In [94]:
```
import scipy.io as scio
import pandas as pd
import numpy as np
import os
from pandas import Series,DataFrame
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.utils import shuffle
import random
from sklearn.model_selection import train_test_split
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.externals import joblib
from sklearn import  metrics
import xgboost as xgb
from xgboost.sklearn import XGBClassifier
from sklearn.model_selection import cross_val_score

from matplotlib import pyplot as plt
from sklearn.datasets import load_breast_cancer
from sklearn.metrics import confusion_matrix
from sklearn.neighbors import KNeighborsClassifier
from sklearn.preprocessing import MinMaxScaler
from sklearn.model_selection import KFold
import seaborn as sns
from sklearn.metrics import accuracy_score
from sklearn.decomposition import PCA
import warnings
warnings.filterwarnings("ignore")

import time
import cProfile
import psutil


sns.set()
```

In [95]:
```
#set lists for final graph comparison
model_time = [] #how much time required to train model
model_accuracy = [] #test accuracy
model_similarity = [] #percentage test_accuracy/train_accuracy
names = [] #names of models
```

Set Path

In [96]:
```
#Fall2019-proj3-sec1--proj3-sec1-grp2
pwd = os.path.dirname(os.path.dirname(os.getcwd()))

# set the working directory of output
checkpoint_wd = os.path.join(pwd, "output", "checkpoint")
if not os.path.exists(checkpoint_wd):
    os.makedirs(checkpoint_wd)
```

Train

Data Preprocessing

In [97]:
```
scaler = MinMaxScaler(feature_range = (0,1))
```

In [98]:
```
random.seed(3345)
```

In [99]:
```
def distance_feature(x): # calcuate distance between points, choose upri
gt triangle
    #sqrt(dx^2+dy^2)
    a = (x[None, :, :] - x[:, None, :])
    b = np.linalg.norm(a, axis=2)
    return b[np.triu_indices(78, 1)] # feature size (78-1)(78-2) /2
```

In [100]:
```
def euc_distance_feature(x): # instead of distance, keep two dimensional
distance vector
    #(dx,dy)
    a = (x[None, :, :] - x[:, None, :])
    index = np.triu_indices(78, 1)
    b = a[index]
    return b.reshape((-1,)) # feature size (78-1)(78-2) /2 * 2
```

In [101]:
```
df = pd.read_csv("../../data/train_set/label.csv")
labels = df["emotion_idx"].tolist()
```

In [102]:
```
data = list()
for i in range(1, 2501):
    name = "../../data/train_set/points/%04d.mat" % i
    dic = scio.loadmat(name)
    if "faceCoordinatesUnwarped" in dic:
        data.append(dic["faceCoordinatesUnwarped"])
    else:
        data.append(dic["faceCoordinates2"])
```

In [103]:
```
x_train, x_test, train_y, test_y = train_test_split(data, labels, test_s
ize=0.2)
```

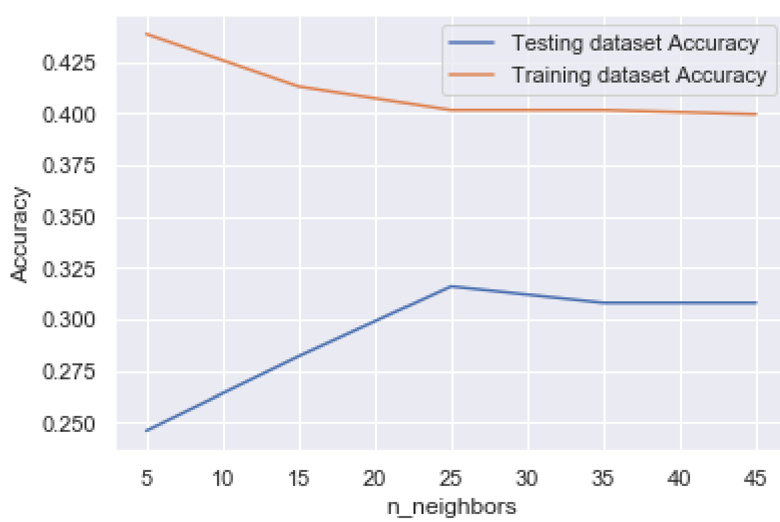
First we try Euclidian distance as features

In [104]:
```
train_x = [euc_distance_feature(d) for d in x_train] #(dx,dy)
test_x = [euc_distance_feature(d) for d in x_test]
```

In [105]:
```
scaler.fit(train_x)
train_x = scaler.transform(train_x)
test_x = scaler.transform(test_x)
```

Base Line Model: KNN

In [106]:
```
neighbors = np.arange(5, 50, 10)
train_accuracy = np.empty(len(neighbors))
test_accuracy = np.empty(len(neighbors))

start = time.time() #start time
# Loop over K values
for i, k in enumerate(neighbors):
    knn = KNeighborsClassifier(n_neighbors=k)
    knn.fit(train_x, train_y)

    # Compute traning and test data accuracy
    train_accuracy[i] = knn.score(train_x, train_y)
    test_accuracy[i] = knn.score(test_x, test_y)

#Generate plot
plt.plot(neighbors, test_accuracy, label = 'Testing dataset Accuracy')
plt.plot(neighbors, train_accuracy, label = 'Training dataset Accuracy')

plt.legend()
plt.xlabel('n_neighbors')
plt.ylabel('Accuracy')
plt.show()
```



In [107]:
```
knn = KNeighborsClassifier(n_neighbors=15)
knn.fit(train_x, train_y)

end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))

time_KN_euc = end - start #time to train model
model_time.append(time_KN_euc) #add model info to final comparison graph
names.append("KNN Euclid baseline")
```

```
Training Time: 272.8572437763214 seconds
```

In [108]:
```
print("Training dataset Accuracy")
train_accuracy = baseline.score(train_x, train_y)
print(train_accuracy)

print("Testing dataset Accuracy")
test_accuracy = knn.score(test_x, test_y)
print(test_accuracy)

acc_diff_KN_euclid = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_KN_euclid)
```

```
Training dataset Accuracy
0.383
Testing dataset Accuracy
0.282
```

Second we try the distance as features

In [114]:
```
train_x = [distance_feature(d) for d in x_train] #sqrt(dx^2+dy^2)
test_x = [distance_feature(d) for d in x_test]
```

In [115]:
```
np.save("../../output/train_x.npy",train_x)
```

In [116]:
```
scaler.fit(train_x)
train_x = scaler.transform(train_x)
test_x = scaler.transform(test_x)
```

Base Line Model: KNN

In [49]:
```
neighbors = np.arange(5, 50, 10)
train_accuracy = np.empty(len(neighbors))
test_accuracy = np.empty(len(neighbors))

start = time.time() #start time
# Loop over K values
for i, k in enumerate(neighbors):
    knn = KNeighborsClassifier(n_neighbors=k)
    knn.fit(train_x, train_y)

    # Compute traning and test data accuracy
    train_accuracy[i] = knn.score(train_x, train_y)
    test_accuracy[i] = knn.score(test_x, test_y)

#Generate plot
plt.plot(neighbors, test_accuracy, label = 'Testing dataset Accuracy')
plt.plot(neighbors, train_accuracy, label = 'Training dataset Accuracy')

plt.legend()
plt.xlabel('n_neighbors')
plt.ylabel('Accuracy')
plt.show()
```

In [117]:
```
baseline = KNeighborsClassifier(n_neighbors=15)
baseline.fit(train_x, train_y)

end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))

time_KN = end - start #time to train model
model_time.append(time_KN) #add model info to final comparison graph
names.append("KNN Baseline")
```

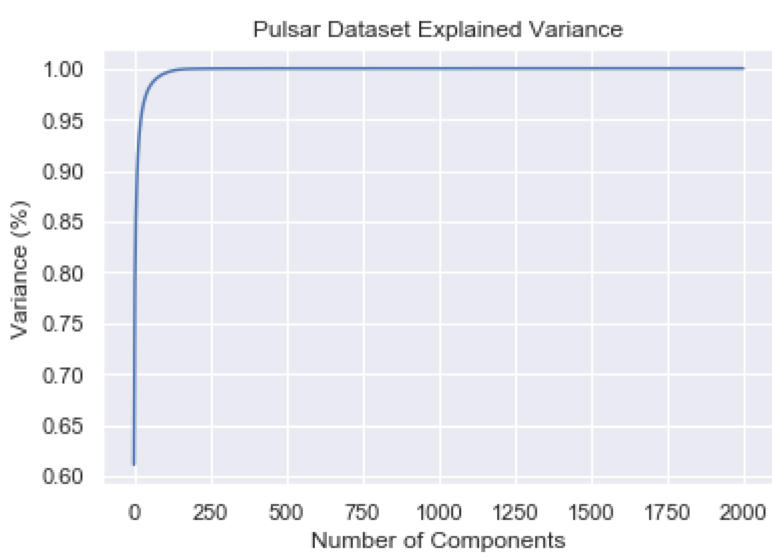
```
Training Time: 599.6543228626251 seconds
```

In [119]:
```
print("Training dataset Accuracy")
train_accuracy = baseline.score(train_x, train_y)
print(train_accuracy)

print("Testing dataset Accuracy")
test_accuracy = baseline.score(test_x, test_y)
print(test_accuracy)

acc_diff_KN = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_KN)
```

```
Training dataset Accuracy
0.418
Testing dataset Accuracy
0.306
```

We see that the distance formula sqrt(dx^2+dy^2) produces a higher accuracy rate than the Euclidian distance formula. Therefore, we choose the distance formula to use in evaluation of future models.

In [52]:
```
#Fitting the PCA algorithm with our Data
pca = PCA().fit(train_x)
#Plotting the Cumulative Summation of the Explained Variance
plt.figure()
plt.plot(np.cumsum(pca.explained_variance_ratio_))
plt.xlabel('Number of Components')
plt.ylabel('Variance (%)') #for each component
plt.title('Pulsar Dataset Explained Variance')
plt.show()
```



In [53]:
```
pca = PCA(n_components=80).fit(train_x)
train_x_reduce = pca.transform(train_x)
```

In [54]:
```
start = time.time() #start time

knn = KNeighborsClassifier(n_neighbors=25)
knn.fit(train_x_reduce, train_y)

end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))

time_KN_pca = end - start #time to train model
model_time.append(time_KN_pca) #add model info to final comparison graph
names.append("KNN PCA")
```

```
Training Time: 0.005665063858032226б seconds
```

In [55]:
```
print("Training dataset Accuracy")
train_accuracy = knn.score(train_x_reduce, train_y)
print(train_accuracy)
knn_preds = knn.predict(pca.transform(test_x))
print("Testing dataset Accuracy")
test_accuracy = knn.score(pca.transform(test_x), test_y)
print(test_accuracy)

acc_diff_KN_pca = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_KN_pca)
```

```
Training dataset Accuracy
0.41
Testing dataset Accuracy
0.274
```

GBM

In [57]:
```
start = time.time() #start time

gbm = GradientBoostingClassifier(learning_rate=0.01,n_estimators=30,rand
om_state=10).fit(train_x, train_y)
end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))

time_gbm = end - start #time to train model
model_time.append(time_gbm) #add model info to final comparison graph
names.append("GBM")
```

```
Training Time: 318.24587893486023 seconds
```

In [58]:
```
print("Training dataset Accuracy")
train_accuracy = gbm.score(train_x, train_y)
print(train_accuracy)
print("Testing dataset Accuracy")
gbm_preds = gbm.predict(test_x)
test_accuracy = gbm.score(test_x, test_y)
print(test_accuracy)

acc_diff_gbm = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_gbm)
```

```
Training dataset Accuracy
0.67
Testing dataset Accuracy
0.312
```

Logistic Regression

In [59]:
```
start = time.time() #start time
param_grid = {'C': [0.001, 0.01, 1, 5, 10, 25] }
clf = GridSearchCV(LogisticRegression(penalty='l2'), param_grid)
GridSearchCV(cv=None,
             estimator=LogisticRegression(C=1.0, intercept_scaling=1,
                                          dual=False, fit_intercept=True
, penalty='l2', tol=0.0001),
             param_grid={'C': [0.001, 0.01, 1, 5, 10, 25]})

best_clf = clf.fit(train_x, train_y)

end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))
time_logreg = end - start #time to train model

model_time.append(time_logreg) #add model info to final comparison graph
names.append("Log Regr")
```

```
Training Time: 395.672611951828 seconds
```

In [60]:
```
print("Training dataset Accuracy")
train_accuracy = best_clf.score(train_x, train_y)
print(train_accuracy)
print("Testing dataset Accuracy")
lr_preds = best_clf.predict(test_x)
test_accuracy = best_clf.score(test_x, test_y)
print(test_accuracy)

acc_diff_logreg = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_logreg)
```

```
Training dataset Accuracy
0.774
Testing dataset Accuracy
0.522
```

Random Forest

In [61]:
```
start = time.time() #start time

# Create the parameter grid based on the results of random search
param_grid = {
    'max_depth': [10, 20],
    'max_features': [2, 3],
    'min_samples_leaf': [10, 15],
    'min_samples_split': [10, 12],
    'n_estimators': [200, 400]
}
# Create a based model
rf = RandomForestClassifier()
# Instantiate the grid search model
rf = GridSearchCV(estimator = rf, param_grid = param_grid, cv = 3, n_job
s = -1, verbose = 2)
best_rf = rf.fit(train_x, train_y)

end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))

time_forest = end - start #time to train model
model_time.append(time_forest) #add model info to final comparison graph
names.append("Random Forest")
```

```
Fitting 3 folds for each of 32 candidates, totalling 96 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 8 concurrent work
ers.
[Parallel(n_jobs=-1)]: Done  25 tasks      | elapsed:    9.1s
[Parallel(n_jobs=-1)]: Done  96 out of  96 | elapsed:   25.0s finished

Training Time: 26.690473079681396 seconds
```

In [62]:
```
print("Training dataset Accuracy")
train_accuracy = best_rf.score(train_x, train_y)
print(train_accuracy)
print("Testing dataset Accuracy")
rf_preds = best_rf.predict(test_x)
test_accuracy = best_rf.score(test_x, test_y)
print(test_accuracy)

acc_diff_forest = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_forest)
```

```
Training dataset Accuracy
0.869
Testing dataset Accuracy
0.32
```

Xgboost

In [63]:
```
dtrain = xgb.DMatrix(train_x, label=train_y)
dtest = xgb.DMatrix(test_x, label=test_y)
```

parameters = { 'max_depth': [15, 20, 25], 'learning_rate': [0.02, 0.05, 0.1], 'n_estimators': [100, 500, 1000], 'min_child_weight': [0, 2, 5], 'max_delta_step': [0, 0.2, 0.6], 'subsample': [0.6, 0.7, 0.8,], 'colsample_bytree': [0.4, 0.6, 0.8], 'reg_alpha': [0.25, 0.5, 0.75], 'reg_lambda': [0.2, 0.5, 0.8], 'scale_pos_weight': [0.2, 0.5, 0.8] } start = time.time() #start time xlf = xgb.XGBClassifier(max_depth=10, learning_rate=0.01, n_estimators=2000, silent=True, objective='binary:logistic', nthread=-1, gamma=0, min_child_weight=1, max_delta_step=0, subsample=0.85, colsample_bytree=0.7, colsample_bylevel=1, reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=1440, missing=None) # With gridSearch, we do not need fit function gsearch = GridSearchCV(xlf, param_grid=parameters, scoring='accuracy', cv=3) gsearch.fit(train_x, train_y) end = time.time() print("Training Time:","%s seconds"%(end - start)) print("Best score: %0.3f" % gsearch.best_score_) print("Best parameters set:") best_parameters = gsearch.best_estimator_.get_params() for param_name in sorted(parameters.keys()): print("\t%s: %r" % (param_name, best_parameters[param_name])) end = time.time() #end time

In [64]:
```
param = {'booster':'gbtree',
'objective': 'multi:softmax',
'num_class':23,
'n_estimators':500,
'max_depth':20,
'alpha': 3,
'gamma': 1,
'silent': 1,
'subsample': 0.8,
'eta': 0.1,
'learning_rates': 0.03}
num_round= 5

start = time.time() #start time
bst = xgb.train(param, dtrain, num_round)

end = time.time() #end time
print("Training Time:","%s seconds"%(end - start))

time_xgboost = end - start #time to train model
model_time.append(time_xgboost) #add model info to final comparison grap
h
names.append("xgboost")

print("Training dataset Accuracy")
train_preds = bst.predict(dtrain)
train_accuracy = accuracy_score(train_y, train_preds)
print(train_accuracy)
```

```
Training Time: 71.20817112922668 seconds
Training dataset Accuracy
0.8905
```

In [65]:
```
print("Testing dataset Accuracy")
xgb_preds = bst.predict(dtest)
test_accuracy = accuracy_score(test_y, xgb_preds)
print(test_accuracy)

acc_diff_xgboost = 100*test_accuracy/train_accuracy
model_accuracy.append(100*test_accuracy)
model_similarity.append(acc_diff_xgboost)
```

```
Testing dataset Accuracy
0.404
```

Model Ensembling

Method 1: Average

In [66]:
```
preds = (lr_preds+knn_preds+rf_preds+gbm_preds+xgb_preds)/5
preds = np.ceil(preds)
test_accuracy = accuracy_score(test_y, preds)
print ("Test Accuracy: %.2f%%" % (test_accuracy * 100.0))
```

```
Test Accuracy: 16.20%
```

In [68]:
```
preds = (lr_preds+gbm_preds+xgb_preds)/3
preds = np.ceil(preds)
test_accuracy = accuracy_score(test_y, preds)
print ("Test Accuracy: %.2f%%" % (test_accuracy * 100.0))
```

```
Test Accuracy: 23.40%
```

In [69]:
```
preds = (lr_preds+xgb_preds)/2
preds = np.ceil(preds)
test_accuracy = accuracy_score(test_y, preds)
print ("Test Accuracy: %.2f%%" % (test_accuracy * 100.0))
```

```
Test Accuracy: 35.20%
```

Method 2: Stacking

In [153]:
```
#Method 2: Stacking
from sklearn.model_selection import KFold
def stacking(clf, x_train, y_train, x_test, n_folds=8):
    train_num, test_num = x_train.shape[0], x_test.shape[0]
    second_level_train_set = np.zeros((train_num,))
    second_level_test_set = np.zeros((test_num,))
    test_nfolds_sets = np.zeros((test_num, n_folds))
    kf = KFold(n_splits=n_folds)

    for i,(train_index, test_index) in enumerate(kf.split(x_train)):
        x_tra, y_tra = x_train[train_index], y_train[train_index]
        x_tst, y_tst =  x_train[test_index], y_train[test_index]

        clf.fit(x_tra, y_tra)

        second_level_train_set[test_index] = clf.predict(x_tst)
        test_nfolds_sets[:,i] = clf.predict(x_test)

    second_level_test_set[:] = test_nfolds_sets.mean(axis=1)
    return second_level_train_set, second_level_test_set
```

In [154]:
```
train_x = np.array(train_x)
train_y = np.array(train_y)
test_x = np.array(test_x)
test_y = np.array(test_y)
```

In [172]:
```
gbm_model = GradientBoostingClassifier(learning_rate=0.01,n_estimators=3
0,random_state=10)
lr_model = LogisticRegression(max_iter=300, penalty = "l2", solver='lbfg
s', multi_class='multinomial', n_jobs=-1)
```

In [173]:
```
train_sets = []
test_sets = []
for clf in [gbm_model,lr_model]:
    train_set, test_set = stacking(clf, train_x, train_y, test_x)
    train_sets.append(train_set)
    test_sets.append(test_set)

meta_train = np.concatenate([result_set.reshape(-1,1) for result_set in
train_sets], axis=1)
meta_test = np.concatenate([y_test_set.reshape(-1,1) for y_test_set in t
est_sets], axis=1)
```

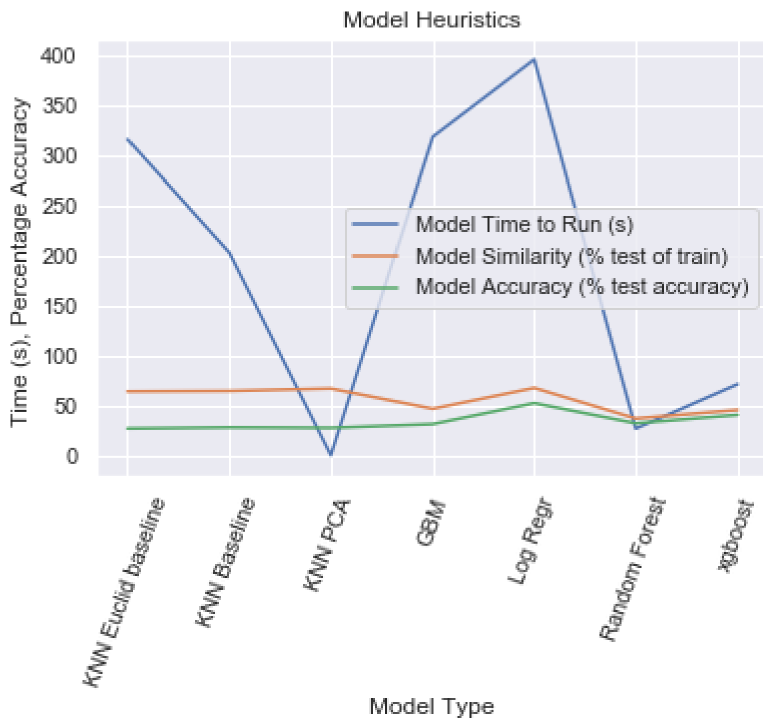
In [174]:
```
model = DecisionTreeClassifier(max_depth = 5)
model.fit(train_x,train_y)
print(model.score(train_x, train_y))
model.score(test_x, test_y)
```

```
0.379
```

Out[174]:
```
0.278
```

Heuristics Plot

In [70]:
```
#Plot time, model similarity, modek accuracy
plt.xticks(rotation='70')
plt.plot(names, model_time, label = 'Model Time to Run (s)')
plt.plot(names, model_similarity, label = 'Model Similarity (% test of t
rain)')
plt.plot(names, model_accuracy, label = 'Model Accuracy (% test accurac
y)')

# Generate plot
plt.legend()
plt.xlabel('Model Type')
plt.ylabel('Time (s), Percentage Accuracy ')
plt.title('Model Heuristics')
plt.show()
```



Save Model

In [120]:
```
joblib.dump(baseline, checkpoint_wd+"/baseline_model.m")
```

Out[120]:
```
['/Users/yuting/Desktop/MS&E_3/Applied DS/Fall2019-proj3-sec1--proj3-se
c1-grp2/output/checkpoint/baseline_model.m']
```

In [71]:
```
joblib.dump(best_clf, checkpoint_wd+"/improved_model.m")
```

Out[71]:
```
['/Users/yuting/Desktop/MS&E_3/Applied DS/Fall2019-proj3-sec1--proj3-se
c1-grp2/output/checkpoint/improved_model.m']
```