In [1]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F
import torchvision
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
```

In [2]:
```
# Detect if we have a GPU available
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
if torch.cuda.is_available():
    print("Using the GPU!")
else:
    print("WARNING: Could not find GPU! Using CPU only")
```

```
Using the GPU!
```

In [3]:
```
x_train_images = np.load("data/x_train_images.npy")
x_test_images = np.load("data/x_test_images.npy")

x_train_images_100 = np.load("data/x_train_images_100.npy")
x_test_images_100 = np.load("data/x_test_images_100.npy")

x_train_images_50 = np.load("data/x_train_images_50.npy")
x_test_images_50 = np.load("data/x_test_images_50.npy")

y_train = np.load("data/y_train.npy")
y_test = np.load("data/y_test.npy")
print("The sample size of training set is: ", x_train_images.shape[0])
print("The sample size of testing set is: ", x_test_images.shape[0])

print(y_train.shape)
print(y_test.shape)
```

```
The sample size of training set is:  3556
The sample size of testing set is:  889
(3556, 1)
(889, 1)
```

In [4]:
```
# bridge numpy to torch
x_train_images_torch = torch.as_tensor(x_train_images).float()
x_test_images_torch = torch.as_tensor(x_test_images).float()

x_train_images_torch_100 = torch.as_tensor(x_train_images_100).float()
x_test_images_torch_100 = torch.as_tensor(x_test_images_100).float()

x_train_images_torch_50 = torch.as_tensor(x_train_images_50).float()
x_test_images_torch_50 = torch.as_tensor(x_test_images_50).float()

y_train_torch = torch.as_tensor(y_train[:,0])
y_test_torch = torch.as_tensor(y_test[:,0])
n_train = x_train_images.shape[0]
n_test = x_test_images.shape[0]
# inputs: x_train_nhts, x_train_images, x_test_nhts, x_test_images, y_tra
K = len(np.unique(y_train))
#
pd.value_counts(y_train[:,0])/y_train.shape[0]
```

Out[4]:
```
2    0.336333
1    0.325928
3    0.251969
0    0.085771
dtype: float64
```

In [5]:
```
##### Type 2: CNN with images.
# To-Do: Use GPU...
class CNN(nn.Module):
    def __init__(self):
        super(CNN, self).__init__()
        # To-Do: need to have more channels for higher accuracy.
        self.conv1 = nn.Conv2d(in_channels=4, out_channels=10, kernel_siz
        self.conv2 = nn.Conv2d(in_channels=10, out_channels=8, kernel_siz
        self.conv3 = nn.Conv2d(in_channels=8, out_channels=4, kernel_size
        # Question: Why is this 48*48 correct? bc 97//2 = 48
        self.fc11 = nn.Linear(in_features=4 * 45 * 45, out_features=64)
        self.fc12 = nn.Linear(in_features=64, out_features=128)

        self.fc21 = nn.Linear(in_features=4 * 20 * 20, out_features=64)
        self.fc22 = nn.Linear(in_features=64, out_features=128)

        self.fc31 = nn.Linear(in_features=4 * 8 * 8, out_features=64)
        self.fc32 = nn.Linear(in_features=64, out_features=128)

        self.fcFinal = nn.Linear(in_features=128*3, out_features=K)
        self.relu = F.relu
        self.pool = F.max_pool2d
        self.softmax = nn.Softmax(dim=1)
    def forward(self, x1, x2, x3):
```

