In [230]:

```
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from scipy import stats, io
from scipy.special import expit
```

In [231]:

```
class LogisticRegressionModel(object):

    def __init__(self, name, seed = 42):
        if name != 'data':
            raise ValueError('Incorrect Dataset')
        np.random.seed(seed)
        self.name = name
        self.data = None
        self.trainOrig = None
        self.trLabelsOrig = None
        self.train = None
        self.trLabels = None
        self.val = None
        self.valLabels = None
        self.test = None
        self.dim = None
        self.weight = None
        self.pred = None

        self.load_data()
        self.split(1000)

    def load_data(self):
        self.data = io.loadmat(self.name + '.mat')
        print('Loaded: ' + self.name)
        self.normalize()
        self.trainOrig = self.data['X']
        self.trLabelsOrig = self.data['y'].reshape(-1)
        self.test  = self.data['X_test']
        self.test = np.apply_along_axis(self.add1, 1, self.test)

        print('Training size (Before Split): ' + str(len(self.trainOri
g)))
        print('Training labels (Before Split):' + str(len(self.trLabel
sOrig)))
        print('Test size: ' + str(len(self.test)))


    def split(self,valSize):
        totalLen = len(self.trainOrig)
        trainSize = totalLen - valSize
        randIdx = np.random.permutation(totalLen)
        self.train = self.trainOrig[randIdx][:trainSize]
        self.train = np.apply_along_axis(self.add1, 1, self.train)
        self.trLabels = self.trLabelsOrig[randIdx][:trainSize]
        self.val = self.trainOrig[randIdx][trainSize:]
        self.val = np.apply_along_axis(self.add1, 1, self.val)
        self.valLabels = self.trLabelsOrig[randIdx][trainSize:]
        self.dim = self.train.shape

        print('Training Data Len: ' + str(len(self.train)))
        print('Training Labels Len: ' + str(len(self.trLabels)))
        print('Validation Data Len: ' + str(len(self.val)))
        print('Validation Labels Len: ' + str(len(self.valLabels)))

    def normalize(self):
        for idx in ['X', 'X_test']:
            mean = np.mean(self.data[idx], axis = 0)
            std = np.std(self.data[idx], axis = 0)
            z_score = lambda val: (val-mean)/std
            self.data[idx] = np.apply_along_axis(z_score,1,self.data[i
dx])

    def add1(self, arr):
        return np.append(arr, [[1]])

    def cost(self,X,y,w,l):
        s = expit(X @ w)
        s = np.maximum(s, 1e-7)
        s = np.minimum(s, 1-1e-7)
        return l*w@w - (1/len(X))*(y.dot(np.log(s)) + (1-y).dot(np.log
(1-s)))

    def grad_penalty(self,X,y,w,l):
        s = expit(X @ w)
        return -X.T.dot(y - s) + 2*l*w

    def gradient_descent(self,typeGrad,e,l,changingE,tol=1e-7,graph=Tr
ue,numIter=1000,maxLoops = 5):
        costLst, valCost = [], []
        converged = False
        w = np.zeros(self.dim[1])
        J_o, J_new = float("Inf"), self.cost(self.train, self.trLabels
, w, l)
        i = 0
        if typeGrad == 'batch':
            while i < numIter and not converged:
                w = w - e * self.grad_penalty(self.train, self.trLabel
s, w, l)
                J_o, J_new = J_new, self.cost(self.train, self.trLabel
s, w, l)
```

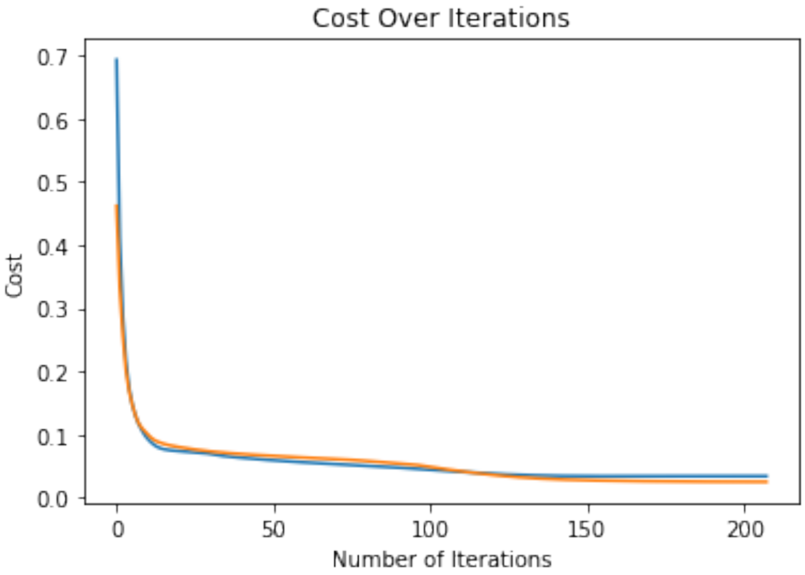
```
                costLst.append(J_o)
                valCost.append(self.cost(self.val, self.valLabels, w,
l))
                i+=1
                if abs(J_o - J_new) < tol:
                    converged = True
                    break
        if typeGrad == 'stochastic':
            numLoops = 0
            while numLoops < maxLoops and not converged:
                numLoops += 1
                randIdx = np.random.permutation(self.dim[0])
                X = self.train[randIdx]
                y = self.trLabels[randIdx]
                for x_i, y_i in zip(X, y):
                    if changingE:
                        w = w - e/(.03*(i+10)) * self.grad_penalty(x_i
, y_i, w, l)
                    else:
                        w = w - e*self.grad_penalty(x_i, y_i, w, l)
                    J_o, J_new = J_new, self.cost(X, y, w, l)
                    costLst.append(J_o)
                    valCost.append(self.cost(self.val, self.valLabels,
w, l))
                    i+=1
                    if abs(J_o - J_new) < tol:
                        converged = True
                        break
        print("Cost Final: " + str(J_o))
        print("Converged:" + str(i) + "iterations")
        if graph:
            plt.plot(costLst, label = "Training")
            plt.plot(valCost, label = "Validation")
            plt.xlabel("Number of Iterations")
            plt.ylabel("Cost")
            plt.title("Cost Over Iterations")
        self.weight = w


    def experiment(self,typeGrad,testData,e,l,changingE):
        self.gradient_descent(typeGrad,e,l,changingE,graph=False)
        y_val = expit(testData @ self.weight)
        y_pred = (y_val > 0.5).astype(np.int)
        self.pred = y_pred
        return y_pred

    def accuracy(self,labels):
        return np.sum(self.pred.reshape(-1) == labels.reshape(-1))/len
(self.pred)
```

In [238]:
```
m = LogisticRegressionModel('data', 42)
m.gradient_descent('batch', .01, 1e-6, changingE = False)
```

```
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03451128789693964
Converged:208iterations
```



In [234]:
```
lrs = [10**(-7), 10**(-6), 10**(-5), 10**(-4), 10**(-3), 10**(-2)]
regs = [.01,.001,.0001,.00001,.000001,.0000001]
for lr in lrs:
    for reg in regs:
        mod = LogisticRegressionModel('data', 42)
        mod.experiment('batch', mod.val, lr, reg, changingE = False)
        print("LR: "+str(lr)+'  RegParam: '+str(reg)+ '  Accuracy: '+
str(mod.accuracy(mod.valLabels)))
```

```
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
```

```
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.5129414392036031
Converged:1000iterations
LR: 1e-07  RegParam: 0.01  Accuracy: 0.962
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.5121343753396624
Converged:1000iterations
LR: 1e-07  RegParam: 0.001  Accuracy: 0.962
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.5120536688016132
Converged:1000iterations
LR: 1e-07  RegParam: 0.0001  Accuracy: 0.962
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.5120455981462916
Converged:1000iterations
LR: 1e-07  RegParam: 1e-05  Accuracy: 0.962
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.5120447910807444
Converged:1000iterations
LR: 1e-07  RegParam: 1e-06  Accuracy: 0.962
Loaded: data
```

```
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.5120447103741896
Converged:1000iterations
LR: 1e-07  RegParam: 1e-07  Accuracy: 0.962
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.2038027086929647
Converged:1000iterations
LR: 1e-06  RegParam: 0.01  Accuracy: 0.977
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.18553734429978758
Converged:1000iterations
LR: 1e-06  RegParam: 0.001  Accuracy: 0.977
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.1837107763228988
Converged:1000iterations
LR: 1e-06  RegParam: 0.0001  Accuracy: 0.977
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.18352811955325443
Converged:1000iterations
LR: 1e-06  RegParam: 1e-05  Accuracy: 0.977
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.1835098538422282
Converged:1000iterations
LR: 1e-06  RegParam: 1e-06  Accuracy: 0.977
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.1835080272710942
Converged:1000iterations
LR: 1e-06  RegParam: 1e-07  Accuracy: 0.977
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.17324801893735775
Converged:1000iterations
LR: 1e-05  RegParam: 0.01  Accuracy: 0.991
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.07048163099075341
Converged:1000iterations
LR: 1e-05  RegParam: 0.001  Accuracy: 0.991
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.06020321401375592
Converged:1000iterations
LR: 1e-05  RegParam: 0.0001  Accuracy: 0.991
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.059175354531653845
Converged:1000iterations
LR: 1e-05  RegParam: 1e-05  Accuracy: 0.991
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.05907256840559691
Converged:1000iterations
LR: 1e-05  RegParam: 1e-06  Accuracy: 0.991
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.05906228979121318
Converged:1000iterations
LR: 1e-05  RegParam: 1e-07  Accuracy: 0.991
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
```

```
Cost Final: 0.357604435955906
Converged:1000iterations
LR: 0.0001  RegParam: 0.01  Accuracy: 0.995
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.06444357566896411
Converged:268iterations
LR: 0.0001  RegParam: 0.001  Accuracy: 0.992
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.041655862093800636
Converged:1000iterations
LR: 0.0001  RegParam: 0.0001  Accuracy: 0.995
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03877904273626833
Converged:1000iterations
LR: 0.0001  RegParam: 1e-05  Accuracy: 0.995
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03849135627464602 6
Converged:1000iterations
LR: 0.0001  RegParam: 1e-06  Accuracy: 0.995
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
```

```
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.0384625875832243
Converged:1000iterations
LR: 0.0001  RegParam: 1e-07  Accuracy: 0.995
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.6568052834526016
Converged:1000iterations
LR: 0.001  RegParam: 0.01  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.0973664924757946
Converged:1000iterations
LR: 0.001  RegParam: 0.001  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.04034624649051768
Converged:448iterations
LR: 0.001  RegParam: 0.0001  Accuracy: 0.995
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.035192866625506684
```

```
Converged:1000iterations
LR: 0.001  RegParam: 1e-05  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03462706691031586
Converged:1000iterations
LR: 0.001  RegParam: 1e-06  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03457048635840218
Converged:1000iterations
LR: 0.001  RegParam: 1e-07  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.8000429683031589
Converged:963iterations
LR: 0.01  RegParam: 0.01  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.11250010130894003
Converged:809iterations
LR: 0.01  RegParam: 0.001  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
```

```
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.04219741338341202
Converged:625iterations
LR: 0.01  RegParam: 0.0001  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03534560097392368
Converged:172iterations
LR: 0.01  RegParam: 1e-05  Accuracy: 0.996
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03451128789693964
Converged:208iterations
LR: 0.01  RegParam: 1e-06  Accuracy: 0.997
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03442628911709663
Converged:202iterations
LR: 0.01  RegParam: 1e-07  Accuracy: 0.997
```

In [240]:

```
#Cell for submission
m = LogisticRegressionModel('data', 42)
y_pred = m.experiment('batch', m.test, .01, 1e-6, changingE = False).reshape(-1)

def results_to_csv(y_test):
    y_test = y_test.astype(int)
    df = pd.DataFrame({'Category': y_test})
    df.index += 1  # Ensures that the index starts at 1.
    df.to_csv('submission.csv', index_label='Id')

results_to_csv(y_pred)
```

```
Loaded: data
Training size (Before Split): 6000
Training labels (Before Split):6000
Test size: 497
Training Data Len: 5000
Training Labels Len: 5000
Validation Data Len: 1000
Validation Labels Len: 1000
Cost Final: 0.03451128789693964
Converged:208iterations
```

In [ ]: