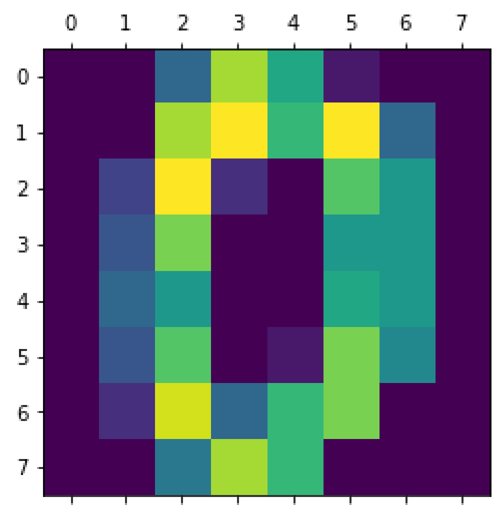
In [1]:
```
#import packages
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import warnings
warnings.filterwarnings('ignore')
import tensorflow as tf

#Load data
from sklearn.datasets import load_digits
import matplotlib.pyplot as plt
digits= load_digits()

#Digit Visualization
plt.matshow(digits.images[0])
plt.show()
```



In [2]:
```
#making training and testing sets
from sklearn.model_selection import train_test_split
x_train , x_test, y_train , y_test = train_test_split(digits.data, digits.target,
```

Part 1 : Regularization

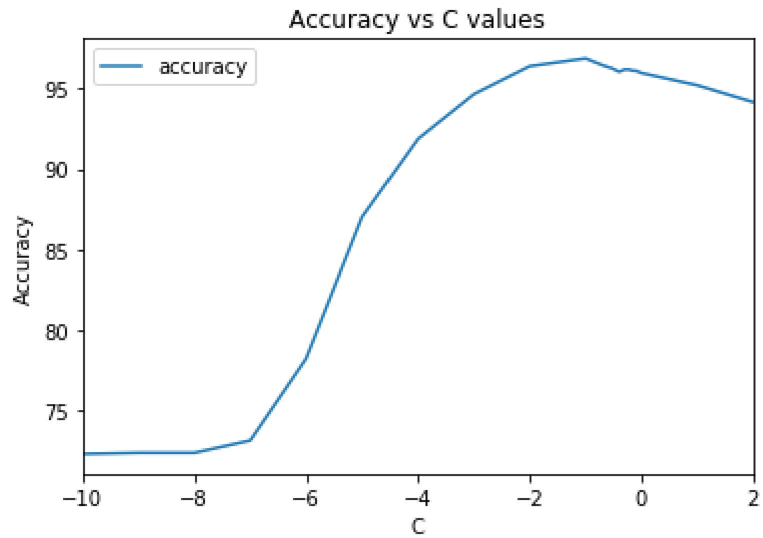
In [3]:
```
#l2 penalty Logistic Regression
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import StratifiedKFold
skf = StratifiedKFold(n_splits=5)
skf.get_n_splits(x_train, y_train)
acc_list=[]
c_list=[]
alpha_lasso = [1e-10, 1e-9, 1e-8, 1e-7, 1e-6, 1e-5, 1e-4,1e-3,1e-2,0.1,0.2,0.3
,0.4,0.5,0.6,0.7,0.8,0.9, 1, 10, 100 ]
for i in alpha_lasso:
    acc_sum=0
    for train_index, test_index in skf.split(x_train, y_train):
        x_tra, x_tes = x_train[train_index], x_train[test_index]
        y_tra, y_tes = y_train[train_index], y_train[test_index]
        mod1 = LogisticRegression(penalty='l2',C=i)
        mod1.fit(x_tra, y_tra) # fit
        y_pred = mod1.predict(x_tes) # predict
        acc_log = round(mod1.score(x_tes, y_tes) * 100, 2)
        acc_sum += acc_log
    acc_list.append(acc_sum/5.0)
    c_list.append(i)
```

In [4]:
```
#Dataframe for graph
df1 = pd.DataFrame({'c': np.round(np.log10(c_list),2), 'accuracy': acc_list})
df1
```

Out[4]:

	accuracy	c
0	72.306	-10.00
1	72.376	-9.00
2	72.376	-8.00
3	73.142	-7.00
4	78.232	-6.00
5	87.004	-5.00
6	91.874	-4.00
7	94.650	-3.00
8	96.388	-2.00
9	96.868	-1.00
10	96.452	-0.70
11	96.244	-0.52
12	96.038	-0.40
13	96.178	-0.30
14	96.174	-0.22
15	96.104	-0.15
16	96.104	-0.10
17	96.032	-0.05
18	95.962	0.00
19	95.200	1.00
20	94.156	2.00

In [5]:
```
#Graph c values vs Accuracy
df1.plot('c','accuracy')
plt.title('Accuracy vs C values')
plt.xlabel('C')
plt.ylabel('Accuracy')
plt.show()
```



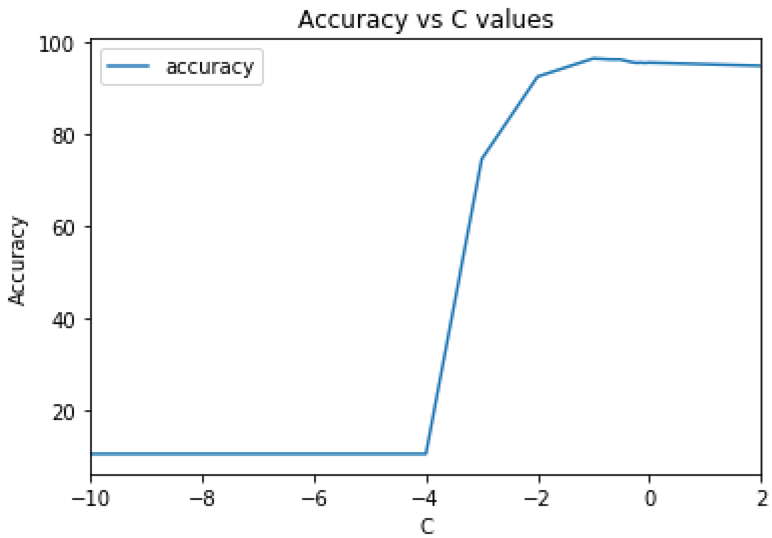
In [6]:
```
#l1 penalty Logistic Regression
skf2 = StratifiedKFold(n_splits=5)
skf2.get_n_splits(x_train, y_train)
acc_list2=[]
c_list2=[]
alpha_lasso = [1e-10, 1e-9, 1e-8, 1e-7, 1e-6, 1e-5, 1e-4,1e-3,1e-2,0.1,0.2,0.3
,0.4,0.5,0.6,0.7,0.8,0.9, 1, 10, 100 ]
for i in alpha_lasso:
    acc_sum2=0
    for train_index, test_index in skf.split(x_train, y_train):
        x_tra, x_tes = x_train[train_index], x_train[test_index]
        y_tra, y_tes = y_train[train_index], y_train[test_index]
        mod2 = LogisticRegression(penalty='l1',C=i)
        mod2.fit(x_tra, y_tra) # fit
        y_pred2 = mod2.predict(x_tes) # predict
        acc_log2 = round(mod2.score(x_tes, y_tes) * 100, 2)
        acc_sum2 += acc_log2
    acc_list2.append(acc_sum2/5.0)
    c_list2.append(i)
```

In [7]:
```
#Dataframe for graph
df2 = pd.DataFrame({'c': np.round(np.log10(c_list2),2), 'accuracy': (acc_list2)})
df2
```

Out[7]:

	accuracy	c
0	10.508	-10.00
1	10.508	-9.00
2	10.508	-8.00
3	10.508	-7.00
4	10.508	-6.00
5	10.508	-5.00
6	10.508	-4.00
7	74.602	-3.00
8	92.560	-2.00
9	96.524	-1.00
10	96.314	-0.70
11	96.312	-0.52
12	95.966	-0.40
13	95.688	-0.30
14	95.548	-0.22
15	95.616	-0.15
16	95.550	-0.10
17	95.548	-0.05
18	95.618	0.00
19	95.270	1.00
20	94.922	2.00

In [8]:
```
#Graph c values vs Accuracy
df2.plot('c','accuracy')
plt.title('Accuracy vs C values')
plt.xlabel('C')
plt.ylabel('Accuracy')
plt.show()
```



Part 2 : Neural Networks

#Q1

In [9]:

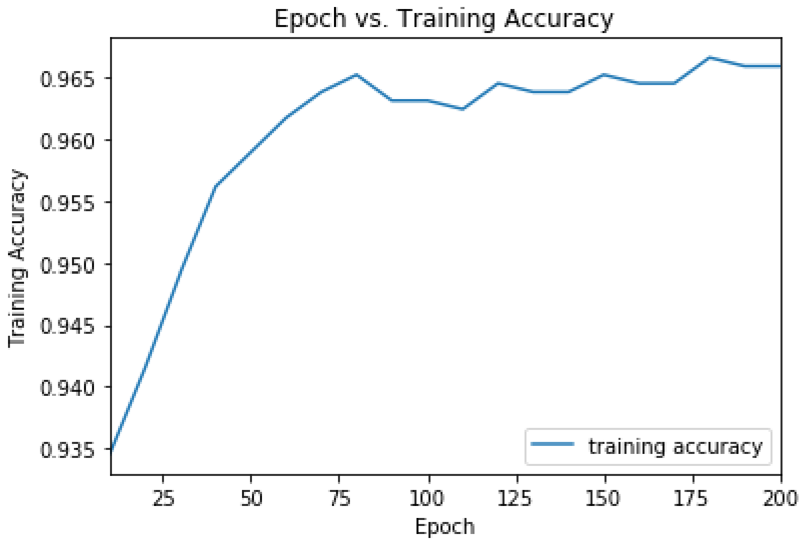
```
#setting up tensorboard
tf.reset_default_graph()

from datetime import datetime
import os
import pathlib

t = datetime.utcnow().strftime("%Y%m%d%H%M%S")
log_dir = "tf_logs"
logd = "/tmp/{}/r{}/".format(log_dir, t)

from pathlib import Path
home = str(Path.home())

logdir = os.path.join(os.sep,home,logd)

if not os.path.exists(logdir):
    os.makedirs(logdir)

# TensorBoard Graph visualizer
import numpy as np
from IPython.display import clear_output, Image, display, HTML

def strip_consts(graph_def, max_const_size=32):
    """Strip large constant values from graph_def."""
    strip_def = tf.GraphDef()
    for n0 in graph_def.node:
        n = strip_def.node.add()
        n.MergeFrom(n0)
        if n.op == 'Const':
            tensor = n.attr['value'].tensor
            size = len(tensor.tensor_content)
            if size > max_const_size:
                tensor.tensor_content = "<stripped %d bytes>"%size
    return strip_def

def show_graph(graph_def, max_const_size=32):
    """Visualize TensorFlow graph."""
    if hasattr(graph_def, 'as_graph_def'):
        graph_def = graph_def.as_graph_def()
    strip_def = strip_consts(graph_def, max_const_size=max_const_size)
    code = """
        <script src="//cdnjs.cloudflare.com/ajax/libs/polymer/0.3.3/platform.js">
        <script>
          function load() {{
            document.getElementById("{id}").pbtxt = {data};
          }}
        </script>
        <link rel="import" href="https://tensorboard.appspot.com/tf-graph-basic.b
        <div style="height:600px">
          <tf-graph-basic id="{id}"></tf-graph-basic>
        </div>
    """.format(data=repr(str(strip_def)), id='graph'+str(np.random.rand()))

    iframe = """
        <iframe seamless style="width:1200px;height:620px;border:0" srcdoc="{}"><
```

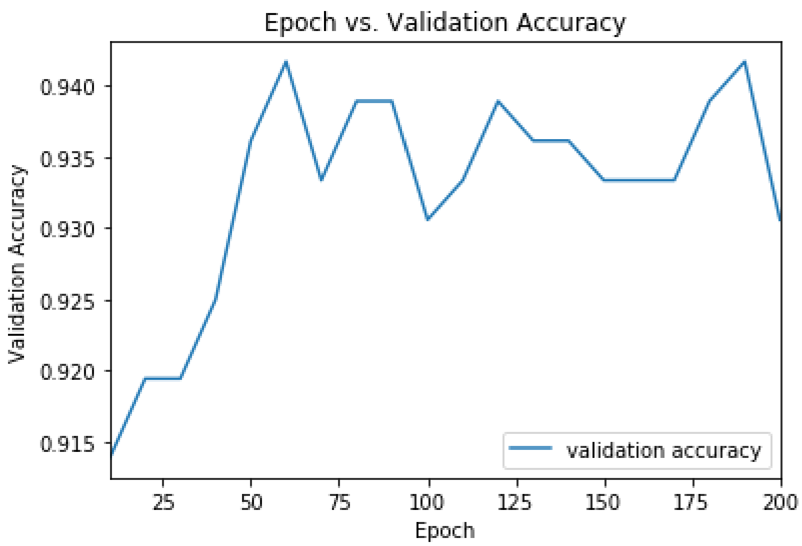
```
    """.format(code.replace('"', '&quot;'))
    display(HTML(iframe))
```

In [10]:
```
# Define input placeholder
x = tf.placeholder(tf.float32,shape = [None,64])


W = tf.Variable(tf.zeros([64, 10])) # number of weights
b = tf.Variable(tf.zeros([10])) # number of bias terms

#softmax regression
y_hat = tf.nn.softmax(tf.matmul(x, W) + b)

#output placeholder
y = tf.placeholder(tf.float32, [None, 10])


# Cross entropy
ce = tf.reduce_mean(-tf.reduce_sum( y* tf.log(y_hat),axis=1))

#optimizing function to minimize loss with learning rate = 0.001
train_step = tf.train.GradientDescentOptimizer(0.001).minimize(ce)

#One Hot Encoder for training set
from sklearn.preprocessing import OneHotEncoder
data = y_train
onehot_encoder = OneHotEncoder(sparse=False)
data2 = data.reshape(len(data),1)
y_train_enc = onehot_encoder.fit_transform(data2)

#Repeating the same for test set
data = y_test
onehot_encoder = OneHotEncoder(sparse=False)
data2 = data.reshape(len(data),1)
y_test_enc = onehot_encoder.fit_transform(data2)


#defining function to make batches of training data
def next_batch_fun(num, x, y):
    idx = np.arange(0 , len(data))
    np.random.shuffle(idx)
    idx = idx[:num]
    x_shuffle = [x[i] for i in idx]
    y_shuffle = [y[i] for i in idx]
    return np.asarray(x_shuffle), np.asarray(y_shuffle)

#list variables for graph later
ta = []
va = []
e = []

#training taking batch_size=100, epochs=200
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
    for epoch in range(200):
        avg_cost = 0.
        total_batch = int(digits.target.size/100)
        # Loop over all batches
        for i in range(total_batch):
```

```
            batch_xs, batch_ys = next_batch_fun(100,x_train,y_train_enc)
            # Fit training using batch data
            _, c = sess.run([train_step, ce], feed_dict={x: batch_xs, y: batch_ys

            # Compute average loss
            avg_cost += c / total_batch
         # To compute logs per 10 epoch step for graph later
        if (epoch+1) % 10 == 0:
            #accuracy
            correct_prediction = tf.equal(tf.argmax(y,1), tf.argmax(y_hat,1))
            accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
            acc_train = accuracy.eval(feed_dict={x:x_train , y: y_train_enc})
            acc_val = accuracy.eval(feed_dict={x: x_test,y: y_test_enc})
            ta.append(acc_train)
            va.append(acc_val)
            e.append(epoch+1)
        #To display logs per 50 epochs
        if (epoch+1) % 50 == 0:
            print ("Epoch:", '%04d' % (epoch+1), "cost=", "{:.9f}".format(avg_cos
            print ("Train accuracy:", np.round((acc_train)*100,2),"%  ","Val accu

    print ("Optimization Finished!")


#Dataframes for graphs
df_ta = pd.DataFrame({'epoch': e , 'training accuracy': ta})
df_va = pd.DataFrame({'epoch': e , 'validation accuracy': va})

#Plotting Epoch vs Training Accuracy
df_ta.plot('epoch','training accuracy')
plt.title('Epoch vs. Training Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Training Accuracy')
plt.show()

#Plotting Epoch vs Validation Accuracy
df_va.plot('epoch','validation accuracy')
plt.title('Epoch vs. Validation Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Validation Accuracy')
plt.show()
```

```
Epoch: 0050 cost= 0.163905337
Train accuracy: 95.89 %   Val accuracy: 93.61 %
Epoch: 0100 cost= 0.111125199
Train accuracy: 96.31 %   Val accuracy: 93.06 %
Epoch: 0150 cost= 0.076180501
Train accuracy: 96.52 %   Val accuracy: 93.33 %
Epoch: 0200 cost= 0.065715626
Train accuracy: 96.59 %   Val accuracy: 93.06 %
Optimization Finished!
```


Epoch vs. Training Accuracy
Training Accuracy
0.965
0.960
0.955
0.950
0.945
0.940
0.935
training accuracy
25
50
75
100
125
150
175
200
Epoch


Epoch vs. Validation Accuracy
Validation Accuracy
0.940
0.935
0.930
0.925
0.920
0.915
validation accuracy
25
50
75
100
125
150
175
200
Epoch

In [11]:
```
#Tensorboard Graph
show_graph(tf.get_default_graph())
```

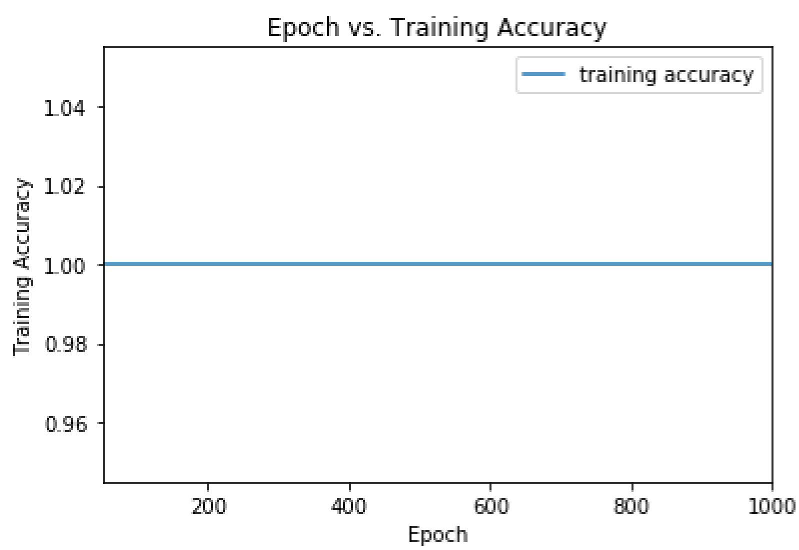
#Q2

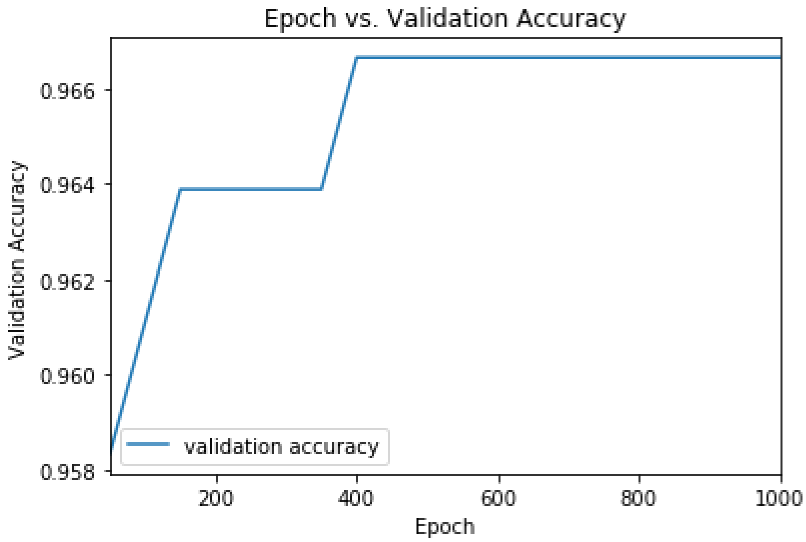
In [16]:
```
#Hyperparameters
n_hidden1 = 300
n_hidden2 = 200
n_hidden3 = 100
n_outputs = 10

#resetting the tensorboard graph
tf.reset_default_graph()

#Input and output placeholders
X = tf.placeholder(tf.float32, shape=[None, 64], name="X")
Y = tf.placeholder(tf.int64, shape=[None], name="Y")

#Defining function to write weights, biases and loss for each layer
def neuron_layer(X, n_neurons,  keep_prob, name, activation=None):
    # X input to neuron
    # number of neurons for the layer
    # name of layer
    # pass in eventual activation function

    with tf.name_scope(name):
        n_inputs = int(X.get_shape()[1])

        # initialize weights to prevent vanishing / exploding gradients
        stddev = 2 / np.sqrt(n_inputs)
        init = tf.truncated_normal((n_inputs, n_neurons), stddev=stddev)

        # Initialize weights for the layer
        W = tf.Variable(init, name="weights")
        # biases
        b = tf.Variable(tf.zeros([n_neurons]), name="bias")

        drop_out = tf.nn.dropout(X, keep_prob)

        # Output from every neuron
        Z = tf.matmul(X, W) + b
        if activation is not None:
            return activation(Z)
        else:
            return Z


#DNN for each layer along with tanh activation
with tf.name_scope("dnn"):
    hidden1 = neuron_layer(X, n_hidden1,0.9, name="hidden1", activation=tf.nn.tan
    hidden2 = neuron_layer(hidden1, n_hidden2,0.9, name="hidden2", activation=tf.
    hidden3 = neuron_layer(hidden2, n_hidden3,0.9, name="hidden3", activation=tf.
    logits = neuron_layer(hidden3, 10,0.9, name="outputs")


#Softmax regression
with tf.name_scope("loss"):
    # logits are from the last output of the dnn
    xentropy = tf.nn.sparse_softmax_cross_entropy_with_logits(labels=Y,logits=log
    ce = tf.reduce_mean(xentropy, name="loss")
```

```
learning_rate = 0.01

#Optimizer
with tf.name_scope("train"):
    optimizer = tf.train.GradientDescentOptimizer(learning_rate)
    train_step = optimizer.minimize(ce)

#Accuracy
with tf.name_scope("eval"):
    correct = tf.nn.in_top_k(logits, Y, 1)
    accuracy = tf.reduce_mean(tf.cast(correct, tf.float32))

#Making batches
def next_batch_fun(num, x, y):
    idx = np.arange(0 , len(y))
    np.random.shuffle(idx)
    idx = idx[:num]
    x_shuffle = [x[i] for i in idx]
    y_shuffle = [y[i] for i in idx]
    return np.asarray(x_shuffle), np.asarray(y_shuffle)

#List for graphs
ta2 = []
va2 = []
e2 = []

