1. Data

In [2]:

```
from matplotlib import pyplot as plt
import numpy as np
from torchvision import transforms, datasets
import torch
import torch.nn as nn
import torch.optim as optim
import torch.nn.functional as F
from torch.autograd import Variable
```

In [3]:

```
transform = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((0.1307,),(0.3081,)),  # mean value = 0.1307, standard deviation value = 0.3081
])
```

In [4]:

```
batch_size = 32
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=True, download=False, transform=transforms.ToTensor()),
    batch_size = batch_size, shuffle=True)
```

In [5]:

```
test_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=False, transform=transforms.ToTensor()),
    batch_size= batch_size)
```

2. Model

In [167]:

```
class classification(nn.Module):
    def __init__(self):
        super(classification, self).__init__()

        # construct layers for a neural network
        self.classifier1 = nn.Sequential(
            nn.Linear(in_features=28*28, out_features=20*20),
            nn.Sigmoid(),
        )
        self.classifier2 = nn.Sequential(
            nn.Linear(in_features=20*20, out_features=10*10),
            nn.Sigmoid(),
        )
        self.classifier3 = nn.Sequential(
            nn.Linear(in_features=10*10, out_features=10),
            nn.LogSoftmax(dim=1),
        )


    def forward(self, inputs):                # [batchSize, 1, 28, 28]
        x = inputs.view(inputs.size(0), -1)    # [batchSize, 28*28]
        x = self.classifier1(x)                # [batchSize, 20*20]
        x = self.classifier2(x)                # [batchSize, 10*10]
        out = self.classifier3(x)              # [batchSize, 10]

        return out

model = classification()
model
```

Out[167]:

```
classification(
  (classifier1): Sequential(
    (0): Linear(in_features=784, out_features=400, bias=True)
    (1): Sigmoid()
  )
  (classifier2): Sequential(
    (0): Linear(in_features=400, out_features=100, bias=True)
    (1): Sigmoid()
  )
  (classifier3): Sequential(
    (0): Linear(in_features=100, out_features=10, bias=True)
    (1): LogSoftmax(dim=1)
  )
)
```

3. 학습

1) batch = 32

In [163]:

```
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=True, download=False, transform=transforms.ToTensor()),
    batch_size=32, shuffle=True)

test_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=False, transform=transforms.ToTensor()),
    batch_size=32)
```

In [168]:

```
criterion = nn.NLLLoss()
optimizer = torch.optim.SGD(model.parameters(), lr = 0.005)
```

In [ ]:

```
model.train()
train_loss = []
train_accu = []

test_loss = []
test_accu = []

for epoch in range(50):
    # train data
    for data, target in train_loader:
        data, target = Variable(data), Variable(target)
        optimizer.zero_grad()

        output = model(data)
        loss = F.nll_loss(output, target)
        loss.backward()
        optimizer.step()

        prediction = output.data.max(1)[1]
        accuracy = prediction.eq(target.data).sum() / 32 * 100

    # test_data
    correct = 0
    total = 0
    with torch.no_grad():
        for data in test_loader:
            images, labels = data
            outputs = model(images)
            _, predicted = torch.max(outputs.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
            test_accuracy = correct / total * 100
            t_loss = F.nll_loss(outputs, labels)

    print('Train₩t epoch: {}₩tLoss: {:.3f}₩tAccuracy: {:.3f}'.format(epoch, loss.data, accuracy))
    print('Test₩t epoch: {}₩tLoss: {:.3f}₩tAccuracy: {:.3f}'.format(epoch, t_loss.data, test_accuracy))

    # save info
    train_accu.append(accuracy)
```

```
    train_loss.append(loss.data)
    test_accu.append(test_accuracy)
    test_loss.append(t_loss.data)
```

2) batch = 64

- 모델 초기화

In [203]:

```
model = classification()
model
```

Out[203]:

```
classification(
  (classifier1): Sequential(
    (0): Linear(in_features=784, out_features=400, bias=True)
    (1): Sigmoid()
  )
  (classifier2): Sequential(
    (0): Linear(in_features=400, out_features=100, bias=True)
    (1): Sigmoid()
  )
  (classifier3): Sequential(
    (0): Linear(in_features=100, out_features=10, bias=True)
    (1): LogSoftmax(dim=1)
  )
)
```

In [204]:

```
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=True, download=False, transform=transforms.ToTensor()),
    batch_size=64, shuffle=True)

test_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=False, transform=transforms.ToTensor()),
    batch_size=64)

criterion = nn.NLLLoss()
optimizer = torch.optim.SGD(model.parameters(), lr = 0.003)
```

In [ ]:

```
model.train()
train_loss_64 = []
train_accu_64 = []

test_loss_64 = []
test_accu_64 = []

for epoch in range(50):
    # train data
    for data, target in train_loader:
        data, target = Variable(data), Variable(target)
        optimizer.zero_grad()

        output = model(data)
        loss = F.nll_loss(output, target)
        loss.backward()
        optimizer.step()

        prediction = output.data.max(1)[1]
        accuracy = prediction.eq(target.data).sum() / 64 * 100

    # test_data
    correct = 0
    total = 0
    with torch.no_grad():
        for data in test_loader:
            images, labels = data
            outputs = model(images)
            _, predicted = torch.max(outputs.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
            test_accuracy = correct / total * 100
            t_loss = F.nll_loss(outputs, labels)

    print('Train₩t epoch: {}₩tLoss: {:.3f}₩tAccuracy: {:.3f}'.format(epoch, loss.data, accuracy))
    print('Test₩t epoch: {}₩tLoss: {:.3f}₩tAccuracy: {:.3f}'.format(epoch, t_loss.data, test_accuracy))

    # save info
    train_accu_64.append(accuracy)
```

```
    train_loss_64.append(loss.data)
    test_accu_64.append(test_accuracy)
    test_loss_64.append(t_loss.data)
```

3) batch = 128

- 모델 초기화

In [226]:

```
model = classification()
model
```

Out[226]:

```
classification(
  (classifier1): Sequential(
    (0): Linear(in_features=784, out_features=400, bias=True)
    (1): Sigmoid()
  )
  (classifier2): Sequential(
    (0): Linear(in_features=400, out_features=100, bias=True)
    (1): Sigmoid()
  )
  (classifier3): Sequential(
    (0): Linear(in_features=100, out_features=10, bias=True)
    (1): LogSoftmax(dim=1)
  )
)
```

In [227]:

```
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=True, download=False, transform=transforms.ToTensor()),
    batch_size=128, shuffle=True)

test_loader = torch.utils.data.DataLoader(
    datasets.MNIST('MNIST', train=False, transform=transforms.ToTensor()),
    batch_size=128)

criterion = nn.NLLLoss()
optimizer = torch.optim.SGD(model.parameters(), lr = 0.003)
```

In [ ]:

```
model.train()
train_loss_128 = []
train_accu_128 = []

test_loss_128 = []
test_accu_128 = []

for epoch in range(50):
    # train data
    for data, target in train_loader:
        data, target = Variable(data), Variable(target)
        optimizer.zero_grad()

        output = model(data)
        loss = F.nll_loss(output, target)
        loss.backward()
        optimizer.step()

        prediction = output.data.max(1)[1]
        accuracy = prediction.eq(target.data).sum() / 128 * 100

    # test_data
    correct = 0
    total = 0
    with torch.no_grad():
        for data in test_loader:
            images, labels = data
            outputs = model(images)
            _, predicted = torch.max(outputs.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
            test_accuracy = correct / total * 100
            t_loss = F.nll_loss(outputs, labels)

    print('Train₩t epoch: {}₩tLoss: {:.3f}₩tAccuracy: {:.3f}'.format(epoch, loss.data, accuracy))
    print('Test₩t epoch: {}₩tLoss: {:.3f}₩tAccuracy: {:.3f}'.format(epoch, t_loss.data, test_accuracy))

    # save info
    train_accu_128.append(accuracy)
```

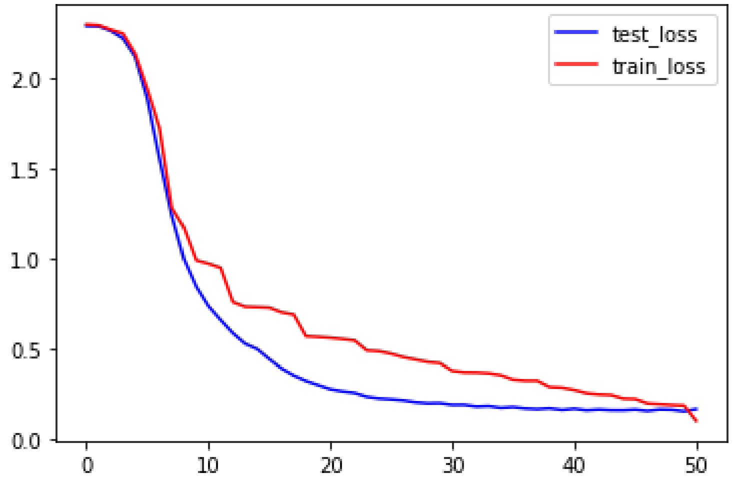
```
    train_loss_128.append(loss.data)
    test_accu_128.append(test_accuracy)
    test_loss_128.append(t_loss.data)
```

Output

1. Plot the training and testing losses with a batch size of 32 [4pt]

In [181]:

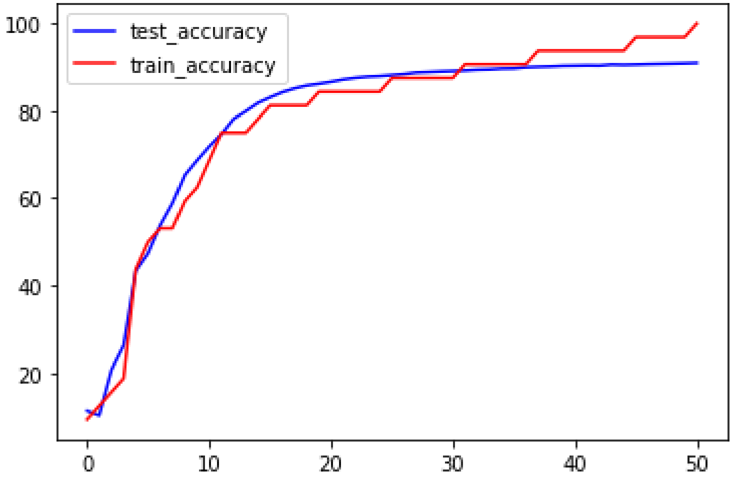
```
plt.plot([i for i in range(len(test_loss))], test_loss, c = 'blue', label = 'test_loss')
plt.plot([i for i in range(len(train_loss))], train_loss, c = 'red', label = 'train_loss')
plt.legend()
plt.show()
```



2. Plot the training and testing accuracies with a batch size of 32 [4pt]

In [186]:

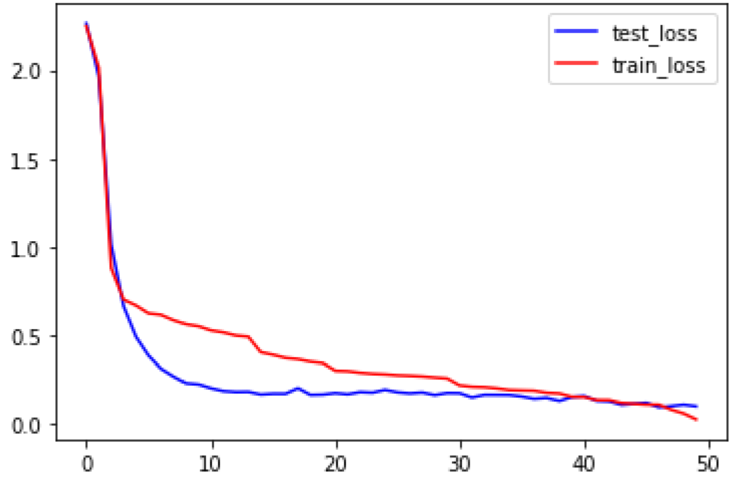
```
plt.plot([i for i in range(len(test_accu))], test_accu, c = 'blue', label = 'test_accuracy')
plt.plot([i for i in range(len(train_accu))], train_accu, c = 'red', label = 'train_accuracy')
plt.legend()
plt.show()
```



3. Plot the training and testing losses with a batch size of 64 [4pt]

In [208]:

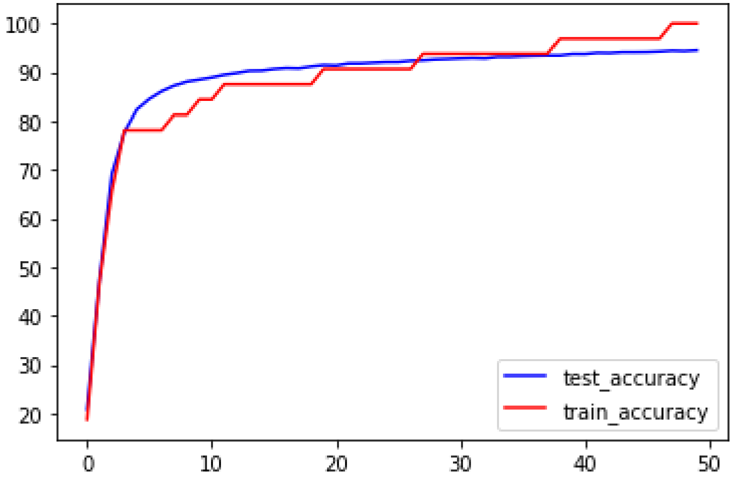
```
plt.plot([i for i in range(len(test_loss_64))], test_loss_64, c = 'blue', label = 'test_loss')
plt.plot([i for i in range(len(train_loss_64))], train_loss_64, c = 'red', label = 'train_loss')
plt.legend()
plt.show()
```



4. Plot the training and testing accuracies with a batch size of 64 [4pt]

In [211]:

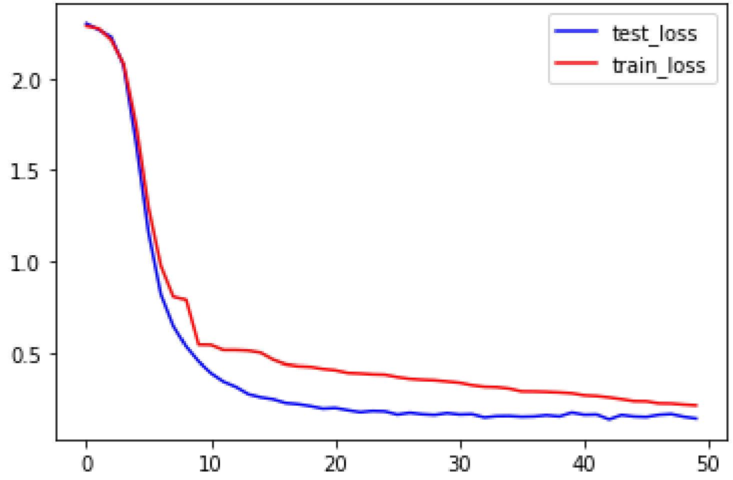
```
plt.plot([i for i in range(len(test_accu_64))], test_accu_64, c = 'blue', label = 'test_accuracy')
plt.plot([i for i in range(len(train_accu_64))], train_accu_64, c = 'red', label = 'train_accuracy')
plt.legend()
plt.show()
```



5. Plot the training and testing losses with a batch size of 128 [4pt]

In [235]:

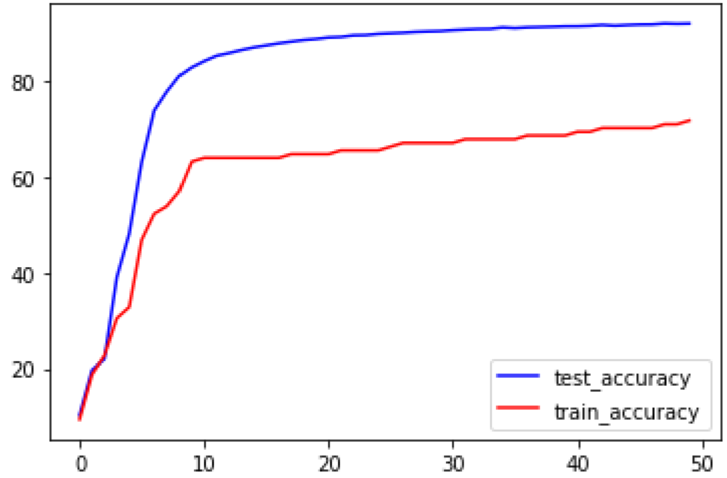
```
plt.plot([i for i in range(len(test_loss_128))], test_loss_128, c = 'blue', label = 'test_loss')
plt.plot([i for i in range(len(train_loss_128))], train_loss_128, c = 'red', label = 'train_loss')
plt.legend()
plt.show()
```



6. Plot the training and testing accuracies with a batch size of 128 [4pt]

In [234]:

```
plt.plot([i for i in range(len(test_accu_128))], test_accu_128, c = 'blue', label = 'test_accuracy')
plt.plot([i for i in range(len(train_accu_128))], train_accu_128, c = 'red', label = 'train_accuracy')
plt.legend()
plt.show()
```



7. Print the loss at convergence with different mini-batch sizes [3pt]

In [230]:

```
print('batch 32₩t training loss: {:.2f}₩t testing loss:{:.2f}'.format(train_loss[-1], test_loss[-1]))
print('batch 64₩t training loss: {:.2f}₩t testing loss:{:.2f}'.format(train_loss_64[-1], test_loss_64[-1]))
print('batch 128₩t training loss: {:.2f}₩t testing loss:{:.2f}'.format(train_loss_128[-1], test_loss_128[-1]))
```

```
batch 32         training loss: 0.06     testing loss:0.09
batch 64         training loss: 0.03     testing loss:0.09
batch 128        training loss: 0.22     testing loss:0.14
```

8. Print the accuracy at convergence with different mini-batch sizes [3pt]

In [231]:

```
print('batch 32₩t training accuracy: {:.2f}₩t testing accuracy:{:.2f}'.format(train_accu[-1], test_accu[-1]))
print('batch 64₩t training accuracy: {:.2f}₩t testing accuracy:{:.2f}'.format(train_accu_64[-1], train_accu_64[-1]))
print('batch 128₩t training accuracy: {:.2f}₩t testing accuracy:{:.2f}'.format(train_accu_128[-1], test_accu_128[-1]))
```

```
batch 32	 training accuracy: 100.00	 testing accuracy:94.26
batch 64	 training accuracy: 100.00	 testing accuracy:100.00
batch 128	 training accuracy: 71.88	 testing accuracy:92.12
```