```
        out = self.relu(self.conv1(x1))
        out = self.pool(out, 2)
        out = self.relu(self.conv2(out))
        out = self.pool(out, 2)
        out = self.relu(self.conv3(out))
        #print(out.shape,"out1")
        out = out.reshape(out.size(0), -1)
        out = self.relu(self.fc11(out))
        out = self.fc12(out)

        out2 = self.relu(self.conv1(x2))
        out2 = self.pool(out2, 2)
        out2 = self.relu(self.conv2(out2))
        out2 = self.pool(out2, 2)
        out2 = self.relu(self.conv3(out2))
        #print(out2.shape,"out2")
        out2 = out2.reshape(out2.size(0), -1)
        out2 = self.relu(self.fc21(out2))
        out2 = self.fc22(out2)


        out3 = self.relu(self.conv1(x3))
        out3 = self.pool(out3, 2)
        out3 = self.relu(self.conv2(out3))
        out3 = self.pool(out3, 2)
        out3 = self.relu(self.conv3(out3))
        #print(out3.shape,"out3")
        out3 = out3.reshape(out3.size(0), -1)
        out3 = self.relu(self.fc31(out3))
        out3 = self.fc32(out3)

        #print(torch.cat((torch.cat((out,out2),1),out3),1).shape)
        final_out = self.fcFinal(torch.cat((torch.cat((out,out2),1),out3)
        #print("hello")
        final_out = self.softmax(final_out)
        return final_out
```

In [6]:
```
# normalize the data
x_train_images_norm_torch = x_train_images_torch/255.0
x_test_images_norm_torch = x_test_images_torch/255.0

x_train_images_norm_torch_100 = x_train_images_torch_100/255.0
x_test_images_norm_torch_100 = x_test_images_torch_100/255.0

x_train_images_norm_torch_50 = x_train_images_torch_50/255.0
x_test_images_norm_torch_50 = x_test_images_torch_50/255.0
#
cnn_net = CNN().float().to(device)
optim = torch.optim.Adam(cnn_net.parameters(), lr=0.001)
criterion = nn.CrossEntropyLoss()
#
n_epoches = 150 # To-Do: need more epoches.
batch_size = 200
```

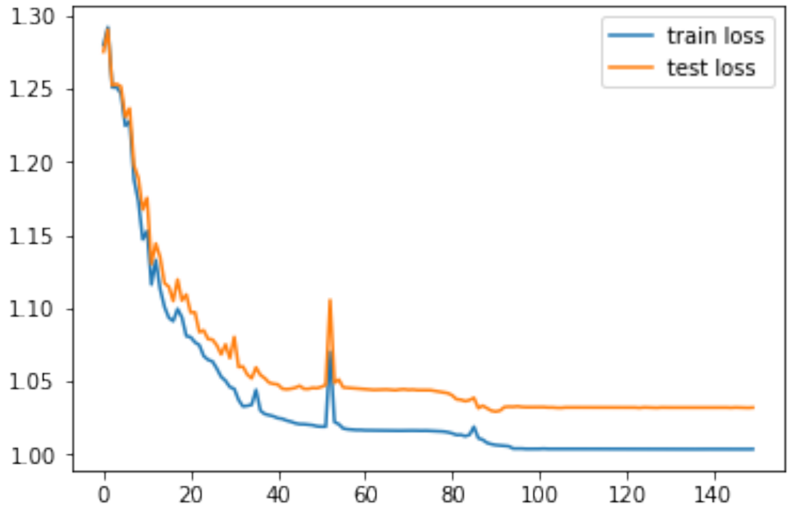
In [7]:
```
# training
train_losses = []
test_losses = []
train_accuracies = []
test_accuracies = []
for n_epoch in range(n_epoches):
    # create permutation for batch training
    # To-Do: add permutation for SGD...But it is slow.
#    permutation = torch.randperm(x_train_images_norm_torch.size()[0])
    for i in range(0, x_train_images_norm_torch.size()[0], batch_size):
        print(n_epoch, i)
        # clear gradients first (for each iteration!)!
        optim.zero_grad()
        # forward pass
        batch_x, batch_y = x_train_images_norm_torch[i:i+batch_size, :, :

        batch_x_100 = x_train_images_norm_torch_100[i:i+batch_size, :, :,
        batch_x_50 = x_train_images_norm_torch_50[i:i+batch_size, :, :, :

        batch_y_pred_train = cnn_net(batch_x,batch_x_100,batch_x_50)
        # loss
        loss = criterion(batch_y_pred_train.squeeze(), batch_y)
        # compute gradients
        loss.backward()
        # one step optim
        optim.step()

    # eval training accuracy
    with torch.no_grad():
        y_pred_train = cnn_net(x_train_images_norm_torch.to(device),x_tra
        loss_train = criterion(y_pred_train.squeeze(), y_train_torch.to(d
        train_losses.append(loss_train)
```

```
        _, predict_train = torch.max(y_pred_train, axis = 1)
        accuracy_train = (predict_train == y_train_torch.to(device)).sum(
        train_accuracies.append(accuracy_train)
        # evaluate testing sets step-wise
        cnn_net.eval()
        y_pred_test = cnn_net(x_test_images_norm_torch.to(device),x_test_

        loss_test = criterion(y_pred_test.squeeze().to(device), y_test_to
        test_losses.append(loss_test)
        _, predict_test = torch.max(y_pred_test.to(device), axis = 1)
        accuracy_test = (predict_test == y_test_torch.to(device)).sum().i
        test_accuracies.append(accuracy_test)
        # print info
        if n_epoch % 1 == 0:
            print('Epoch {}: train loss: {}; test loss: {}'.format(n_epoc
            print('Epoch {}: train accuracy: {}; test accuracy: {}'.forma


# notes:
# CPU training: about 30 mins, with SIMPLEST CNN architecture, 20 epoches
# training accuracy: 60%; testing accuracy: 60%.
```

```
0 0
0 200
0 400
0 600
0 800
0 1000
0 1200
0 1400
0 1600
0 1800
0 2000
0 2200
0 2400
0 2600
0 2800
0 3000
0 3200
0 3400
Epoch 0: train loss: 1.270066566467285; test loss: 1.27539587020874
```

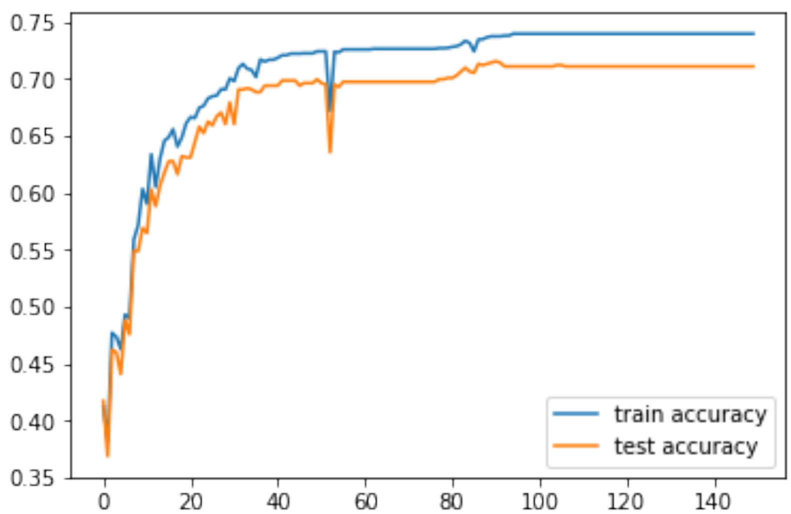
In [8]:
```
plt.plot(train_losses, label = "train loss")
plt.plot(test_losses, label = "test loss")
plt.legend()
```

Out[8]: <matplotlib.legend.Legend at 0x7f168029b2e8>



In [9]:
```
plt.plot(train_accuracies, label = "train accuracy")
plt.plot(test_accuracies, label = "test accuracy")
plt.legend()
```

Out[9]: <matplotlib.legend.Legend at 0x7f168022f390>



In [ ]:
```
torch.save(cnn_net.state_dict(), "data/cnn_gaussian_6layer")
```

In [ ]: