In [1]:
```
%matplotlib inline
```

In [2]:
```
import numpy as np
import matplotlib
import matplotlib.pyplot as plt
```

In [3]:
```
import classifier_utils as utils
```

In [4]:
```
import cv2
```

In [5]:
```
np.seterr(divide='ignore')
```

Out[5]:
```
{'divide': 'warn', 'invalid': 'warn', 'over': 'warn', 'under': 'ignore'}
```

# Import SVM Implementation

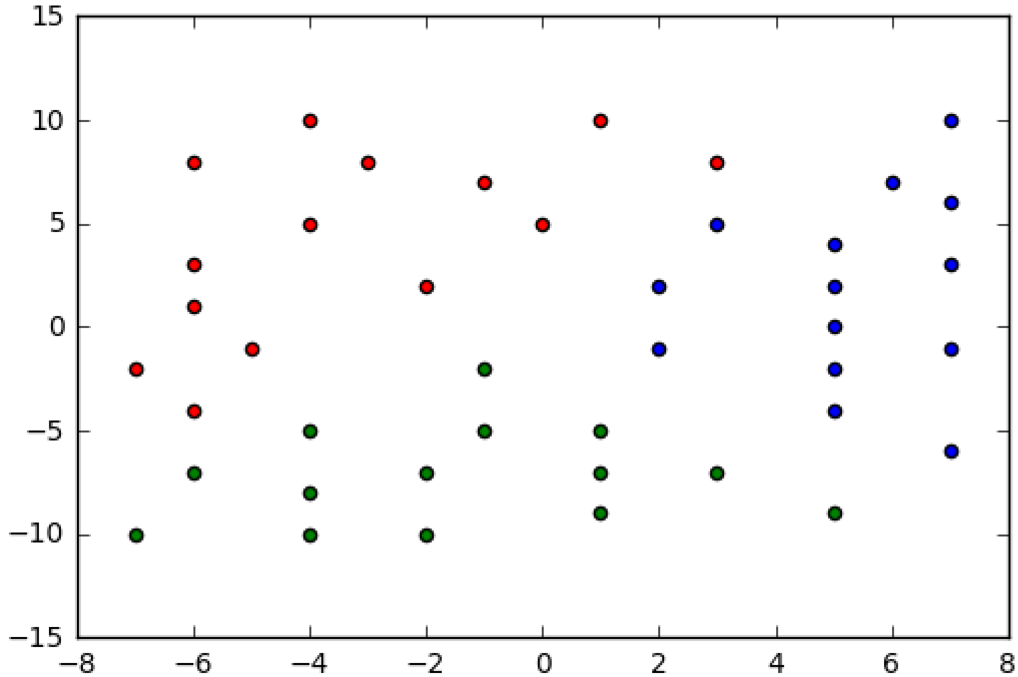
In [173]:
```
# TODO: shouldn't polute the namespace like this, svm is a pretty short p
refix!
from svm import get_gradient
from svm import get_activations
from svm import get_cost
from svm import get_cost_and_gradient
from svm import training_step
from svm import get_multiclass_predictions
from svm import train_loop
from svm import get_np_weighted_f1
from svm import status_report
from svm import multiclass_train_loop
```

# Simple Dataset SVM Example

In [164]:
```
data = np.array([[-4, 10], # class 0
                 [1, 10],
                 [-6, 8],
                 [-3, 8],
                 [3, 8],
                 [-1, 7],
                 [-4, 5],
                 [0, 5],
                 [-6, 3],
                 [-2, 2],
                 [-6, 1],
                 [-5, -1],
                 [-7, -2],
                 [-6, -4],

                 [-1, -2], # class 1
                 [-4, -5],
                 [-1, -5],
                 [1, -5],
                 [-6, -7],
                 [-2, -7],
                 [1, -7],
                 [3, -7],
                 [-4, -8],
                 [1, -9],
                 [5, -9],
                 [-7, -10],
                 [-4, -10],
                 [-2, -10],

                 [7, 10], # class 2
                 [6, 7],
                 [7, 6],
                 [3, 5],
                 [5, 4],
                 [7, 3],
                 [2, 2],
                 [5, 2],
                 [5, 0],
                 [2, -1],
                 [7, -1],
                 [5, -2],
                 [5, -4],
                 [7, -6]])
labels = np.array([[1, 0, 0]]*14 + [[0, 1, 0]]*14 + [[0, 0, 1]]*14)
```

In [165]:
```
# Plot dataset
plt.scatter(data[:14,0], data[:14,1], c='r')
plt.scatter(data[14:28,0], data[14:28,1], c='g')
plt.scatter(data[28:,0], data[28:,1], c='b')
```

Out[165]: <matplotlib.collections.PathCollection at 0x7f5369b73690>

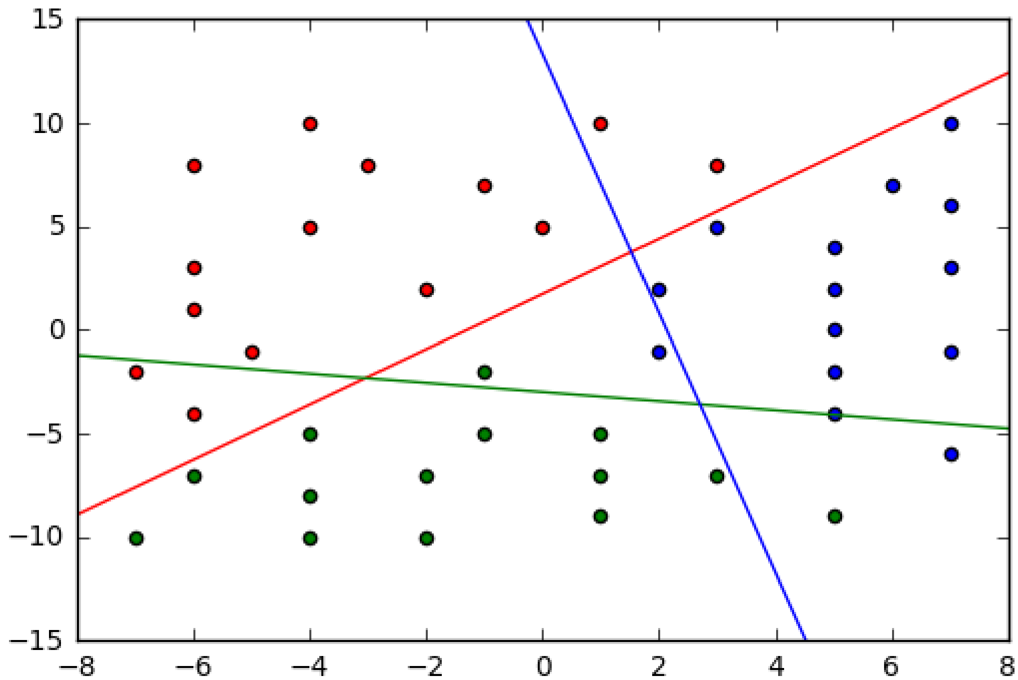


In [172]:
```
# Run SVM
C = 10
learning_rate = 0.003
batch_size = 2800 # Just some really big number to mean "the entire datas
et in one batch"
epochs = 1000
ws = multiclass_train_loop(data, labels, data, labels, data, labels, C, l
earning_rate, batch_size, epochs, quiet=True)
print ws
```

```
Epoch FINAL, step FINAL:
        train loss [1.0913469653460335, 2.5954427415520955, 2.58299007780
49462],
        validation loss [1.0913469653460335, 2.5954427415520955, 2.582990
0778049462],
        test loss [1.0913469653460335, 2.5954427415520955, 2.582990077804
9462],
        per-category test accuracy [ 1.          0.90476191  0.90476191],
        overall validation accuracy 1.000000,
        overall test accuracy 1.000000,
        validation f1 1.000000,
        test f1 1.000000
[[-0.55644254 -0.0645514   0.39326842]
 [ 0.4173721  -0.29224589  0.06284798]
 [-0.72548389 -0.8712765  -0.83905256]]
```

In [174]:
```
# Visualize results
# Dots are correctly classifier, crosses are incorrectly classifier
# Coloured lines are decision boundaries for each classifier
(predictions, _) = get_multiclass_predictions(data, ws)
actual = np.argmax(labels, axis=1)
correct = np.equal(predictions, actual)

mask = np.logical_and(correct, np.equal(actual, 0))
plt.scatter(data[mask, 0], data[mask,1], c='r')
mask = np.logical_and(np.logical_not(correct), np.equal(actual, 0))
plt.scatter(data[mask, 0], data[mask,1], c='r', marker='+')

mask = np.logical_and(correct, np.equal(actual, 1))
plt.scatter(data[mask, 0], data[mask,1], c='g')
mask = np.logical_and(np.logical_not(correct), np.equal(actual, 1))
plt.scatter(data[mask, 0], data[mask,1], c='g', marker='+')

mask = np.logical_and(correct, np.equal(actual, 2))
plt.scatter(data[mask, 0], data[mask,1], c='b')
mask = np.logical_and(np.logical_not(correct), np.equal(actual, 2))
plt.scatter(data[mask, 0], data[mask,1], c='b', marker='+')

plt.axis((-8, 8, -15, 15))

a, b, c = ws[:, 0]
x = np.linspace(-8, 8)
y = -a/b * x - c/b
plt.plot(x, y, c='r')

a, b, c = ws[:, 1]
x = np.linspace(-8, 8)
y = -a/b * x - c/b
plt.plot(x, y, c='g')

a, b, c = ws[:, 2]
x = np.linspace(-8, 8)
y = -a/b * x - c/b
plt.plot(x, y, c='b')
```

```
Out[174]: [<matplotlib.lines.Line2D at 0x7f537f2d46d0>]
```



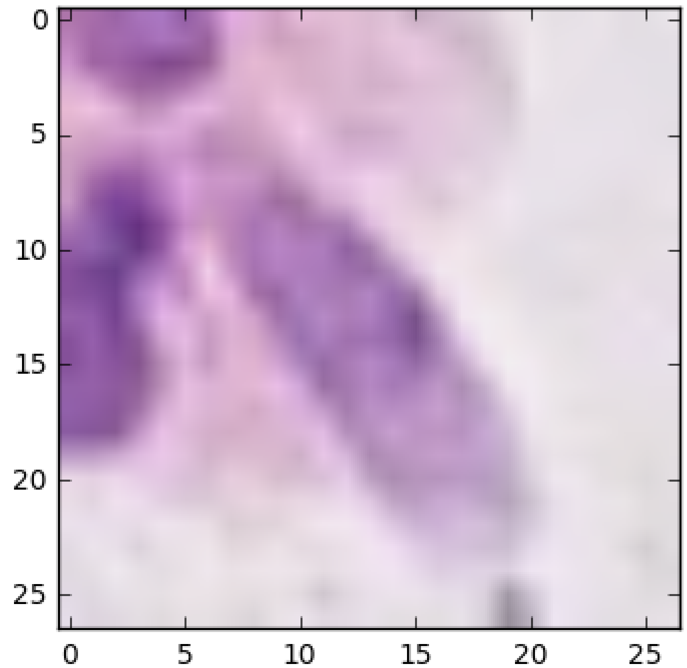

# Get Dataset

In [6]:
```
# To save memory, delete old dataset before creating new one
try:
    del test, train, validation # if they exist
except:
    pass

# Dataset
categories = [
    'epithelial',
    'fibroblast',
    'inflammatory',
    'others',
]
train, test = utils.get_augmented_dataset(categories)

# Carve out a validation set from our test set
# Split it 50/50
validation = {}
for k in list(test.iterkeys()):
    values = test[k]
    N = len(values)
    new_N = N/2
    test[k], validation[k] = np.split(values, [new_N])
```

```
Dropped 2082 patches because too close to image border
```

In [7]:
```
plt.imshow(train['patches'][0])
```

Out[7]: <matplotlib.image.AxesImage at 0x7f537f0e3090>




# Get HOG Features

In [8]:
```
def get_hog_features(hog, patches):
    N = patches.shape[0]
    descriptor_size = hog.getDescriptorSize()
    results = np.zeros((N, descriptor_size))
    for (i, patch) in enumerate(patches):
        uint_patch = (patch * 255).astype('uint8')
        resized_patch = cv2.resize(uint_patch, winSize, interpolation=cv2
TER_LINEAR)
        feature_vector = hog.compute(resized_patch)[:, 0]
        results[i] = feature_vector
    return results
```

In [9]:
```
# Compute HOG descriptors for each test/train example

# Specify HOG parameters
winSize = (32, 32)
blockSize = (16, 16)
blockStride = (8, 8)
cellSize = (8, 8)
nbins = 9
hog = cv2.HOGDescriptor(winSize, blockSize, blockStride, cellSize, nbins)

# Get training descriptors
train['hog_features'] = get_hog_features(hog, train['patches'])

# Get validation descriptors
validation['hog_features'] = get_hog_features(hog, validation['patches'])

# Get test descriptors
test['hog_features'] = get_hog_features(hog, test['patches'])
```

# Load Autoencoder Features

In [12]:
```
train['autoencodings'] = np.load("train_autoencodings.npy")
test_encodings = np.load("test_autoencodings.npy")

# Split test encodings into validation and test
new_N = test['patches'].shape[0]
test['autoencodings'], validation['autoencodings'] = np.split(test_encodi
ngs, [new_N])
```

In [13]:
```
for (k, v) in train.iteritems():
    print "train", k, v.shape
for (k, v) in validation.iteritems():
    print "validation", k, v.shape
for (k, v) in test.iteritems():
    print "test", k, v.shape
```

```
train hog_features (60000, 324)
train hsv_factors (60000, 3)
train deltas (60000, 2)
train patches (60000, 27, 27, 3)
train rots (60000,)
train labels (60000, 4)
train flips (60000,)
train centres (60000, 2)
train autoencodings (60000, 128)
train img_ids (60000,)
validation hog_features (2037, 324)
validation patches (2037, 27, 27, 3)
validation labels (2037, 4)
validation centres (2037, 2)
validation autoencodings (2037, 128)
validation img_ids (2037,)
test hog_features (2036, 324)
test patches (2036, 27, 27, 3)
test labels (2036, 4)
test centres (2036, 2)
test autoencodings (2036, 128)
test img_ids (2036,)
```

# Functions for Model Selection

```
def output_global_status(C, prefix):
    # Helper function to access per-category time series
    def g(series, category):
        return [x[category] for x in series]

    def save_plot(suffix):
        full_dir = os.path.join(prefix, suffix)
        full_name = os.path.join(full_dir, "C=%010.4f.png" % C)
        if not os.path.exists(full_dir):
            os.makedirs(full_dir)
        plt.savefig(full_name)
        plt.clf()

    best_by_f1 = np.argmax(val_f1)
    print "Best according to f1: index %d, val f1 %f, test f1 %f" % (
        best_by_f1, val_f1[best_by_f1], test_f1[best_by_f1])
    best_by_acc = np.argmax(val_accuracy)
    print "Best according to accuracy: index %d, val acc %f, test acc %f"
 % (
        best_by_acc, val_accuracy[best_by_acc],
test_accuracy[best_by_acc])

    x = range(len(g(loss, 0)))
    plt.plot(x, g(loss, 0), 'r')
    plt.plot(x, g(loss, 1), 'g')
    plt.plot(x, g(loss, 2), 'b')
    plt.plot(x, g(loss, 3), 'y')
    plt.title("C = %f, train loss" % C)
    save_plot("train_loss")
    x = range(len(g(test_loss, 0)))
    plt.plot(x, g(test_loss, 0), 'r')
    plt.plot(x, g(test_loss, 1), 'g')
    plt.plot(x, g(test_loss, 2), 'b')
    plt.plot(x, g(test_loss, 3), 'y')
    plt.title("C = %f, test loss" % C)
    save_plot("test_loss")
    x = range(len(g(val_loss, 0)))
    plt.plot(x, g(val_loss, 0), 'r')
    plt.plot(x, g(val_loss, 1), 'g')
    plt.plot(x, g(val_loss, 2), 'b')
    plt.plot(x, g(val_loss, 3), 'y')
    plt.title("C = %f, val loss" % C)
    save_plot("val_loss")

    plt.plot(x, val_accuracy)
    plt.title("C = %f, overall val accuracy" % C)
    save_plot("overall_val_accuracy")

    plt.plot(x, test_accuracy)
    plt.title("C = %f, overall test accuracy" % C)
    save_plot("overall_test_accuracy")

    plt.plot(x, val_f1)
    plt.title("C = %f, overall val f1" % C)
    save_plot("overall_val_f1")

    plt.plot(x, test_f1)
```

```
    plt.title("C = %f, overall test f1" % C)
    save_plot("overall_test_f1")

    return (best_by_f1, best_by_acc)
```

In [108]:

```
def svm_C_search(train, validation, test, feature_name, learning_rate, ba
tch_size, epochs, Cs, prefix):
    results = {
        'Cs' : [],
        'best_validation_f1_index': [],
        'best_validation_accuracy_index': [],
        'best_ws_by_validation_f1': [],
        'best_ws_by_validation_accuracy': [],
        'best_validation_f1': [],
        'best_validation_accuracy': [],
        'test_f1_at_best': [],
        'test_accuracy_at_best': [],
    }

    # Run SVM with various values of C
    for C in Cs:
        print "C=%f" % C
        multiclass_train_loop(train[feature_name], train['labels'],
                              validation[feature_name], validation['label
s'],
                              test[feature_name], test['labels'],
                              C, learning_rate, batch_size, epochs,
                              quiet=True)
        (f1_index, accuracy_index) = output_global_status(C, prefix)
        results['Cs'].append(C)
        results['best_validation_f1_index'].append(f1_index)
        results['best_validation_accuracy_index'].append(accuracy_index)
        results['best_ws_by_validation_f1'].append(params[f1_index])
        results['best_ws_by_validation_accuracy'].append(params[accuracy_
index])
        results['best_validation_f1'].append(val_f1[f1_index])
        results['best_validation_accuracy'].append(val_accuracy[accuracy_
index])
        results['test_f1_at_best'].append(test_f1[f1_index])
        results['test_accuracy_at_best'].append(test_accuracy[accuracy_in
dex])
        print ""
        print ""

    # Print a summary message and return the results
    best_f1_C_index = np.argmax(results['best_validation_f1'])
    best_accuracy_C_index =
np.argmax(results['best_validation_accuracy'])
    print "OVERALL"
    print "Best f1 is at index %d, best accuracy is at index %d" % (best_
f1_C_index, best_accuracy_C_index)

    return results
```

# Apply SVM to HOG Features

In [109]:
```
# Run SVM with various values of C
learning_rate = 0.0003
batch_size = 200
epochs = 100
# Recommended to try C in range 2^{-5 ... 15} from http://www.csie.ntu.ed
u.tw/~cjlin/papers/guide/guide.pdf
Cs = [2.0**x for x in xrange(-5, 16)]
hog_results = svm_C_search(
    train, validation, test, 'hog_features', learning_rate, batch_size, e
pochs, Cs, 'svm_graphs/hog')
```

```
OVERALL
Best f1 is at index 16, best accuracy is at index 16
```

```
<matplotlib.figure.Figure at 0x7f53784cd4d0>
```

In [154]:

```
# Store results
#import pickle
#with open('hog_svn_results.p', 'wb') as f:
#    pickle.dump(hog_results, f)
#np.save('hog_svn_best_ws.npy', np.hstack(hog_results['best_ws_by_validat
ion_f1'][16]))
```

In [157]:

```
# Restore results
import pickle
with open('hog_svn_results.p', 'rb') as f:
    hog_results = pickle.load(f)
```

In [160]:

```
print hog_results['test_accuracy_at_best'][16]
print hog_results['test_f1_at_best'][16]
```

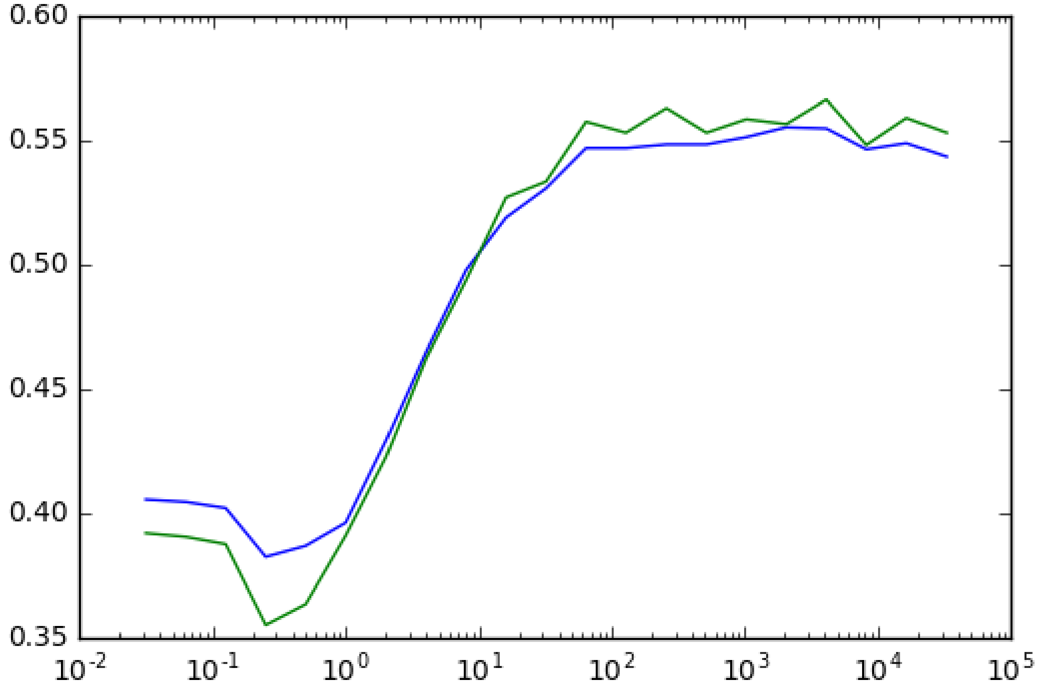
```
0.556483
0.526957574876
```

In [162]:

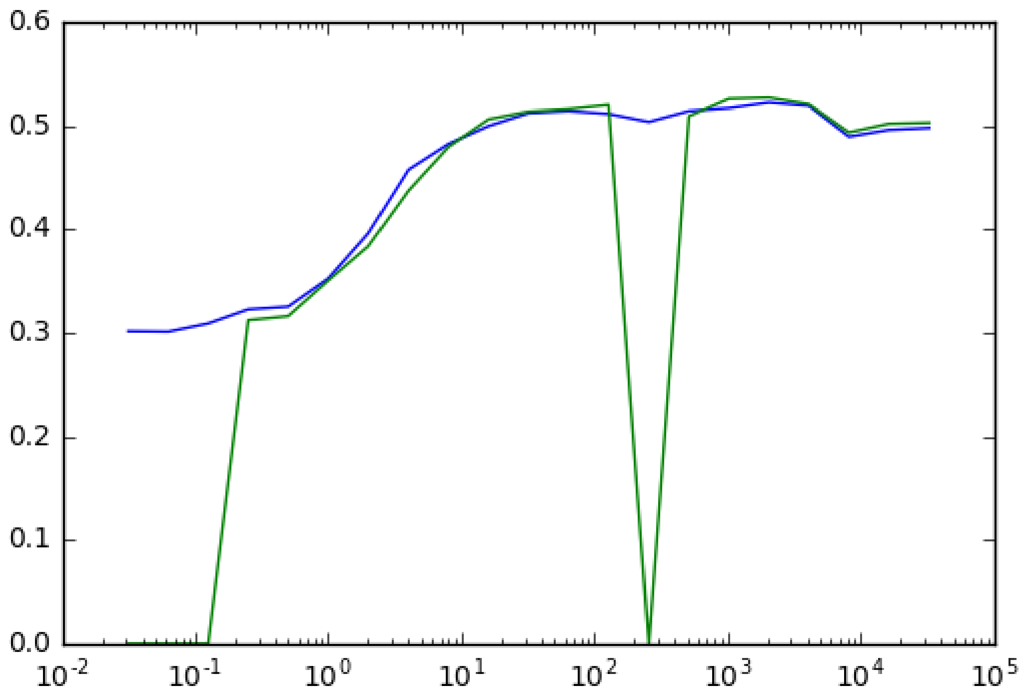
```
hog_ws = np.hstack(hog_results['best_ws_by_validation_f1'][16])
hog_predictions, _ = get_multiclass_predictions(test['hog_features'], hog
_ws)
hog_actuals = np.argmax(test['labels'], axis=1)
print np.count_nonzero(np.equal(hog_predictions, hog_actuals)) / float(le
n(hog_actuals))
print get_np_weighted_f1(hog_predictions, hog_actuals, 4)
```

```
0.548133595285
0.526957574876
```

In [120]:
```
plt.plot(hog_results['Cs'], hog_results['best_validation_accuracy'])
plt.plot(hog_results['Cs'], hog_results['test_accuracy_at_best'])
plt.xscale('log')
```




In [116]:
```
plt.plot(hog_results['Cs'], hog_results['best_validation_f1'])
plt.plot(hog_results['Cs'], hog_results['test_f1_at_best'])
plt.xscale('log')
```



In [164]:
```
(predictions, _) = get_multiclass_predictions(validation['hog_features'],
 ws)
print np.count_nonzero(np.equal(predictions, 0))
print np.count_nonzero(np.equal(predictions, 1))
print np.count_nonzero(np.equal(predictions, 2))
print np.count_nonzero(np.equal(predictions, 3))
```

```
832
921
284
0
```

# Apply SVM to Autoencoder Features

In [121]:
```
# Run SVM with various values of C
learning_rate = 0.0001
batch_size = 200
epochs = 200 # Many of these take longer to converge than HOG, so run for
 200 epochs
# Recommended to try C in range 2^{-5 ... 15} from http://www.csie.ntu.ed
u.tw/~cjlin/papers/guide/guide.pdf
Cs = [2.0**x for x in xrange(-5, 16)]
auto_results = svm_C_search(
    train, validation, test, 'autoencodings', learning_rate, batch_size,
epochs, Cs, 'svm_graphs/auto')
```

```
OVERALL
Best f1 is at index 10, best accuracy is at index 10

<matplotlib.figure.Figure at 0x7f537ef7a250>
```

In [146]:
```
# Store results
#import pickle
#with open('auto_svn_results.p', 'wb') as f:
#    pickle.dump(auto_results, f)
#np.save('auto_svn_best_ws.npy', np.hstack(auto_results['best_ws_by_valid
ation_f1'][10]))
```

In [147]:
```
# Restore results
import pickle
with open('auto_svn_results.p', 'rb') as f:
    auto_results = pickle.load(f)
```

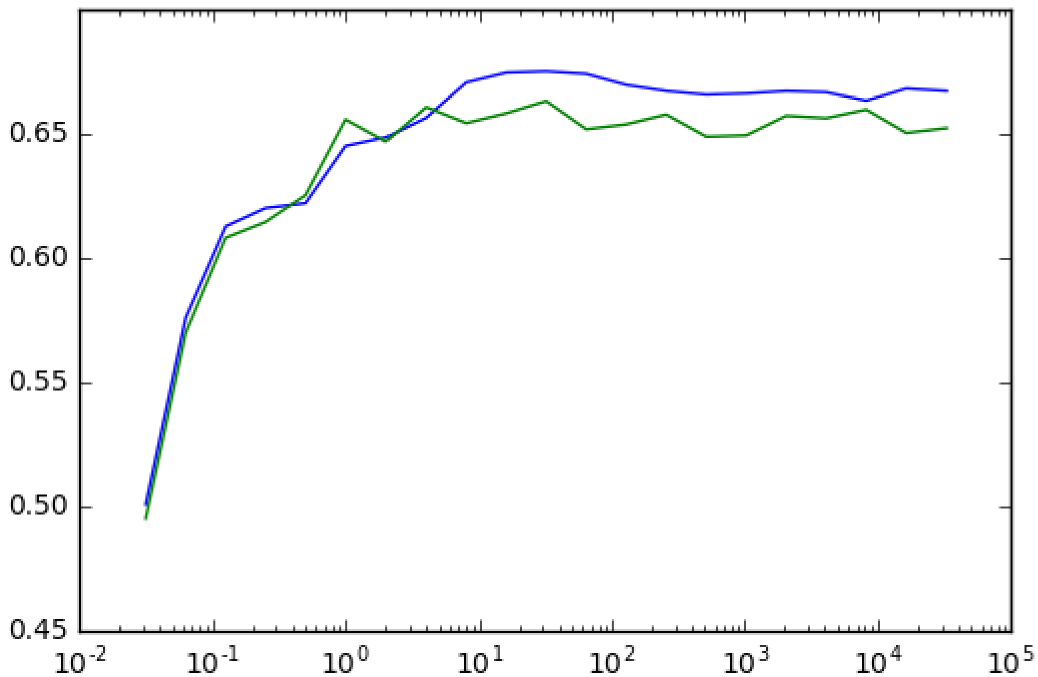
In [149]:
```
print auto_results['test_accuracy_at_best'][10]
print auto_results['test_f1_at_best'][10]
```

```
0.663065
0.657819415973
```

In [153]:
```
auto_ws = np.hstack(auto_results['best_ws_by_validation_f1'][10])
auto_predictions, _ = get_multiclass_predictions(test['autoencodings'], a
uto_ws)
#print auto_predictions[:100]
auto_actuals = np.argmax(test['labels'], axis=1)
#print auto_actuals[:100]
print np.count_nonzero(np.equal(auto_predictions, auto_actuals)) /
float(len(auto_actuals))
print get_np_weighted_f1(auto_predictions, auto_actuals, 4)
```

```
0.669941060904
0.657819415973
```

In [122]:
```
plt.plot(auto_results['Cs'], auto_results['best_validation_accuracy'])
plt.plot(auto_results['Cs'], auto_results['test_accuracy_at_best'])
plt.xscale('log')
```




In [125]:
```
plt.plot(auto_results['Cs'], auto_results['best_validation_f1'])
plt.plot(auto_results['Cs'], auto_results['test_f1_at_best'])
plt.xscale('log')
```