn.BatchNorm2d(32),
            nn.MaxPool2d(2,2),
            nn.Conv2d(32,64,3,padding=1),
            nn.ReLU(),
            nn.Dropout2d(0.2),
            #nn.BatchNorm2d(64),
            nn.MaxPool2d(2,2)
        )
        self.fc_layer=nn.Sequential(
            nn.Linear(64*8*8, 100),
            nn.ReLU(),
            nn.Dropout2d(0.2),
            #nn.BatchNorm2d(100),
            nn.Linear(100,10)
        )

    def forward(self,x):
        out=self.layer(x)
        out=out.view(batch_size,-1)
        out=self.fc_layer(out)

        return out
model=CNN().cuda()
```

## (1) drop out



```
ComputeAccr(test_loader, model)
Accuracy of Test Data: 14.7599992752
```

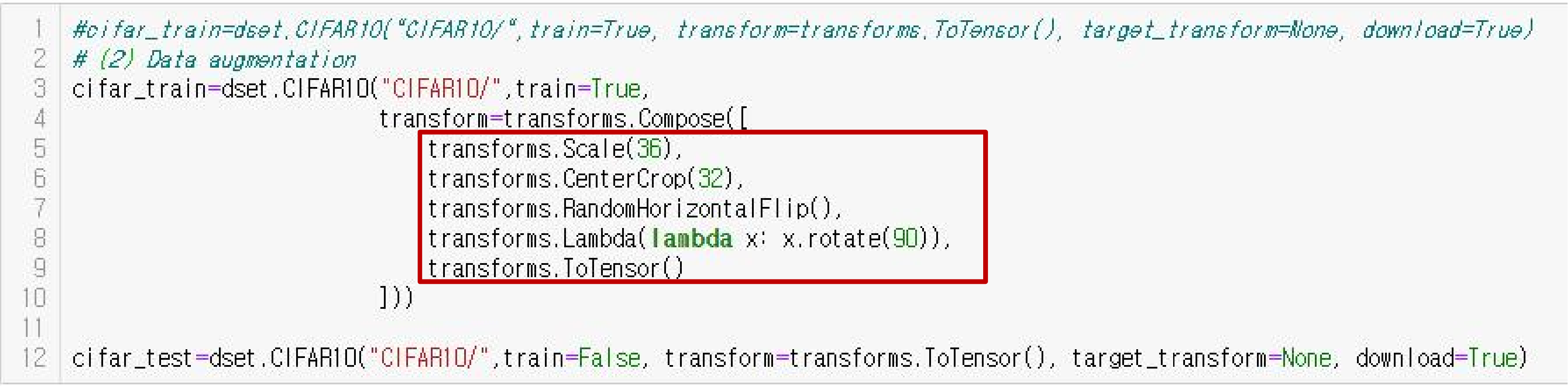
- (1) 에 바뀐 것 원상 복귀할 것
- (2)~마지막 까지 같은 방식으로 원상 복귀 후 실험 권장



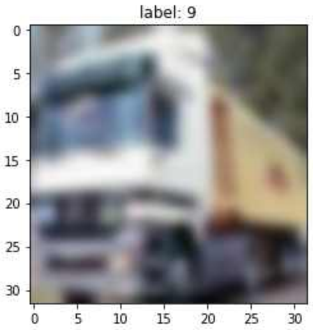
```
# === 4. 모델 선언 ===
class CNN(nn.Module):
    def __init__(self):
        super(CNN,self).__init__()
        self.layer=nn.Sequential(
            nn.Conv2d(3,16,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),     # (1) drop out
            #nn.BatchNorm2d(16),  # (6) Batch normalization
            nn.Conv2d(16,32,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(32),
            nn.MaxPool2d(2,2),
            nn.Conv2d(32,64,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(64),
            nn.MaxPool2d(2,2)
        )
        self.fc_layer=nn.Sequential(
            nn.Linear(64*8*8, 100),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(100),
            nn.Linear(100,10)
        )
```

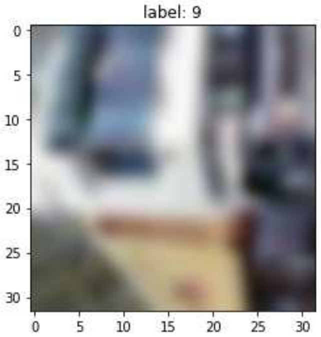
# 1. CIFAR10 train, test dataset 가져오기 (163 MB)

MNIST: 11MB

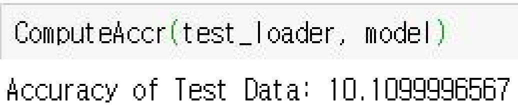


```
#cifar_train=dset.CIFAR10("CIFAR10/",train=True, transform=transforms.ToTensor(), target_transform=None, download=True)
# (2) Data augmentation
cifar_train=dset.CIFAR10("CIFAR10/",train=True,
                         transform=transforms.Compose([
                             transforms.Scale(36),
                             transforms.CenterCrop(32),
                             transforms.RandomHorizontalFlip(),
                             transforms.Lambda(lambda x: x.rotate(90)),
                             transforms.ToTensor()
                         ]))

cifar_test=dset.CIFAR10("CIFAR10/",train=False, transform=transforms.ToTensor(), target_transform=None, download=True)
```



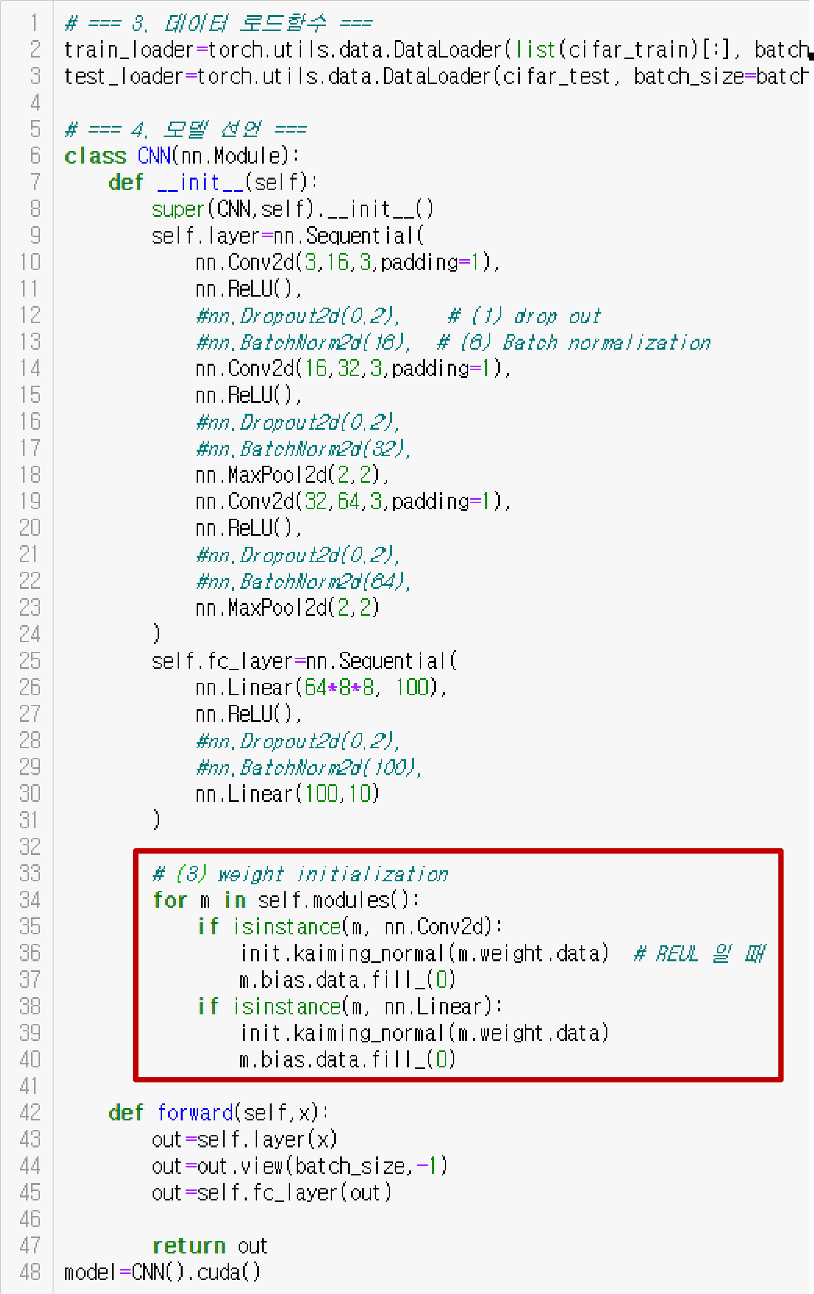


## (2) Data augmentation

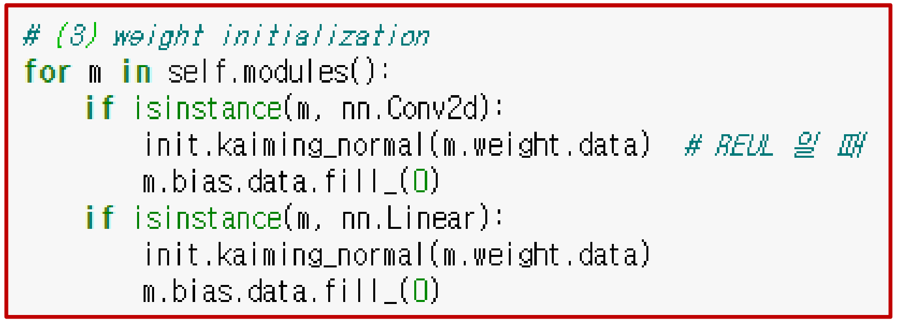


```
ComputeAccr(test_loader, model)
```

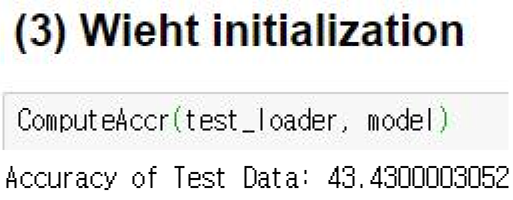
```
Accuracy of Test Data: 10.1099996567
```



```
# === 3. 데이터 로드함수 ===
train_loader=torch.utils.data.DataLoader(list(cifar_train)[:], batch
test_loader=torch.utils.data.DataLoader(cifar_test, batch_size=batch

# === 4. 모델 선언 ===
class CNN(nn.Module):
    def __init__(self):
        super(CNN,self).__init__()
        self.layer=nn.Sequential(
            nn.Conv2d(3,16,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),    # (1) drop out
            #nn.BatchNorm2d(16),   # (6) Batch normalization
            nn.Conv2d(16,32,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(32),
            nn.MaxPool2d(2,2),
            nn.Conv2d(32,64,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(64),
            nn.MaxPool2d(2,2)
        )
        self.fc_layer=nn.Sequential(
            nn.Linear(64*8*8, 100),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            #nn.BatchNorm2d(100),
            nn.Linear(100,10)
        )

        # (3) weight initialization
        for m in self.modules():
            if isinstance(m, nn.Conv2d):
                init.kaiming_normal(m.weight.data)  # REUL 일 때
                m.bias.data.fill_(0)
            if isinstance(m, nn.Linear):
                init.kaiming_normal(m.weight.data)
                m.bias.data.fill_(0)

    def forward(self,x):
        out=self.layer(x)
        out=out.view(batch_size,-1)
        out=self.fc_layer(out)

        return out
model=CNN().cuda()
```



```
# (3) weight initialization
for m in self.modules():
    if isinstance(m, nn.Conv2d):
        init.kaiming_normal(m.weight.data)  # REUL 일 때
        m.bias.data.fill_(0)
    if isinstance(m, nn.Linear):
        init.kaiming_normal(m.weight.data)
        m.bias.data.fill_(0)
```



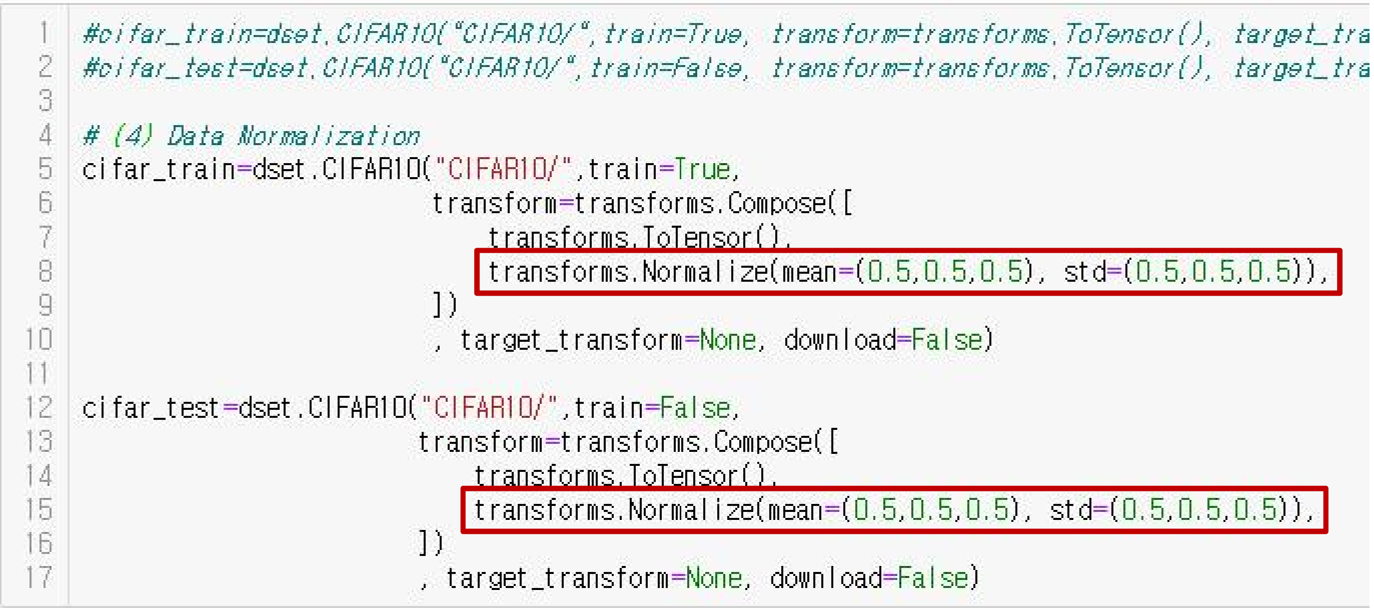
## (3) Wieht initialization

```
ComputeAccr(test_loader, model)
```

```
Accuracy of Test Data: 43.4300003052
```

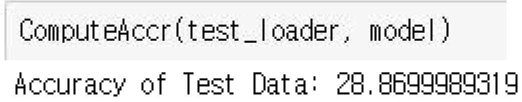
# 1. CIFAR10 train, test dataset 가져오기 (163 MB)

MNIST: 11MB



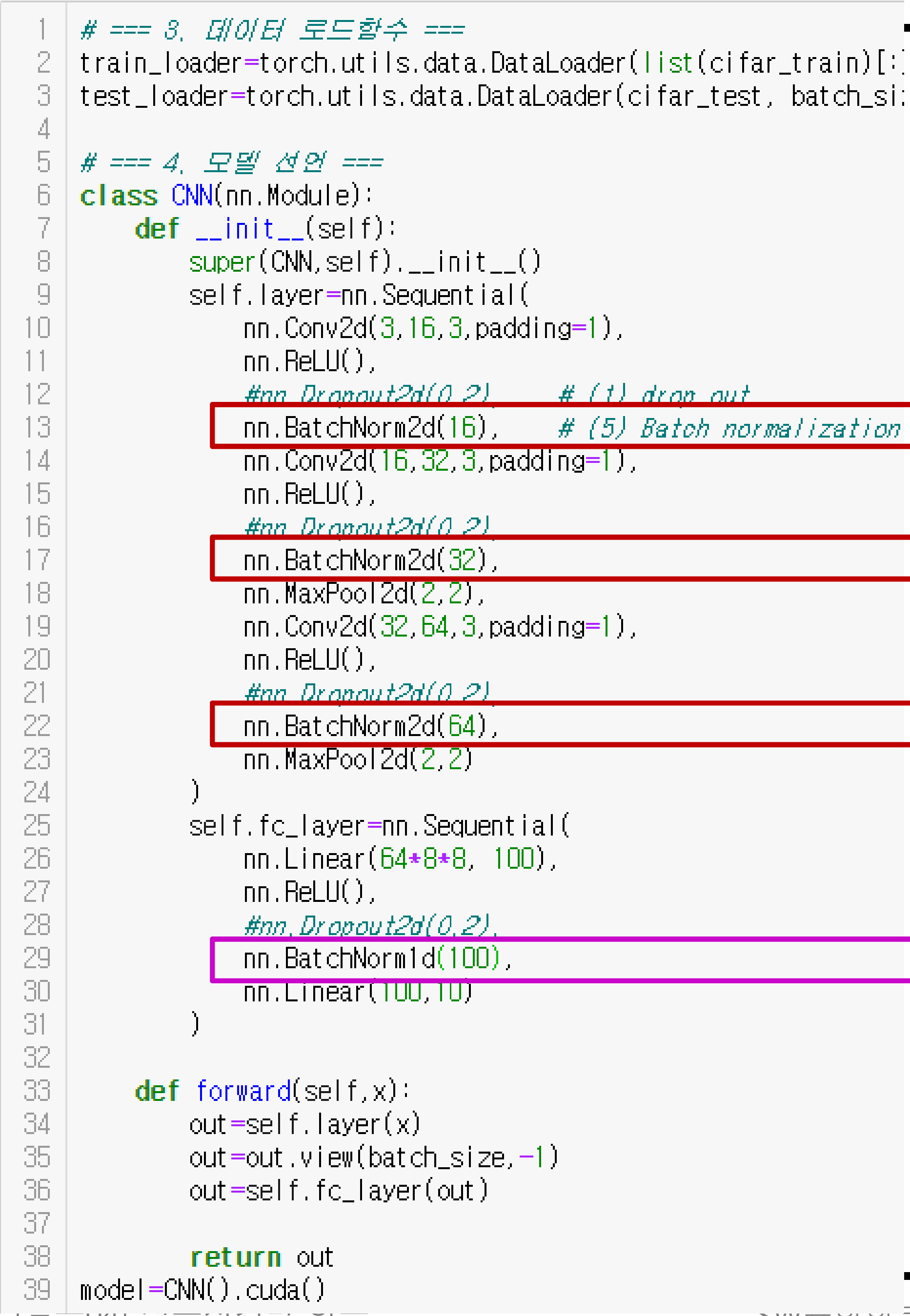
```
#cifar_train=dset.CIFAR10("CIFAR10/",train=True, transform=transforms.ToTensor(), target_tra
#cifar_test=dset.CIFAR10("CIFAR10/",train=False, transform=transforms.ToTensor(), target_tra

# (4) Data Normalization
cifar_train=dset.CIFAR10("CIFAR10/",train=True,
                         transform=transforms.Compose([
                             transforms.ToTensor(),
                             transforms.Normalize(mean=(0.5,0.5,0.5), std=(0.5,0.5,0.5)),
                         ])
                         , target_transform=None, download=False)

cifar_test=dset.CIFAR10("CIFAR10/",train=False,
                        transform=transforms.Compose([
                            transforms.ToTensor(),
                            transforms.Normalize(mean=(0.5,0.5,0.5), std=(0.5,0.5,0.5)),
                        ])
                        , target_transform=None, download=False)
```

## (4) Data Normalization



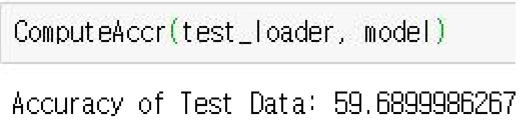
```
ComputeAccr(test_loader, model)
```

```
Accuracy of Test Data: 28.8699989319
```

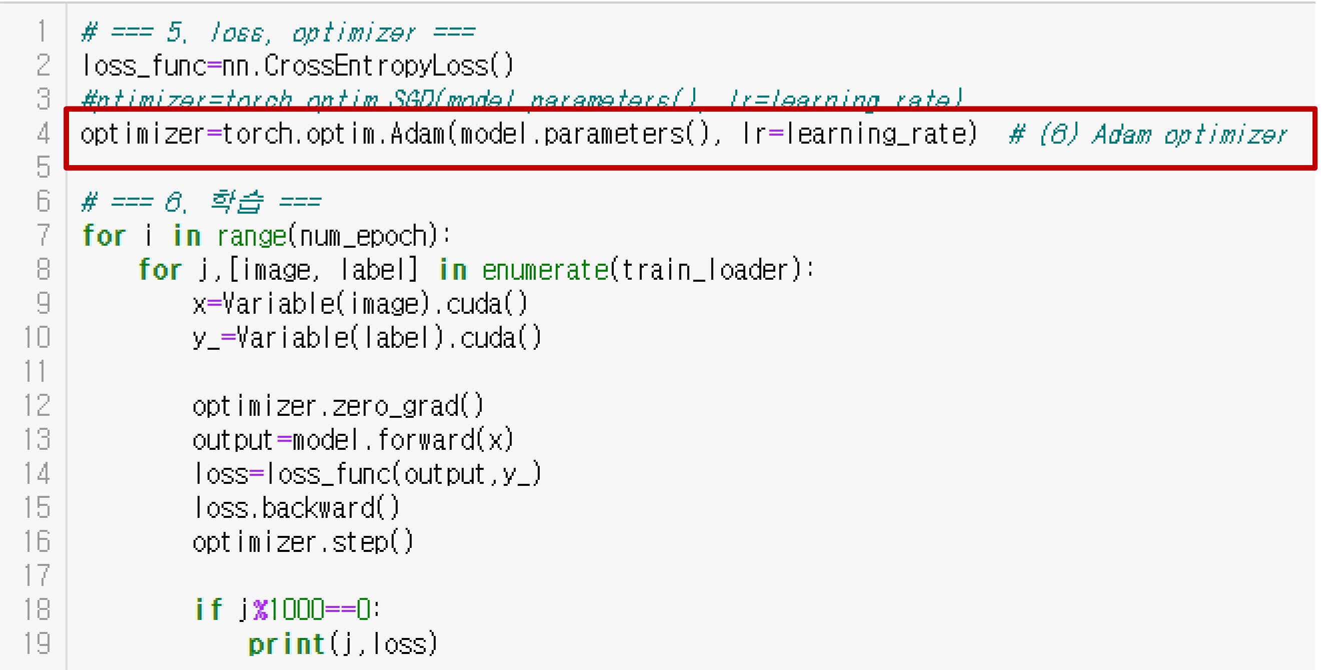


```
# === 3. 데이터 로드함수 ===
train_loader=torch.utils.data.DataLoader(list(cifar_train)[:
test_loader=torch.utils.data.DataLoader(cifar_test, batch_si

# === 4. 모델 선언 ===
class CNN(nn.Module):
    def __init__(self):
        super(CNN,self).__init__()
        self.layer=nn.Sequential(
            nn.Conv2d(3,16,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2)      # (1) drop out
            nn.BatchNorm2d(16),     # (5) Batch normalization
            nn.Conv2d(16,32,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2)
            nn.BatchNorm2d(32),
            nn.MaxPool2d(2,2),
            nn.Conv2d(32,64,3,padding=1),
            nn.ReLU(),
            #nn.Dropout2d(0.2)
            nn.BatchNorm2d(64),
            nn.MaxPool2d(2,2)
        )
        self.fc_layer=nn.Sequential(
            nn.Linear(64*8*8, 100),
            nn.ReLU(),
            #nn.Dropout2d(0.2),
            nn.BatchNorm1d(100),
            nn.Linear(100,10)
        )

    def forward(self,x):
        out=self.layer(x)
        out=out.view(batch_size,-1)
        out=self.fc_layer(out)

        return out
model=CNN().cuda()
```

## (5) Batch normalization

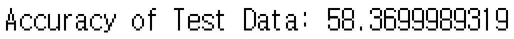


```
ComputeAccr(test_loader, model)

Accuracy of Test Data: 59.6899986267
```

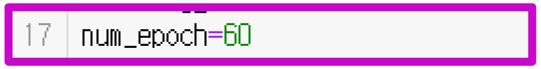


```
# === 5. loss, optimizer ===
loss_func=nn.CrossEntropyLoss()
#optimizer=torch.optim.SGD(model.parameters(), lr=learning_rate)
optimizer=torch.optim.Adam(model.parameters(), lr=learning_rate)  # (6) Adam optimizer

# === 6. 학습 ===
for i in range(num_epoch):
    for j,[image, label] in enumerate(train_loader):
        x=Variable(image).cuda()
        y_=Variable(label).cuda()

        optimizer.zero_grad()
        output=model.forward(x)
        loss=loss_func(output,y_)
        loss.backward()
        optimizer.step()

        if j%1000==0:
            print(j,loss)
```

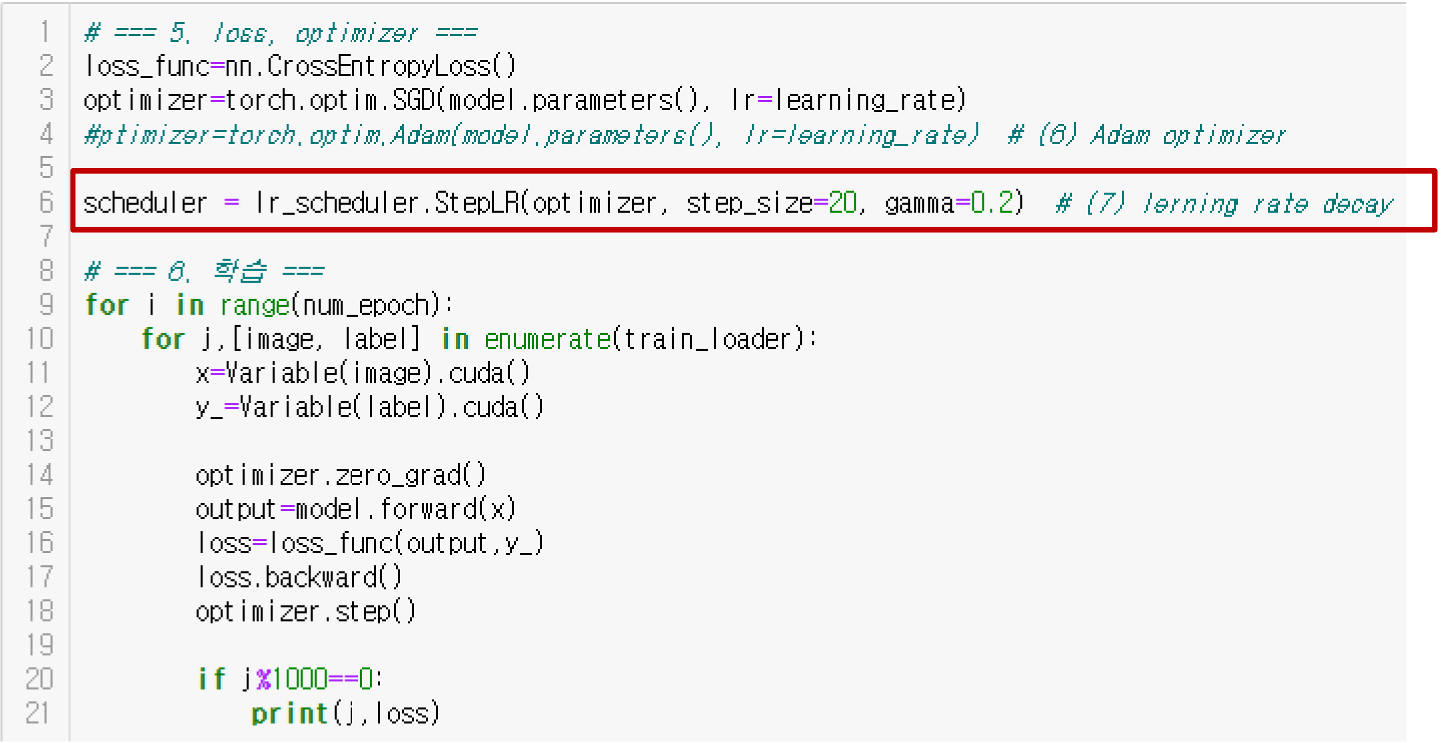
## (6) Adam optimizer



```
Accuracy of Test Data: 58.3699989319
```

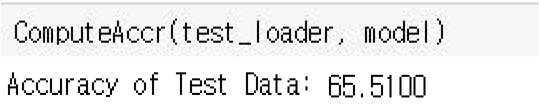


```
num_epoch=60
```



```
# === 5. loss, optimizer ===
loss_func=nn.CrossEntropyLoss()
optimizer=torch.optim.SGD(model.parameters(), lr=learning_rate)
#ptimizer=torch.optim.Adam(model.parameters(), lr=learning_rate)  # (6) Adam optimizer

scheduler = lr_scheduler.StepLR(optimizer, step_size=20, gamma=0.2)  # (7) lerning rate decay

# === 6. 학습 ===
for i in range(num_epoch):
    for j,[image, label] in enumerate(train_loader):
        x=Variable(image).cuda()
        y_=Variable(label).cuda()

        optimizer.zero_grad()
        output=model.forward(x)
        loss=loss_func(output,y_)
        loss.backward()
        optimizer.step()

        if j%1000==0:
            print(j,loss)
```

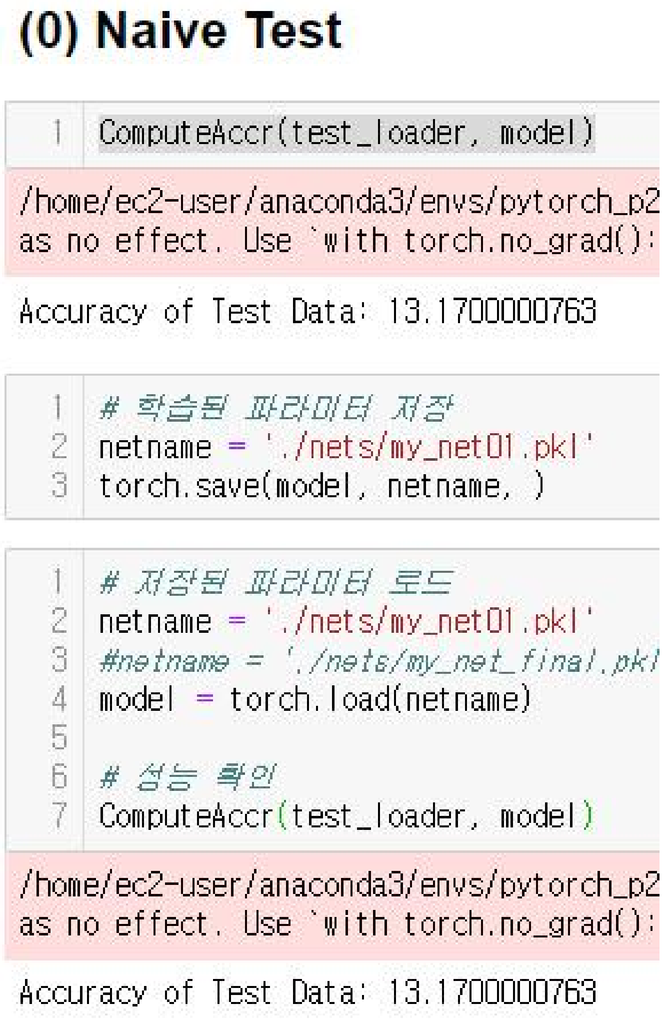
## (7) learning rate decay



```
ComputeAccr(test_loader, model)
Accuracy of Test Data: 65.5100
```

# 성능 측정 전/후 저장 & 로드 후 테스트

- 모델 파라미터 저장
  - 성능 측정 전 or 후에 파라미터 저장
- 저장된 모델 로드 후 성능 확인



(0) Naive Test

```
ComputeAccr(test_loader, model)
```

```
/home/ec2-user/anaconda3/envs/pytorch_p2
as no effect. Use `with torch.no_grad():
```

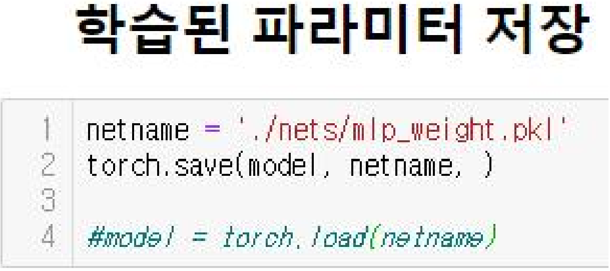
```
Accuracy of Test Data: 13.1700000763
```

```
# 학습된 파라미터 저장
netname = './nets/my_net01.pkl'
torch.save(model, netname, )
```

```
# 저장된 파라미터 로드
netname = './nets/my_net01.pkl'
#netname = './nets/my_net_final.pkl
model = torch.load(netname)

# 성능 확인
ComputeAccr(test_loader, model)
```

```
/home/ec2-user/anaconda3/envs/pytorch_p2
as no effect. Use `with torch.no_grad():
```

```
Accuracy of Test Data: 13.1700000763
```



학습된 파라미터 저장

```
netname = './nets/mlp_weight.pkl'
torch.save(model, netname, )

#model = torch.load(netname)
```