Homework4

September 27, 2019

This notebook uses the packages **pandas**(loads datasets and output tables), **numpy**(label formatting) and **matplotlib**(contains module for plotting graphs). In this project, the datasets used are the **gissette**, **madelon** and **dexter** datasets. The folders containing the three datasets must be in the same directory as this notebook.

In order to run the code for this project, the following packages must be imported first

[1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

The style and size used for graph and fonts were found in: https://www.kdnuggets.com/2019/04/data-visualization-python-matplotlib-seaborn.html

[2]:
```
# style and size for graph fonts
fontdict_title = {'fontsize': 24, 'weight': 'bold', 'horizontalalignment':␣
 ↪'center'}
fontdict_xlabel = {'fontsize': 18, 'weight': 'bold', 'horizontalalignment':␣
 ↪'center'}
fontdict_ylabel = {'fontsize': 16, 'weight': 'bold', 'horizontalalignment':␣
 ↪'center', 'verticalalignment': 'baseline'}
```

Helper functions defined below are part of tisp logistic regression algorithm. ***sigmoid*** applies the sigmoid function to a numpy array. ***hard_thresholding_penalty*** applies the tisp threshold. ***prediction*** returns a numpy array of the same size as the input numpy array with values assigned according to the threshold: assigns 1 if the value is more than or equal to 0.5 otherwise, 0. ***misclassification_error*** calculates the mean misclassification error by comparing the values predicted with the actual labels and counting how many were incorrectly misclassified. The output of this function is then *amount of misclassifications/amount of classifications*. **feature_count** returns true if the the number of features matches *threshold+bound*. Finally, ***normalize*** normalizes a dataset.

[3]:
```
def sigmoid(x):
    return 1 / (1 + np.exp(-x))


def prediction(probabilities, threshold=0.5):
    return np.where(probabilities >= threshold, 1, 0)
```

```
def misclassification_error(predictions, labels):
    return np.where(predictions != labels, 1, 0).mean()


def normalize(m, std, data):
    return (data - m) / std


def hard_thresholding_penalty(w, learning_rate):
    return np.where(np.absolute(w) > learning_rate, w, 0)


def feature_count(it, weights, threshold):
    count = np.count_nonzero(weights)
    bounds = 10 if threshold > 10 else 5
    if threshold >= 300:
        bounds = 75
    if threshold == 100:
        bounds = 35
    if count in list(range(threshold - bounds, threshold + bounds + 1)):
        return True
```

Function for the logistic regression algorithm. This function returns the mean classification error for the training, all the loss values and the last updated weights after all the iterations. The intercept is set to 0.

[4]:
```
def tisp_classifier(features, labels, learning_rate, iterations, shrinkage=0.
↪0001):
    weights = np.zeros(features.shape[1])
    observation_num = features.shape[0]
    misclassification_errors = {}
    feature_num = [10, 30, 100, 300, 500]

    for iteration in range(1, iterations + 1):
        scores = np.dot(features, weights)
        probs = sigmoid(scores)
        pred = prediction(probs)
        error = misclassification_error(labels, pred)

        # Calculate gradient
        gradient = np.dot(features.T, labels - probs) / observation_num

        # Update weights
        weights = hard_thresholding_penalty(weights + gradient, learning_rate)
```

```
        for num in feature_num:
            if feature_count(iteration, weights, num):
                misclassification_errors[num] = error

    return misclassification_errors, weights
```

Problem 1: TISP Logistic Regression: Gisette Dataset

Load training and test set

[5]:
```
gisette_train_data = pd.read_csv("./Gisette/gisette_train.data", header=None,␣
 ↪sep=" ").dropna(axis=1).values
gisette_train_labels = np.where(np.ravel(
    pd.read_csv("./Gisette/gisette_train.labels", header=None, sep=" ").
 ↪dropna(axis=1).values) == -1, 0, 1)
gisette_test_data = pd.read_csv("./Gisette/gisette_valid.data", header=None,␣
 ↪sep=" ").dropna(axis=1).values
gisette_test_labels = np.where(np.ravel(
    pd.read_csv("./Gisette/gisette_valid.labels", header=None, sep=" ").
 ↪dropna(axis=1).values) == -1, 0, 1)
```

Normalize training and test set

[6]:
```
gisette_train_data_mean = gisette_train_data.mean(axis=0)
gisette_train_data_std = np.where(gisette_train_data.std(axis=0) == 0, 1,␣
 ↪gisette_train_data.std(axis=0))
normalized_gisette_train_data = normalize(gisette_train_data_mean,␣
 ↪gisette_train_data_std, gisette_train_data)
normalized_gisette_test_data = normalize(gisette_train_data_mean,␣
 ↪gisette_train_data_std, gisette_test_data)
```

Set iterations and learning rates in decreasing order of features obtained.