init = tf.global_variables_initializer()
saver = tf.train.Saver()

#train
with tf.Session() as sess:
    init.run()
    for epoch in range(1000):
        for iteration in range(int(digits.target.size/100)):
            batch_xs, batch_ys = next_batch_fun(100,x_train,y_train)
            sess.run(train_step, feed_dict={X: batch_xs, Y: batch_ys})
        if (epoch+1)%50==0:
            acc_train = accuracy.eval(feed_dict={X: batch_xs, Y: batch_ys})
            acc_val = accuracy.eval(feed_dict={X: x_test,Y: y_test})
            ta2.append(acc_train)
            va2.append(acc_val)
            e2.append(epoch+1)
            print(epoch+1,"Train accuracy:",np.round((acc_train)*100,2),"%  ","Va

    save_path = saver.save(sess, "./my_model_final.ckpt") # save model


#Dataframes for graphs
df_ta2 = pd.DataFrame({'epoch': e2 , 'training accuracy': ta2})
df_va2 = pd.DataFrame({'epoch': e2 , 'validation accuracy': va2})

#Graphs for Epoch vs Training Accuracy
df_ta2.plot('epoch','training accuracy')
plt.title('Epoch vs. Training Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Training Accuracy')
plt.show()
```

```
#Graphs for Epoch vs Validation Accuracy
df_va2.plot('epoch','validation accuracy')
plt.title('Epoch vs. Validation Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Validation Accuracy')
plt.show()
```

```
50 Train accuracy: 100.0 %   Val accuracy: 95.83 %
100 Train accuracy: 100.0 %   Val accuracy: 96.11 %
150 Train accuracy: 100.0 %   Val accuracy: 96.39 %
200 Train accuracy: 100.0 %   Val accuracy: 96.39 %
250 Train accuracy: 100.0 %   Val accuracy: 96.39 %
300 Train accuracy: 100.0 %   Val accuracy: 96.39 %
350 Train accuracy: 100.0 %   Val accuracy: 96.39 %
400 Train accuracy: 100.0 %   Val accuracy: 96.67 %
450 Train accuracy: 100.0 %   Val accuracy: 96.67 %
500 Train accuracy: 100.0 %   Val accuracy: 96.67 %
550 Train accuracy: 100.0 %   Val accuracy: 96.67 %
600 Train accuracy: 100.0 %   Val accuracy: 96.67 %
650 Train accuracy: 100.0 %   Val accuracy: 96.67 %
700 Train accuracy: 100.0 %   Val accuracy: 96.67 %
750 Train accuracy: 100.0 %   Val accuracy: 96.67 %
800 Train accuracy: 100.0 %   Val accuracy: 96.67 %
850 Train accuracy: 100.0 %   Val accuracy: 96.67 %
900 Train accuracy: 100.0 %   Val accuracy: 96.67 %
950 Train accuracy: 100.0 %   Val accuracy: 96.67 %
1000 Train accuracy: 100.0 %   Val accuracy: 96.67 %
```




Epoch vs. Validation Accuracy
Validation Accuracy
0.966
0.964
0.962
0.960
0.958
validation accuracy
200
400
600
800
1000
Epoch

In [13]:

```
#Tensorboard Graph
show_graph(tf.get_default_graph())
```

In [ ]: