q2

November 25, 2018

In [1]:
```
import numpy as np
import tensorflow as tf
from tensorflow.python.framework import ops
from tensorflow.python.ops import clip_ops
import matplotlib.pyplot as plt
from sklearn.datasets import load_digits
from sklearn.cross_validation import train_test_split
```

```
/anaconda3/envs/tfdeeplearning/lib/python3.5/site-packages/sklearn/cross_validation.py:41: Depr
  "This module will be removed in 0.20.", DeprecationWarning)
```

In [2]:
```
#Loading MNIST dataset
X, y = load_digits(return_X_y=True)
```

In [3]:
```
#Apply stratified sampling
X_train ,X_test,y_train,y_test = train_test_split(X,y,train_size = 0.7,random_state =
```

In [4]:
```
"""Hyper-parameters"""
batch_size = 300            # Batch size for stochastic gradient descent
test_size = batch_size      # Temporary heuristic. In future we'd like to decouple tes
num_centr = 150             # Number of "hidden neurons" that is number of centroids
max_iterations = 1000       # Max number of iterations
learning_rate = 5e-2        # Learning rate
num_classes = 10            # Number of target classes, 10 for MNIST
var_rbf = 225               # What variance do you expect workable for the RBF?

#Obtain and proclaim sizes
N,D = X_train.shape
Ntest = X_test.shape[0]
print('We have %s observations with %s dimensions'%(N,D))

#Proclaim the epochs
epochs = np.floor(batch_size*max_iterations / N)
print('Train with approximately %d epochs' %(epochs))
```

```
We have 1257 observations with 64 dimensions
Train with approximately 238 epochs
```

In [5]:
```
#Placeholders for data
x = tf.placeholder('float',shape=[batch_size,D],name='input_data')
y_ = tf.placeholder(tf.int64, shape=[batch_size], name = 'Ground_truth')
```

In [6]:
```
with tf.name_scope("Hidden_layer") as scope:
  #Centroids and var are the main trainable parameters of the first layer
    centroids = tf.Variable(tf.random_uniform([num_centr,D],dtype=tf.float32),name='cen
    var = tf.Variable(tf.truncated_normal([num_centr],mean=var_rbf,stddev=5,dtype=tf.fl

  #For now, we collect the distances
    exp_list = []
    for i in range(num_centr):
        exp_list.append(tf.exp((-1*tf.reduce_sum(tf.square(tf.subtract(x,centroids[i,:]
        phi = tf.transpose(tf.stack(exp_list))

with tf.name_scope("Output_layer") as scope:
    w = tf.Variable(tf.truncated_normal([num_centr,num_classes], stddev=0.1, dtype=tf.f
    bias = tf.Variable( tf.constant(0.1, shape=[num_classes]),name='bias')

    h = tf.matmul(phi,w)+bias
    size2 = tf.shape(h)

with tf.name_scope("Softmax") as scope:
    loss = tf.nn.sparse_softmax_cross_entropy_with_logits(logits=h,labels=y_)
    cost = tf.reduce_sum(loss)
    loss_summ = tf.summary.scalar("cross entropy_loss", cost)
```

```
INFO:tensorflow:Summary name cross entropy_loss is illegal; using cross_entropy_loss instead.
```

In [7]:
```
with tf.name_scope("train") as scope:
    tvars = tf.trainable_variables()
    #We clip the gradients to prevent explosion
    grads = tf.gradients(cost, tvars)
    optimizer = tf.train.AdamOptimizer(learning_rate)
    gradients = zip(grads, tvars)
    train_step = optimizer.apply_gradients(gradients)
#     The following block plots for every trainable variable
    numel = tf.constant([[0]])
    for gradient, variable in gradients:
        if isinstance(gradient, ops.IndexedSlices):
            grad_values = gradient.values
        else:
            grad_values = gradient
        numel += tf.reduce_sum(tf.size(variable))
        h1 = tf.histogram_summary(variable.name, variable)
        h2 = tf.histogram_summary(variable.name + "/gradients", grad_values)
        h3 = tf.histogram_summary(variable.name + "/gradient_norm", clip_ops.global_no
```

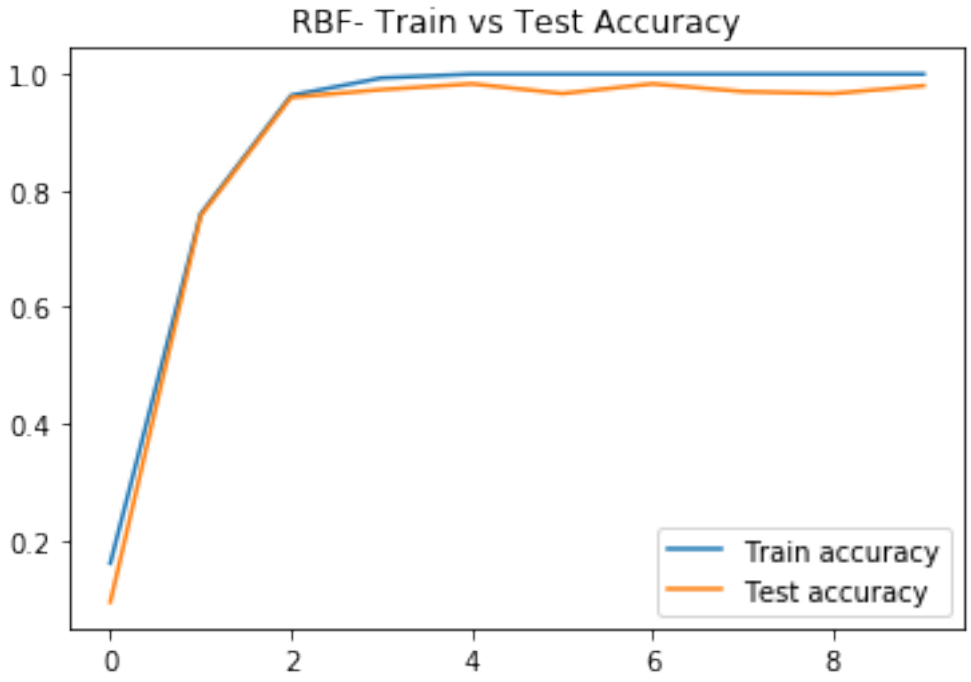
```
        with tf.name_scope("Evaluating") as scope:
            correct_prediction = tf.equal(tf.argmax(h,1), y_)
            accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
            accuracy_summary = tf.summary.scalar("accuracy", accuracy)

        merged = tf.summary.merge_all()


        perf_collect = np.zeros((4,int(np.floor(max_iterations /100))))
```

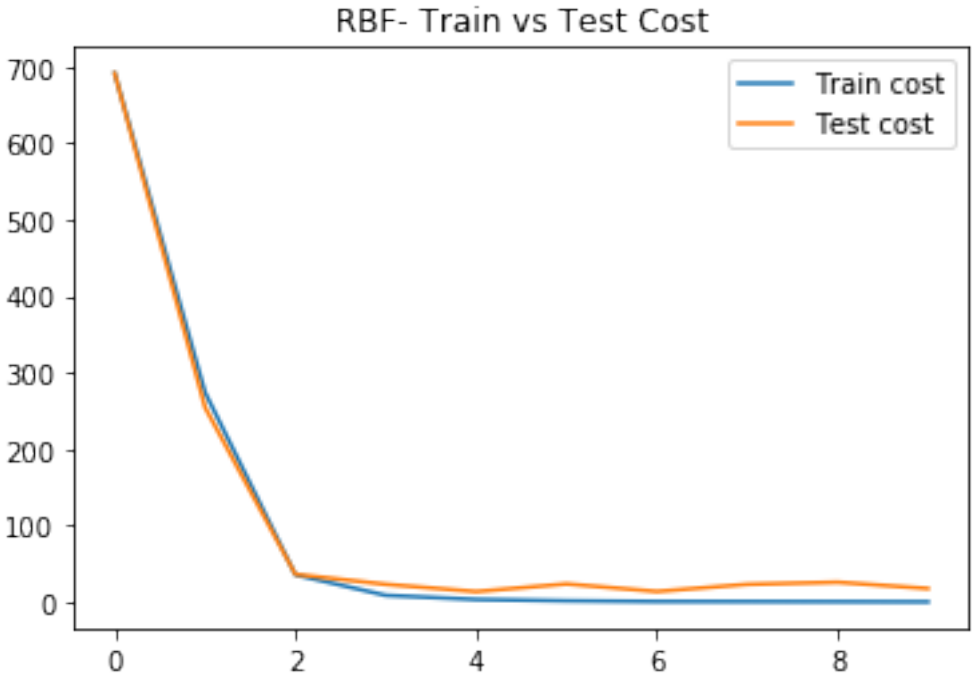
In [8]:
```
        #Begin Training
        with tf.Session() as sess:
            with tf.device("/cpu:0"):
                print('Start session')
                writer = tf.summary.FileWriter("./log_tb", sess.graph_def)

                step = 0
                sess.run(tf.initialize_all_variables())

            for i in range(max_iterations):
                batch_ind = np.random.choice(N,batch_size,replace=False)
                if i%100 == 1:
                    #Measure train performance
                    result = sess.run([cost,accuracy,train_step],feed_dict={x:X_train[batch_in
                    perf_collect[0,step] = result[0]
                    perf_collect[2,step] = result[1]

                    #Measure test performance
                    test_ind = np.random.choice(Ntest,test_size,replace=False)
                    result = sess.run([cost,accuracy,merged], feed_dict={ x: X_test[test_ind],
                    perf_collect[1,step] = result[0]
                    perf_collect[3,step] = result[1]

                    #Write information for Tensorboard
                    summary_str = result[2]
                    writer.add_summary(summary_str, i)
                    writer.flush()  #Don't forget this command! It makes sure Python writes th

                    #Print intermediate numbers to terminal
                    acc = result[1]
                    print("Estimated accuracy at iteration %s of %s: %s" % (i,max_iterations, a
                    step += 1
                else:
                    sess.run(train_step,feed_dict={x:X_train[batch_ind], y_: y_train[batch_ind]
```

```
Start session
WARNING:tensorflow:Passing a `GraphDef` to the SummaryWriter is deprecated. Pass a `Graph` obj
WARNING:tensorflow:From /anaconda3/envs/tfdeeplearning/lib/python3.5/site-packages/tensorflow/p
```

```
Instructions for updating:
Use `tf.global_variables_initializer` instead.
Estimated accuracy at iteration 1 of 1000: 0.0933333
Estimated accuracy at iteration 101 of 1000: 0.756667
Estimated accuracy at iteration 201 of 1000: 0.96
Estimated accuracy at iteration 301 of 1000: 0.973333
Estimated accuracy at iteration 401 of 1000: 0.983333
Estimated accuracy at iteration 501 of 1000: 0.966667
Estimated accuracy at iteration 601 of 1000: 0.983333
Estimated accuracy at iteration 701 of 1000: 0.97
Estimated accuracy at iteration 801 of 1000: 0.966667
Estimated accuracy at iteration 901 of 1000: 0.98
```

In [9]:
```
"""Additional plots"""
plt.figure()
plt.plot(perf_collect[2],label = 'Train accuracy')
plt.plot(perf_collect[3],label = 'Test accuracy')
plt.title('RBF- Train vs Test Accuracy')
plt.legend()
plt.show()

plt.figure()
plt.plot(perf_collect[0],label = 'Train cost')
plt.plot(perf_collect[1],label = 'Test cost')
plt.title('RBF- Train vs Test Cost')
plt.legend()
plt.show()
```





0.0.1 Changing the number of the hidden layer

```
In [10]: num_centr = 300
```

```
In [11]: with tf.name_scope("Hidden_layer") as scope:
           #Centroids and var are the main trainable parameters of the first layer
             centroids = tf.Variable(tf.random_uniform([num_centr,D],dtype=tf.float32),name='c
             var = tf.Variable(tf.truncated_normal([num_centr],mean=var_rbf,stddev=5,dtype=tf.

             #For now, we collect the distances
             exp_list = []
             for i in range(num_centr):
                 exp_list.append(tf.exp((-1*tf.reduce_sum(tf.square(tf.subtract(x,centroids[i,
                 phi = tf.transpose(tf.stack(exp_list))

         with tf.name_scope("Output_layer") as scope:
             w = tf.Variable(tf.truncated_normal([num_centr,num_classes], stddev=0.1, dtype=tf
             bias = tf.Variable( tf.constant(0.1, shape=[num_classes]),name='bias')

             h = tf.matmul(phi,w)+bias
             size2 = tf.shape(h)
```

```
        with tf.name_scope("Softmax") as scope:
            loss = tf.nn.sparse_softmax_cross_entropy_with_logits(logits=h,labels=y_)
            cost = tf.reduce_sum(loss)
            loss_summ = tf.summary.scalar("cross entropy_loss", cost)
```

```
INFO:tensorflow:Summary name cross entropy_loss is illegal; using cross_entropy_loss instead.
```

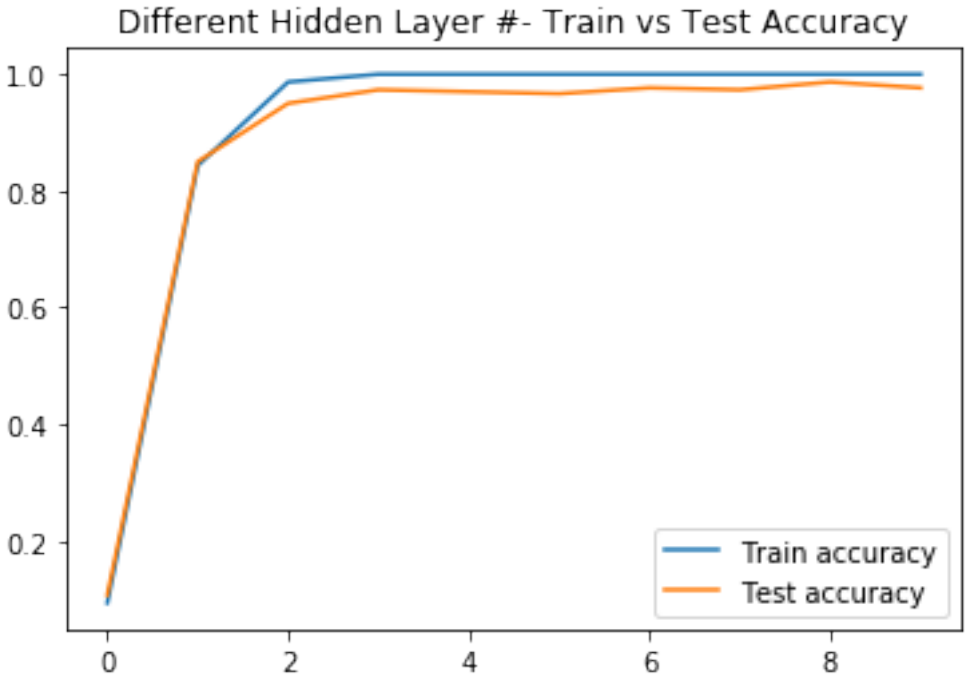
In [12]:
```
        with tf.name_scope("train") as scope:
            tvars = tf.trainable_variables()
            #We clip the gradients to prevent explosion
            grads = tf.gradients(cost, tvars)
            optimizer = tf.train.AdamOptimizer(learning_rate)
            gradients = zip(grads, tvars)
            train_step = optimizer.apply_gradients(gradients)
        #     The following block plots for every trainable variable

            numel = tf.constant([[0]])
            for gradient, variable in gradients:
                if isinstance(gradient, ops.IndexedSlices):
                    grad_values = gradient.values
                else:
                    grad_values = gradient
                numel += tf.reduce_sum(tf.size(variable))
                h1 = tf.histogram_summary(variable.name, variable)
                h2 = tf.histogram_summary(variable.name + "/gradients", grad_values)
                h3 = tf.histogram_summary(variable.name + "/gradient_norm", clip_ops.global_n
        with tf.name_scope("Evaluating") as scope:
            correct_prediction = tf.equal(tf.argmax(h,1), y_)
            accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
            accuracy_summary = tf.summary.scalar("accuracy", accuracy)

        merged = tf.summary.merge_all()


        # For now, we collect performances in a Numpy array.
        # In future releases, I hope TensorBoard allows for more
        # flexibility in plotting
        perf_collect = np.zeros((4,int(np.floor(max_iterations /100))))
```

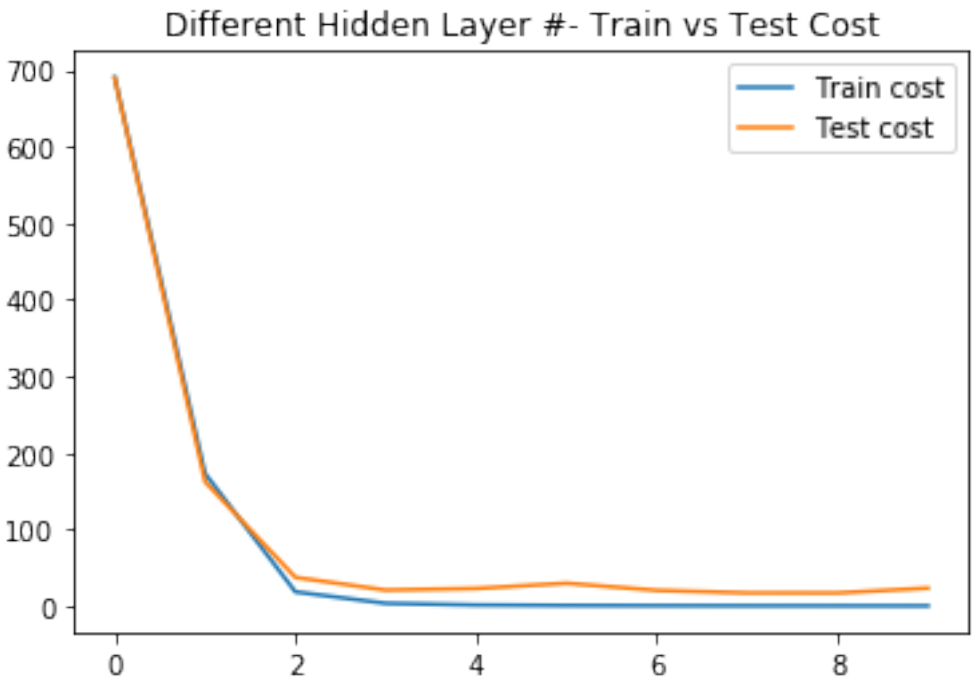
In [13]:
```
        #Begin Training
        with tf.Session() as sess:
            with tf.device("/cpu:0"):
                print('Start session')
                writer = tf.summary.FileWriter("./log_tb", sess.graph_def)

                step = 0
                sess.run(tf.initialize_all_variables())
```

```
#     #Debugging
#     batch_ind = np.random.choice(N,batch_size,replace=False)
#     result = sess.run([phi],feed_dict={x:X_train[batch_ind], y_: y_train[batch_ind]}
#     print(result[0])


    for i in range(max_iterations):
        batch_ind = np.random.choice(N,batch_size,replace=False)
        if i%100 == 1:
            #Measure train performance
            result = sess.run([cost,accuracy,train_step],feed_dict={x:X_train[batch_i
            perf_collect[0,step] = result[0]
            perf_collect[2,step] = result[1]

            #Measure test performance
            test_ind = np.random.choice(Ntest,test_size,replace=False)
            result = sess.run([cost,accuracy,merged], feed_dict={ x: X_test[test_ind]
            perf_collect[1,step] = result[0]
            perf_collect[3,step] = result[1]

            #Write information for Tensorboard
            summary_str = result[2]
            writer.add_summary(summary_str, i)
            writer.flush()  #Don't forget this command! It makes sure Python writes t

            #Print intermediate numbers to terminal
            acc = result[1]
            print("Estimated accuracy at iteration %s of %s: %s" % (i,max_iterations,
            step += 1
        else:
            sess.run(train_step,feed_dict={x:X_train[batch_ind], y_: y_train[batch_in
```

```
Start session
WARNING:tensorflow:Passing a `GraphDef` to the SummaryWriter is deprecated. Pass a `Graph` obj
WARNING:tensorflow:From /anaconda3/envs/tfdeeplearning/lib/python3.5/site-packages/tensorflow/
Instructions for updating:
Use `tf.global_variables_initializer` instead.
Estimated accuracy at iteration 1 of 1000: 0.106667
Estimated accuracy at iteration 101 of 1000: 0.85
Estimated accuracy at iteration 201 of 1000: 0.95
Estimated accuracy at iteration 301 of 1000: 0.973333
Estimated accuracy at iteration 401 of 1000: 0.97
Estimated accuracy at iteration 501 of 1000: 0.966667
Estimated accuracy at iteration 601 of 1000: 0.976667
Estimated accuracy at iteration 701 of 1000: 0.973333
Estimated accuracy at iteration 801 of 1000: 0.986667
Estimated accuracy at iteration 901 of 1000: 0.976667
```

In [14]:
```
"""Additional plots"""
plt.figure()
plt.plot(perf_collect[2],label = 'Train accuracy')
plt.plot(perf_collect[3],label = 'Test accuracy')
plt.title('Different Hidden Layer #- Train vs Test Accuracy')
plt.legend()
plt.show()

plt.figure()
plt.plot(perf_collect[0],label = 'Train cost')
plt.plot(perf_collect[1],label = 'Test cost')
plt.title('Different Hidden Layer #- Train vs Test Cost')
plt.legend()
plt.show()
```





0.0.2 Adding a dropout

```
In [15]: with tf.name_scope("Hidden_layer") as scope:
           #Centroids and var are the main trainable parameters of the first layer
             centroids = tf.Variable(tf.random_uniform([num_centr,D],dtype=tf.float32),name='c
             var = tf.Variable(tf.truncated_normal([num_centr],mean=var_rbf,stddev=5,dtype=tf.

           #For now, we collect the distances
             exp_list = []
             for i in range(num_centr):
                 exp_list.append(tf.exp((-1*tf.reduce_sum(tf.square(tf.subtract(x,centroids[i,
                 phi = tf.transpose(tf.stack(exp_list))

         with tf.name_scope("Output_layer") as scope:
             w = tf.Variable(tf.truncated_normal([num_centr,num_classes], stddev=0.1, dtype=tf
             bias = tf.Variable( tf.constant(0.1, shape=[num_classes]),name='bias')

             h = tf.matmul(phi,w)+bias
             #Adding dropout
             h = tf.nn.dropout(h, 0.5)

             size2 = tf.shape(h)

         with tf.name_scope("Softmax") as scope:
             loss = tf.nn.sparse_softmax_cross_entropy_with_logits(logits=h,labels=y_)
```

```
            cost = tf.reduce_sum(loss)
            loss_summ = tf.summary.scalar("cross entropy_loss", cost)

INFO:tensorflow:Summary name cross entropy_loss is illegal; using cross_entropy_loss instead.


In [16]: with tf.name_scope("train") as scope:
            tvars = tf.trainable_variables()
            #We clip the gradients to prevent explosion
            grads = tf.gradients(cost, tvars)
            optimizer = tf.train.AdamOptimizer(learning_rate)
            gradients = zip(grads, tvars)
            train_step = optimizer.apply_gradients(gradients)
         #     The following block plots for every trainable variable

            numel = tf.constant([[0]])
            for gradient, variable in gradients:
                if isinstance(gradient, ops.IndexedSlices):
                    grad_values = gradient.values
                else:
                    grad_values = gradient
                numel += tf.reduce_sum(tf.size(variable))
                h1 = tf.histogram_summary(variable.name, variable)
                h2 = tf.histogram_summary(variable.name + "/gradients", grad_values)
                h3 = tf.histogram_summary(variable.name + "/gradient_norm", clip_ops.global_n
         with tf.name_scope("Evaluating") as scope:
            correct_prediction = tf.equal(tf.argmax(h,1), y_)
            accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
            accuracy_summary = tf.summary.scalar("accuracy", accuracy)

         merged = tf.summary.merge_all()

         perf_collect = np.zeros((4,int(np.floor(max_iterations /100))))

In [17]: #Begin Training
         with tf.Session() as sess:
            with tf.device("/cpu:0"):
                print('Start session')
                writer = tf.summary.FileWriter("./log_tb", sess.graph_def)

                step = 0
                sess.run(tf.initialize_all_variables())

            for i in range(max_iterations):
                batch_ind = np.random.choice(N,batch_size,replace=False)
                if i%100 == 1:
                    #Measure train performance
                    result = sess.run([cost,accuracy,train_step],feed_dict={x:X_train[batch_i
```

```
                    perf_collect[0,step] = result[0]
                    perf_collect[2,step] = result[1]

                    #Measure test performance
                    test_ind = np.random.choice(Ntest,test_size,replace=False)
                    result = sess.run([cost,accuracy,merged], feed_dict={ x: X_test[test_ind]
                    perf_collect[1,step] = result[0]
                    perf_collect[3,step] = result[1]

                    #Write information for Tensorboard
                    summary_str = result[2]
                    writer.add_summary(summary_str, i)
                    writer.flush()  #Don't forget this command! It makes sure Python writes t

                    #Print intermediate numbers to terminal
                    acc = result[1]
                    print("Estimated accuracy at iteration %s of %s: %s" % (i,max_iterations,
                    step += 1
                else:
                    sess.run(train_step,feed_dict={x:X_train[batch_ind], y_: y_train[batch_in
```

```
Start session
WARNING:tensorflow:Passing a `GraphDef` to the SummaryWriter is deprecated. Pass a `Graph` obj
WARNING:tensorflow:From /anaconda3/envs/tfdeeplearning/lib/python3.5/site-packages/tensorflow/
Instructions for updating:
Use `tf.global_variables_initializer` instead.
Estimated accuracy at iteration 1 of 1000: 0.106667
Estimated accuracy at iteration 101 of 1000: 0.5
Estimated accuracy at iteration 201 of 1000: 0.503333
Estimated accuracy at iteration 301 of 1000: 0.563333
Estimated accuracy at iteration 401 of 1000: 0.546667
Estimated accuracy at iteration 501 of 1000: 0.59
Estimated accuracy at iteration 601 of 1000: 0.613333
Estimated accuracy at iteration 701 of 1000: 0.606667
Estimated accuracy at iteration 801 of 1000: 0.55
Estimated accuracy at iteration 901 of 1000: 0.633333
```

In [18]:
```
"""Additional plots"""
plt.figure()
plt.plot(perf_collect[2],label = 'Train accuracy')
plt.plot(perf_collect[3],label = 'Test accuracy')
plt.legend()
plt.title('Dropout- Train vs Test Accuracy')
plt.show()

plt.figure()
plt.plot(perf_collect[0],label = 'Train cost')
```

```
plt.plot(perf_collect[1],label = 'Test cost')
plt.legend()
plt.title('Dropout- Train vs Test Cost')
plt.show()
```