[7]:
```
iters = 100
gisette_learning_train_rates = [0.04, 0.06, 0.09, 0.14, 0.2]
```

Run logistic regression and store the train error and weights

[8]:
```
gisette_train_errors = [0 for x in range(0,5)]

gisette_train_errors[0], gisette_train_weights500 =␣
 ↪tisp_classifier(normalized_gisette_train_data,

                                                                    ␣

 ↪gisette_train_labels,
```

```
                                                                        ␣
 ↪gisette_learning_train_rates[0],
                                                                         iters)

gisette_train_errors[1], gisette_train_weights300 =␣
 ↪tisp_classifier(normalized_gisette_train_data,
                                                                        ␣
 ↪gisette_train_labels,
                                                                        ␣
 ↪gisette_learning_train_rates[1],
                                                                         iters)
gisette_train_errors[2], gisette_train_weights100 =␣
 ↪tisp_classifier(normalized_gisette_train_data,
                                                                        ␣
 ↪gisette_train_labels,
                                                                        ␣
 ↪gisette_learning_train_rates[2],
                                                                         iters)

gisette_train_errors[3], gisette_train_weights30 =␣
 ↪tisp_classifier(normalized_gisette_train_data,
                                                                      ␣
 ↪gisette_train_labels,
                                                                      ␣
 ↪gisette_learning_train_rates[3],
                                                                       iters)

gisette_train_errors[4], gisette_train_weights10 =␣
 ↪tisp_classifier(normalized_gisette_train_data,
                                                                      ␣
 ↪gisette_train_labels,
                                                                      ␣
 ↪gisette_learning_train_rates[4],
                                                                       iters)

gisette_train_errors[0] = gisette_train_errors[0][500]
gisette_train_errors[1] = gisette_train_errors[1][300]
gisette_train_errors[2] = gisette_train_errors[2][100]
gisette_train_errors[3] = gisette_train_errors[3][30]
gisette_train_errors[4] = gisette_train_errors[4][10]
```

Predict using the test set and calculate the test error

[9]:
```
gisette_test_errors = []
gisette_test_scores500 = np.dot(normalized_gisette_test_data,␣
 ↪gisette_train_weights500)
```

```
gisette_test_preds500 = prediction(sigmoid(gisette_test_scores500))
gisette_test_errors.append(misclassification_error(gisette_test_labels,␣
 ↪gisette_test_preds500))

gisette_test_scores300 = np.dot(normalized_gisette_test_data,␣
 ↪gisette_train_weights300)
gisette_test_preds300 = prediction(sigmoid(gisette_test_scores300))
gisette_test_errors.append(misclassification_error(gisette_test_labels,␣
 ↪gisette_test_preds300))

gisette_test_scores100 = np.dot(normalized_gisette_test_data,␣
 ↪gisette_train_weights100)
gisette_test_preds100 = prediction(sigmoid(gisette_test_scores100))
gisette_test_errors.append(misclassification_error(gisette_test_labels,␣
 ↪gisette_test_preds100))

gisette_test_scores30 = np.dot(normalized_gisette_test_data,␣
 ↪gisette_train_weights30)
gisette_test_preds30 = prediction(sigmoid(gisette_test_scores30))
gisette_test_errors.append(misclassification_error(gisette_test_labels,␣
 ↪gisette_test_preds30))

gisette_test_scores10 = np.dot(normalized_gisette_test_data,␣
 ↪gisette_train_weights10)
gisette_test_preds10 = prediction(sigmoid(gisette_test_scores10))
gisette_test_errors.append(misclassification_error(gisette_test_labels,␣
 ↪gisette_test_preds10))
```

Creates figure object. This is in its own cell so that the plots appear in the correct size.

[10]:
```
fig = plt.figure();
```

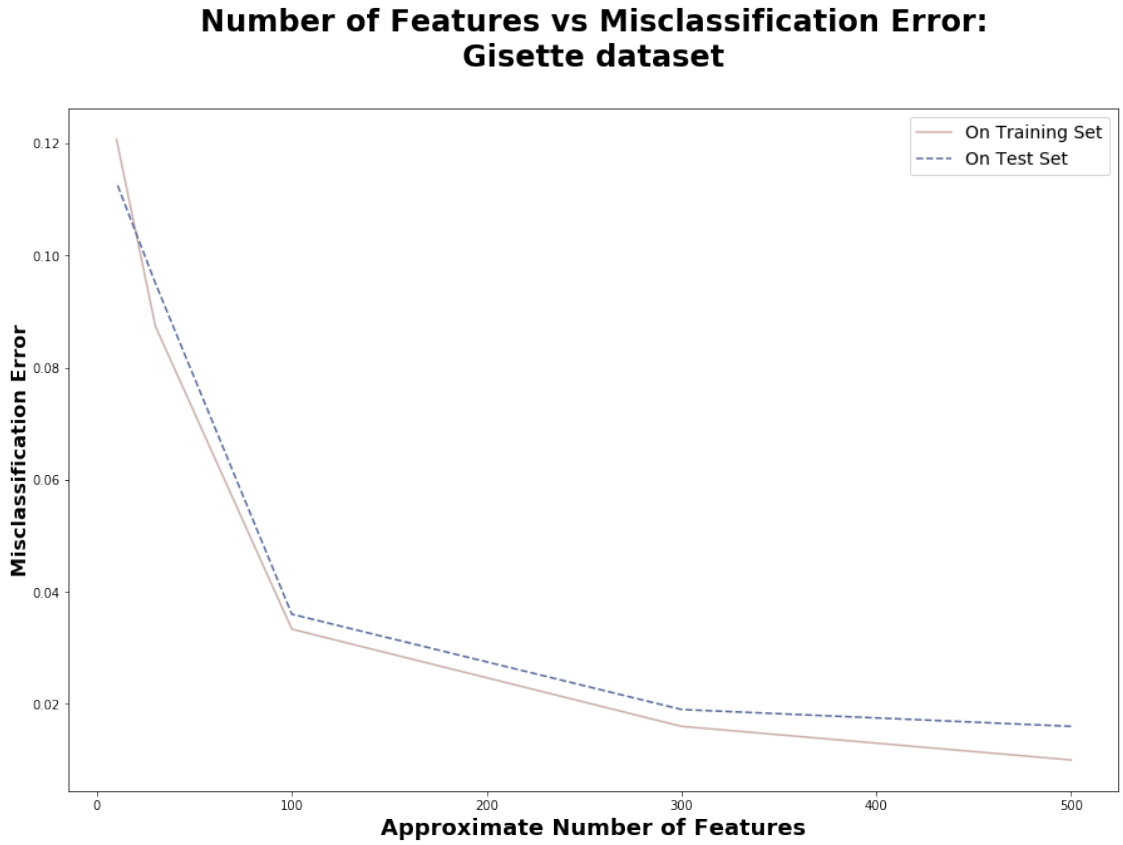
```
<Figure size 432x288 with 0 Axes>
```

Plot a graph of number of features vs error

[11]:
```
# size of graph
plt.rcParams['figure.figsize'] = [15, 10]  # size=15x10 inches

# labels
plt.title("Number of Features vs Misclassification Error:\nGisette dataset\n",␣
 ↪fontdict=fontdict_title)
plt.xlabel("Approximate Number of Features", fontdict=fontdict_xlabel)
plt.ylabel("Misclassification Error", fontdict=fontdict_ylabel)
```

```
# plotting
features_approximately = [500,300,100,30,10]
plt.plot(features_approximately, gisette_train_errors,
         color="#CDB1AD",
         linestyle="-",
         label="On Training Set")
plt.plot(features_approximately, gisette_test_errors,
         color="#5D6E9E",
         linestyle="--",
         label="On Test Set")
plt.legend(fontsize=14);
```



Train and Test Misclassification Errors Table

[12]:
```
# Create labels
rows_labels = gisette_learning_train_rates
columns_labels = ["Lambda Value","Gisette Train Error","Gisette Test Error","␣
 ↪Approximate Number of Features"]
```

```
# Store the misclassification error from each dataset for training and testing
misclassification_errors = {
    columns_labels[1]: gisette_train_errors,
    columns_labels[2]: gisette_test_errors,
    columns_labels[3]: features_approximately
}

# Create dataframe to output table
error_tabledf=pd.DataFrame(misclassification_errors, index=rows_labels)
error_tabledf.index.name = columns_labels[0]
error_tabledf
```

[12]:

Lambda Value	Gisette Train Error	Gisette Test Error	Approximate Number of Features
0.04	0.010000	0.016	500
0.06	0.016000	0.019	300
0.09	0.033333	0.036	100
0.14	0.087333	0.095	30
0.20	0.120667	0.113	10

Problem 2: Logistic Regression: Dexter Dataset

Create csv files from **dexter_train.data** and **dexter_test.data** in order to load it with pandas.

[13]:
```
def reformat_file(input_filepath, output_filepath, row_num, col_num):
    output_file = open(output_filepath, "w+")
    with open(input_filepath, "r") as fp:
        for obs in range(0, row_num):
            line = fp.readline()
            strs = line.split(" ")
            output_line = ["0" for col in range(0, col_num)]

            for s in strs:
                if s != "\n":
                    i, value = s.split(":")
                    output_line[int(i)] = value
```

```
            output_file.write(",".join(output_line) + "\n")

    output_file.close()

reformat_file("./dexter/dexter_train.data", "./dexter/dexter_train.csv", 300,␣
 ↪20000)
reformat_file("./dexter/dexter_valid.data", "./dexter/dexter_valid.csv", 300,␣
 ↪20000)
```

Load training and test set

[14]:
```
dexter_train_data = pd.read_csv("./dexter/dexter_train.csv", header=None).values
dexter_train_labels = np.where(np.ravel(pd.read_csv("./dexter/dexter_train.
 ↪labels", header=None).values) == -1, 0, 1)
dexter_test_data = pd.read_csv("./dexter/dexter_valid.csv", header=None).values
dexter_test_labels = np.where(np.ravel(pd.read_csv("./dexter/dexter_valid.
 ↪labels", header=None).values) == -1, 0, 1)
```

Normalize training and test set

[15]:
```
dexter_train_data_mean = dexter_train_data.mean(axis=0)
dexter_train_data_std = np.where(dexter_train_data.std(axis=0) == 0, 1,␣
 ↪dexter_train_data.std(axis=0))
normalized_dexter_train_data = normalize(dexter_train_data_mean,␣
 ↪dexter_train_data_std, dexter_train_data)
normalized_dexter_test_data = normalize(dexter_train_data_mean,␣
 ↪dexter_train_data_std, dexter_test_data)
```

Set iterations and learning rates in decreasing order of features obtained.

[16]:
```
iters = 100
dexter_learning_train_rates = [0.049, 0.057, 0.07, 0.11, 0.14]
```

Run logistic regression and store the train error and weights

[17]:
```
dexter_train_errors = [0, 0, 0, 0, 0]

dexter_train_errors[0], dexter_train_weights500 =␣
 ↪tisp_classifier(normalized_dexter_train_data,
                                                                 ␣
 ↪dexter_train_labels,
                                                                 ␣
 ↪dexter_learning_train_rates[0],
                                                                  iters)
```

```
dexter_train_errors[1], dexter_train_weights300 =␣
 ↪tisp_classifier(normalized_dexter_train_data,
                                                  ␣
 ↪dexter_train_labels,
                                                  ␣
 ↪dexter_learning_train_rates[1],
                                                   iters)

dexter_train_errors[2], dexter_train_weights100 =␣
 ↪tisp_classifier(normalized_dexter_train_data,
                                                  ␣
 ↪dexter_train_labels,
                                                  ␣
 ↪dexter_learning_train_rates[2],
                                                   iters)


dexter_train_errors[3], dexter_train_weights30 =␣
 ↪tisp_classifier(normalized_dexter_train_data,
                                                ␣
 ↪dexter_train_labels,
                                                ␣
 ↪dexter_learning_train_rates[3],
                                                 iters)

dexter_train_errors[4], dexter_train_weights10 =␣
 ↪tisp_classifier(normalized_dexter_train_data,
                                                ␣
 ↪dexter_train_labels,
                                                ␣
 ↪dexter_learning_train_rates[4],
                                                 iters)

dexter_train_errors[0] = dexter_train_errors[0][500]
dexter_train_errors[1] = dexter_train_errors[1][300]
dexter_train_errors[2] = dexter_train_errors[2][100]
dexter_train_errors[3] = dexter_train_errors[3][30]
dexter_train_errors[4] = dexter_train_errors[4][10]
```

