In [21]:
```
import numpy as np
import pandas as pd
# from mnist import MNIST
from sklearn.metrics import confusion_matrix
from sklearn.mixture import GaussianMixture
from sklearn.metrics import accuracy_score
import matplotlib.pyplot as plt
%matplotlib inline
```

In [22]:
```
# #Genarating Data Files
# mndata =  MNIST('')
```

In [23]:
```
# imgs, labels = mndata.load_training()
```

In [24]:
```
# train_data = pd.DataFrame(imgs)
# train_labels = pd.DataFrame(list(labels))
```

In [25]:
```
# imgs, labels = mndata.load_testing()
# test_data = pd.DataFrame(imgs)
# test_labels = pd.DataFrame(list(labels))
```

In [26]:
```
# train_data_subset = train_data.loc[:5999]
# train_labels_subset = train_labels.loc[:5999]
# test_data_subset = test_data.loc[:999]
# test_labels_subset = test_labels.loc[:999]
```

In [27]:
```
# train_data_subset = train_data_subset/255.0
# test_data_subset = test_data_subset/255.0
# train_data_subset = train_data_subset.round()
# test_data_subset = test_data_subset.round()
```

In [28]:
```
# train_data_subset.to_csv('mnist_train_data.csv', index=False, header=False)
# train_labels_subset.to_csv('mnist_train_labels.csv', index=False, header=False)
# test_data_subset.to_csv('mnist_test_data.csv', index=False, header=False)
# test_labels_subset.to_csv('mnist_test_labels.csv', index=False, header=False)
```

In [54]:
```
train_data = pd.read_csv('mnist_train_data.csv', header=None)
train_labels = pd.read_csv('mnist_train_labels.csv', names=['label'])
test_data = pd.read_csv('mnist_test_data.csv', header=None)
test_labels = pd.read_csv('mnist_test_labels.csv', names=['label'])
```

In [34]:
```
#Question 1
# 1 mark: correct answer
prior = train_labels.groupby(['label'])['label'].count().reset_index(drop=True)/6000
```

In [35]:
```
prior
```

Out[35]:
```
0    0.098667
1    0.111833
2    0.096833
3    0.101333
4    0.103833
5    0.085667
6    0.101333
7    0.108500
8    0.091833
9    0.100167
Name: label, dtype: float64
```

In [36]:
```
#Question 2
# -1 mark: no laplace smoothing
# -1 mark: wrong answer, correct approach
# -3 marks: wrong approach, no answer

data = pd.concat([train_data, train_labels], axis=1)
num_data = data.groupby(['label']).sum().reset_index()
del num_data['label']
num_data = num_data+1
```

In [37]:
```
denom_data = data.groupby(['label'])['label'].count().reset_index(drop=True)
denom_data = denom_data + 2
likelihood = num_data.divide(denom_data, axis=0)
```

In [38]:
```
np.log(likelihood.max(axis=1))
```

Out[38]:
```
0   -0.160343
1   -0.014970
2   -0.316098
3   -0.212950
4   -0.162990
5   -0.340745
6   -0.163484
7   -0.229673
8   -0.133273
9   -0.142336
dtype: float64
```

In [39]:
```
test_data_values = test_data.values.tolist()
```

In [40]:
```
likelihood_values = likelihood.values.tolist()
```

In [41]:

```
#Question 3
# -1 mark: wrong answer, correct approach
# -2 marks: wrong approach, no answer
pred = []
for i in range(0,1000):
    prob_list = []
    for cls in range(0,10):
        prob_val = np.log(prior.loc[cls])
        for j in range(0,784):
            prob_val += test_data_values[i]
[j]*np.log(likelihood_values[cls][j]) + (1-test_data_values[i][j])*np.lo
g(1-likelihood_values[cls][j])
        prob_list.append(prob_val)
    pred.append(np.argmax(prob_list))
```

In [42]:

```
accuracy_score(test_labels, pred)
```

Out[42]:

```
0.80900000000000005
```

In [43]:

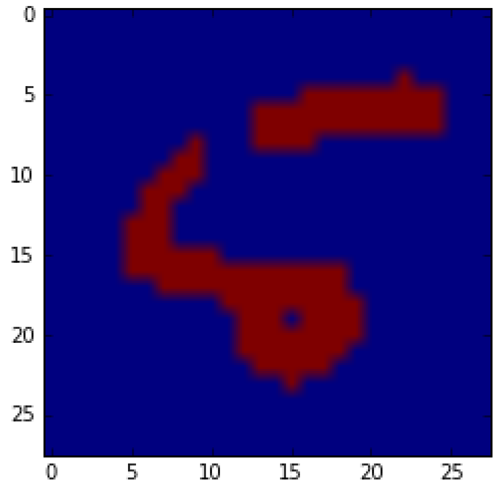
```
#Question 4
# -1 mark: wrong answer, correct approach
# -2 marks: wrong approach, no answer

from sklearn.preprocessing import normalize
cnf_matrix = confusion_matrix(test_labels, pred)
print (cnf_matrix)
#cnf_matrix_norm = normalize(cnf_matrix,axis=1, norm='l1')
#print (np.around(cnf_matrix_norm,2))
#Answer: 4-9 (21),5-3 (11), 8-3 (9)
```

```
[[ 74   0   0   0   0   5   2   0   4   0]
 [  0 120   0   0   0   4   1   0   1   0]
 [  1   7  88   4   0   1   2   3   8   2]
 [  0   2   1  86   1   6   3   2   3   3]
 [  1   1   1   0  83   0   2   0   1  21]
 [  3   1   1  11   2  62   2   3   1   1]
 [  3   0   4   0   3   4  73   0   0   0]
 [  0   6   2   0   3   1   0  77   3   7]
 [  0   2   2   9   4   3   1   2  61   5]
 [  0   1   0   1   4   0   0   0   3  85]]
```

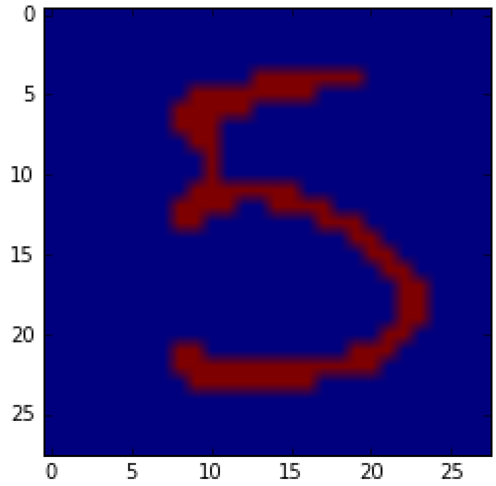
```
In [44]: plt.imshow(np.reshape(test_data.loc[8], (28,28)))
```

```
Out[44]: <matplotlib.image.AxesImage at 0x11a8f3ed0>
```



```
In [45]: plt.imshow(np.reshape(test_data.loc[15], (28,28)))
```

```
Out[45]: <matplotlib.image.AxesImage at 0x11a9849d0>
```



GMM and LDA

In [46]:

```
from sklearn import datasets

bc_data = datasets.load_breast_cancer()

n = bc_data.data.shape[0]

train_data = bc_data.data[:int(0.4*n)]
val_data = bc_data.data[int(0.4*n):int(0.6*n)]
test_data = bc_data.data[int(0.6*n):]
train_labels = bc_data.target[:int(0.4*n)]
val_labels = bc_data.target[int(0.4*n):int(0.6*n)]
test_labels = bc_data.target[int(0.6*n):]

for cov in ['full', 'tied', 'diag', 'spherical']:
    estimator = GaussianMixture(n_components=2,
                   covariance_type=cov, random_state=0)

    estimator.means_init = np.array([train_data[train_labels ==
i].mean(axis=0)
                                for i in range(2)])
    estimator.fit(train_data, train_labels)
    pred = estimator.predict(val_data)
    print ('Validation accuracy for covariance type '+ cov + ' = ' +
str(accuracy_score(val_labels, pred)))
```

```
Validation accuracy for covariance type full = 0.912280701754
Validation accuracy for covariance type tied = 0.859649122807
Validation accuracy for covariance type diag = 0.947368421053
Validation accuracy for covariance type spherical = 0.973684210526
```

In [47]:

```
# Best for diag

train_data = np.concatenate((train_data, val_data))
train_labels = np.concatenate((train_labels, val_labels))

estimator = GaussianMixture(n_components=2,
                covariance_type='spherical', random_state=0)

estimator.means_init = np.array([train_data[train_labels ==
i].mean(axis=0)
                            for i in range(2)])
estimator.fit(train_data, train_labels)
pred = estimator.predict(test_data)
print ('Test accuracy for covariance type '+ cov + ' = ' + str(accuracy_
score(test_labels, pred)))
```

```
Test accuracy for covariance type spherical = 0.938596491228
```

```
In [48]: from sklearn.discriminant_analysis import LinearDiscriminantAnalysis

         # Intialize
         clf = LinearDiscriminantAnalysis()
         # Train
         clf.fit(train_data, train_labels)
         # Test
         pred = clf.predict(test_data)

         print ('Test accuracy for covariance type '+ cov + ' = ' + str(accuracy_
         score(test_labels, pred)))

         Test accuracy for covariance type spherical = 0.973684210526
```

```
In [55]: clf.coef_

Out[55]: array([[-0.00539085, -0.00539085, -0.00539085, -0.00539085, -0.0053908
         5,
                 -0.00539085, -0.03836087, -0.03836087, -0.00539085, -0.0053908
         5,
                 -0.00539085, -0.00539085, -0.00539085, -0.00539085, -0.0053908
         5,
                 -0.00539085, -0.03836087, -0.03836087, -0.00539085, -0.0053908
         5,
                 -0.00539085, -0.00539085, -0.00539085, -0.00539085, -0.0053908
         5,
                 -0.00539085, -0.03836087, -0.03836087, -0.00539085, -0.0053908
         5]])
```

```
In [56]: clf.intercept_

Out[56]: array([-0.61694672])
```

```
In [73]: #Crosscheck
         from sklearn.naive_bayes import BernoulliNB
         clf = BernoulliNB()
         clf.fit(train_data, train_labels)

Out[73]: BernoulliNB(alpha=1.0, binarize=0.0, class_prior=None, fit_prior=True)
```

```
In [74]: pred = clf.predict(test_data)
```

```
In [75]: accuracy_score(test_labels, pred)

Out[75]: 0.80900000000000005
```

```
In [76]: clf.feature_log_prob_
```

```
Out[76]: array([[-6.38687932, -6.38687932, -6.38687932, ..., -6.38687932,
                 -6.38687932, -6.38687932],
                [-6.51174533, -6.51174533, -6.51174533, ..., -6.51174533,
                 -6.51174533, -6.51174533],
                [-6.36818719, -6.36818719, -6.36818719, ..., -6.36818719,
                 -6.36818719, -6.36818719],
                ...,
                [-6.48157713, -6.48157713, -6.48157713, ..., -6.48157713,
                 -6.48157713, -6.48157713],
                [-6.315358  , -6.315358  , -6.315358  , ..., -6.315358  ,
                 -6.315358  , -6.315358  ],
                [-6.4019172 , -6.4019172 , -6.4019172 , ..., -6.4019172 ,
                 -6.4019172 , -6.4019172 ]])
```