Predict using the test set and calculate the test error

[18]:
```
dexter_test_errors = []
dexter_test_scores500 = np.dot(normalized_dexter_test_data,␣
 ↪dexter_train_weights500)
dexter_test_preds500 = prediction(sigmoid(dexter_test_scores500))
```

```
dexter_test_errors.append(misclassification_error(dexter_test_labels,␣
 ↪dexter_test_preds500))

dexter_test_scores300 = np.dot(normalized_dexter_test_data,␣
 ↪dexter_train_weights300)
dexter_test_preds300 = prediction(sigmoid(dexter_test_scores300))
dexter_test_errors.append(misclassification_error(dexter_test_labels,␣
 ↪dexter_test_preds300))

dexter_test_scores100 = np.dot(normalized_dexter_test_data,␣
 ↪dexter_train_weights100)
dexter_test_preds100 = prediction(sigmoid(dexter_test_scores100))
dexter_test_errors.append(misclassification_error(dexter_test_labels,␣
 ↪dexter_test_preds100))

dexter_test_scores30 = np.dot(normalized_dexter_test_data,␣
 ↪dexter_train_weights30)
dexter_test_preds30 = prediction(sigmoid(dexter_test_scores30))
dexter_test_errors.append(misclassification_error(dexter_test_labels,␣
 ↪dexter_test_preds30))

dexter_test_scores10 = np.dot(normalized_dexter_test_data,␣
 ↪dexter_train_weights10)
dexter_test_preds10 = prediction(sigmoid(dexter_test_scores10))
dexter_test_errors.append(misclassification_error(dexter_test_labels,␣
 ↪dexter_test_preds10))
```

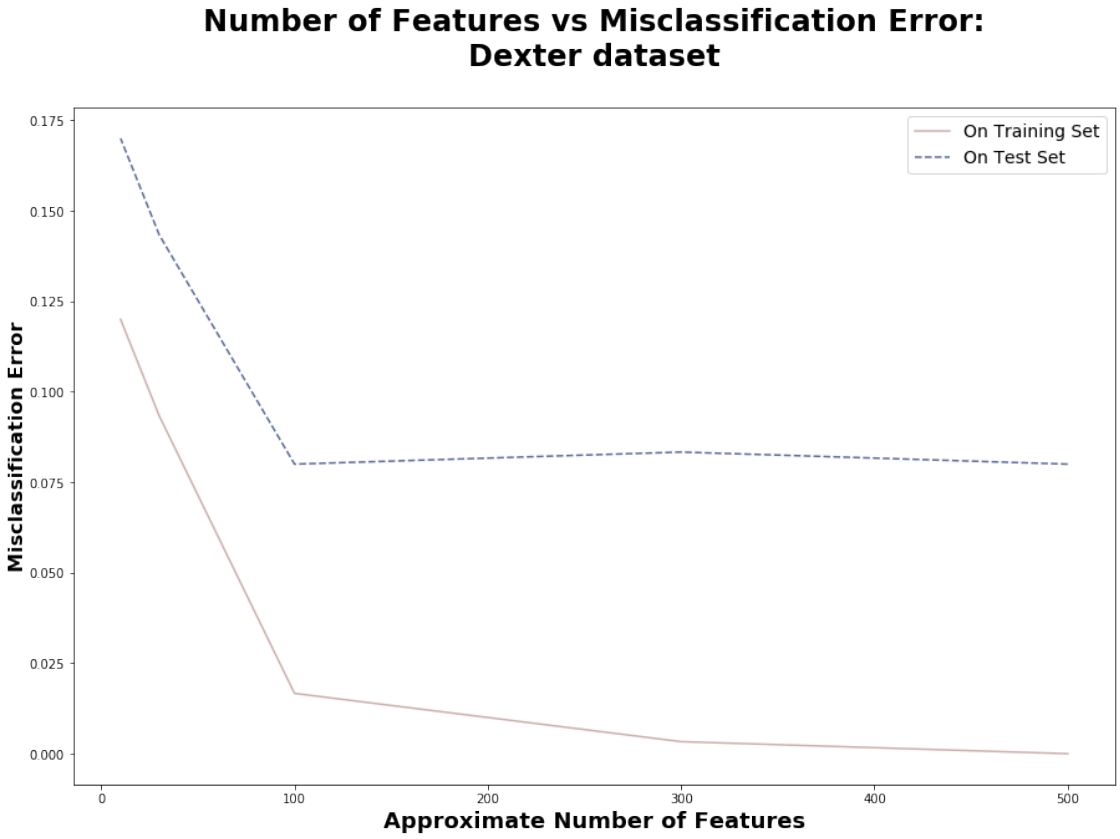
Plot a graph of number of features vs error

[19]:
```
# size of graph
plt.rcParams['figure.figsize'] = [15, 10]  # size=15x10 inches

# labels
plt.title("Number of Features vs Misclassification Error:\nDexter dataset\n",␣
 ↪fontdict=fontdict_title)
plt.xlabel("Approximate Number of Features", fontdict=fontdict_xlabel)
plt.ylabel("Misclassification Error", fontdict=fontdict_ylabel)

# plotting
features_approximately = [500,300,100,30,10]
plt.plot(features_approximately, dexter_train_errors,
         color="#CDB1AD",
         linestyle="-",
         label="On Training Set")
plt.plot(features_approximately, dexter_test_errors,
         color="#5D6E9E",
```

```
         linestyle="--",
         label="On Test Set")
plt.legend(fontsize=14);
```



Train and Test Misclassification Errors Table

[20]:
```
# Create labels
rows_labels = dexter_learning_train_rates
columns_labels = ["Lambda Value","Dexter Train Error","Dexter Test Error","␣
 ↪Approximate Number of Features"]

# Store the misclassification error from each dataset for training and testing
misclassification_errors = {
    columns_labels[1]: dexter_train_errors,
    columns_labels[2]: dexter_test_errors,
    columns_labels[3]: features_approximately
}
```

```
# Create dataframe to output table
error_tabledf=pd.DataFrame(misclassification_errors, index=rows_labels)
error_tabledf.index.name = columns_labels[0]
error_tabledf
```

[20]:

Lambda Value	Dexter Train Error	Dexter Test Error	Approximate Number of Features
0.049	0.000000	0.080000	500
0.057	0.003333	0.083333	300
0.070	0.016667	0.080000	100
0.110	0.093333	0.143333	30
0.140	0.120000	0.170000	10

Problem 3: TISP Logistic Regression: Madelon Dataset

Load training and test set

[21]:
```
madelon_train_data = pd.read_csv("./madelon/madelon_train.data", header=None,␣
↪sep=" ").dropna(axis=1).values
madelon_train_labels = np.where(np.ravel(
    pd.read_csv("./madelon/madelon_train.labels", header=None, sep=" ").
↪dropna(axis=1).values) == -1, 0, 1)

madelon_test_data = pd.read_csv("./madelon/madelon_valid.data", header=None,␣
↪sep=" ").dropna(axis=1).values

madelon_test_labels = np.where(np.ravel(
    pd.read_csv("./madelon/madelon_valid.labels", header=None, sep=" ").
↪dropna(axis=1).values) == -1, 0, 1)
```

Normalize training and test set

[22]:
```
madelon_train_data_mean = madelon_train_data.mean(axis=0)
madelon_train_data_std = np.where(madelon_train_data.std(axis=0) == 0, 1,␣
↪madelon_train_data.std(axis=0))
```

```
normalized_madelon_train_data = normalize(madelon_train_data_mean,␣
 ↪madelon_train_data_std, madelon_train_data)
normalized_madelon_test_data = normalize(madelon_train_data_mean,␣
 ↪madelon_train_data_std, madelon_test_data)
```

Set learning rate and iterations

[23]:
```
iters = 100

madelon_learning_train_rates = [0.001, 0.007, 0.015, 0.025, 0.04]
```

Run logistic regression and store the train error and weights

[24]:
```
madelon_train_errors = [0, 0, 0, 0, 0]

madelon_train_errors[0], madelon_train_weights500 =␣
 ↪tisp_classifier(normalized_madelon_train_data,
                                                                  ␣
 ↪madelon_train_labels,
                                                                  ␣
 ↪madelon_learning_train_rates[0],
                                                                   iters)

madelon_train_errors[1], madelon_train_weights300 =␣
 ↪tisp_classifier(normalized_madelon_train_data,
                                                                  ␣
 ↪madelon_train_labels,
                                                                  ␣
 ↪madelon_learning_train_rates[1],
                                                                   iters)

madelon_train_errors[2], madelon_train_weights100 =␣
 ↪tisp_classifier(normalized_madelon_train_data,
                                                                  ␣
 ↪madelon_train_labels,
                                                                  ␣
 ↪madelon_learning_train_rates[2],
                                                                   iters)

madelon_train_errors[3], madelon_train_weights30 =␣
 ↪tisp_classifier(normalized_madelon_train_data,
                                                                 ␣
 ↪madelon_train_labels,
                                                                 ␣
 ↪madelon_learning_train_rates[3],
                                                                  iters)
```

```
madelon_train_errors[4], madelon_train_weights10 =␣
 ↪tisp_classifier(normalized_madelon_train_data,
                                                                  ␣
 ↪madelon_train_labels,
                                                                  ␣
 ↪madelon_learning_train_rates[4],
                                                                   iters)

madelon_train_errors[0] = madelon_train_errors[0][500]
madelon_train_errors[1] = madelon_train_errors[1][300]
madelon_train_errors[2] = madelon_train_errors[2][100]
madelon_train_errors[3] = madelon_train_errors[3][30]
madelon_train_errors[4] = madelon_train_errors[4][10]
```

Predict using the test set and calculate the test error

[25]:
```
madelon_test_errors = []
madelon_test_scores500 = np.dot(normalized_madelon_test_data,␣
 ↪madelon_train_weights500)
madelon_test_preds500 = prediction(sigmoid(madelon_test_scores500))
madelon_test_errors.append(misclassification_error(madelon_test_labels,␣
 ↪madelon_test_preds500))

madelon_test_scores300 = np.dot(normalized_madelon_test_data,␣
 ↪madelon_train_weights300)
madelon_test_preds300 = prediction(sigmoid(madelon_test_scores300))
madelon_test_errors.append(misclassification_error(madelon_test_labels,␣
 ↪madelon_test_preds300))

madelon_test_scores100 = np.dot(normalized_madelon_test_data,␣
 ↪madelon_train_weights100)
madelon_test_preds100 = prediction(sigmoid(madelon_test_scores100))
madelon_test_errors.append(misclassification_error(madelon_test_labels,␣
 ↪madelon_test_preds100))

madelon_test_scores30 = np.dot(normalized_madelon_test_data,␣
 ↪madelon_train_weights30)
madelon_test_preds30 = prediction(sigmoid(madelon_test_scores30))
madelon_test_errors.append(misclassification_error(madelon_test_labels,␣
 ↪madelon_test_preds30))

madelon_test_scores10 = np.dot(normalized_madelon_test_data,␣
 ↪madelon_train_weights10)
madelon_test_preds10 = prediction(sigmoid(madelon_test_scores10))
```

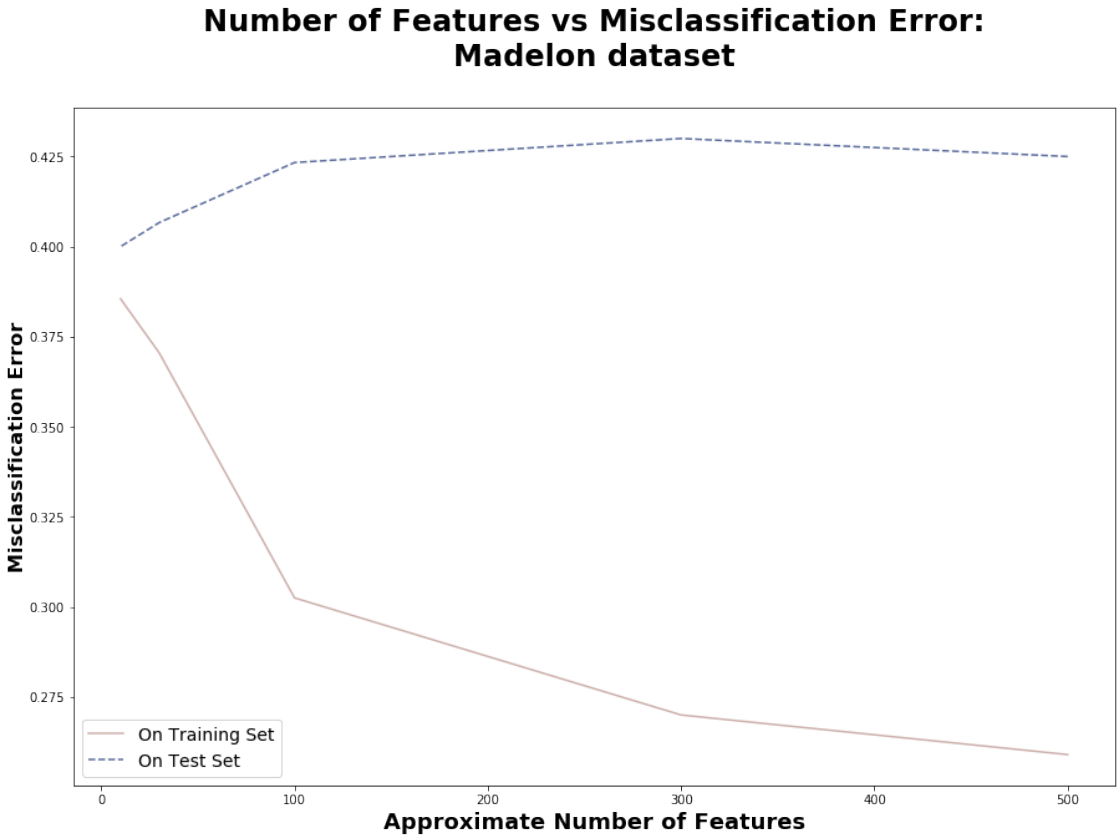
```
madelon_test_errors.append(misclassification_error(madelon_test_labels,␣
 ↪madelon_test_preds10))
```

Plot a graph of number of features vs error

[26]:
```
# size of graph
plt.rcParams['figure.figsize'] = [15, 10]  # size=15x10 inches

# labels
plt.title("Number of Features vs Misclassification Error:\nMadelon dataset\n",␣
 ↪fontdict=fontdict_title)
plt.xlabel("Approximate Number of Features", fontdict=fontdict_xlabel)
plt.ylabel("Misclassification Error", fontdict=fontdict_ylabel)

# plotting
features_approximately = [500,300,100,30,10]
plt.plot(features_approximately, madelon_train_errors,
         color="#CDB1AD",
         linestyle="-",
         label="On Training Set")
plt.plot(features_approximately, madelon_test_errors,
         color="#5D6E9E",
         linestyle="--",
         label="On Test Set")
plt.legend(fontsize=14);
```



Train and Test Misclassification Errors

[27]:
```
# Create labels
rows_labels = gisette_learning_train_rates
columns_labels = ["Lambda Value","Madelon Train Error","Madelon Test Error","␣
 ↪Approximate Number of Features"]

# Store the misclassification error from each dataset for training and testing
misclassification_errors = {
    columns_labels[1]: madelon_train_errors,
    columns_labels[2]: madelon_test_errors,
    columns_labels[3]: features_approximately
}

# Create dataframe to output table
error_tabledf=pd.DataFrame(misclassification_errors, index=rows_labels)
error_tabledf.index.name = columns_labels[0]
error_tabledf
```

[27]:

Lambda Value	Madelon Train Error	Madelon Test Error	Approximate Number of Features
0.04	0.2590	0.425000	500
0.06	0.2700	0.430000	300
0.09	0.3025	0.423333	100
0.14	0.3705	0.406667	30
0.20	0.3855	0.400000	10