In [20]:

```
import sys
import os
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import PIL
from PIL import Image
from scipy.io import loadmat
from scipy.spatial.distance import pdist

from sklearn import ensemble
from sklearn.model_selection import train_test_split, cross_validate, Stratified
KFold
from sklearn.metrics import accuracy_score, make_scorer
from statistics import mean
import time

from sklearn.model_selection import StratifiedKFold
from sklearn.dummy import DummyClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.preprocessing import StandardScaler
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import LinearSVC, SVC
from sklearn.linear_model import LogisticRegression
from sklearn.neural_network import MLPClassifier

from keras.callbacks import EarlyStopping
from keras import models
from keras import layers
from keras.preprocessing.image import ImageDataGenerator
from keras import regularizers
from keras.utils.np_utils import to_categorical
```

Fundamental Configurations

In [4]:

```
"""
Path
"""
DATA_PATH = "../data/train_set"
IMAGE_FOLDER = os.path.join(DATA_PATH, "images")
POINTS_FOLDER = os.path.join(DATA_PATH, "points")
LABELS_FOLDER = DATA_PATH

RANDOM_SEED = 13
```

Data Import

In [2]:

```
def read_all_images(height = 750, width = 1000, crop_gray = False, points = None
):
    """
    Read 2500 training images from the IMAGE_FOLDER, resized to 'height x width'

    :param height: resized height of images
    :param width: resized width of images
    :return: a 4d numpy array in form of (index, height, width, channels), chann
els is RGB
    """
    files = [file for file in os.listdir(IMAGE_FOLDER) if file.endswith('.jpg')]
    files.sort()


    face_images_arr = np.zeros((len(files), height, width, 1 if crop_gray else 3
))

    for index, filename in enumerate(files):
        face_img = Image.open(os.path.join(IMAGE_FOLDER, filename))
        # if crop_gray, then the image will be cropped to fit the facial part
        # and then it will return a grayscale version
        if crop_gray:
            face_img = face_img.convert('L')

            face_points = points[index]
            # calculate crop position
            left = np.min(face_points[:,0])
            right = np.max(face_points[:,0])
            top = np.min(face_points[:,1])
            bot = np.max(face_points[:,1])

            face_img = face_img.crop((left,top,right,bot))

        face_img = face_img.resize((width, height))
        # fit the dimension
        face_images_arr[index] = np.array(face_img).reshape((height,width, -1))

    return face_images_arr

def read_labels():
    """
    Read the image labels from the label.csv file
    :return: a pandas.DataFrame with 3 columns: 'emotion_idx','emotion_cat','typ
e'
    """
    labels_df = pd.read_csv(os.path.join(LABELS_FOLDER, 'label.csv'))
    labels_df = labels_df.loc[:,['emotion_idx','emotion_cat','type']]
    return labels_df


def read_all_points():
    """
    Read all face coordinates points
    :return: a tuple of shape (2500, 78, 2). Because for each of 2500 images the
re are 78 points associated with it
    """
    files = [file for file in os.listdir(POINTS_FOLDER) if file.endswith('.mat'
)]
    files.sort()
```

```
    face_points = np.zeros((len(files), 78, 2))
    for index, filename in enumerate(files):
        face_points_dict = loadmat(os.path.join(POINTS_FOLDER, filename))

        face_points[index] = face_points_dict.get('faceCoordinatesUnwarped',  fa
ce_points_dict.get('faceCoordinates2'))
    return face_points

def load_data(loadImage = False, height = 750, width = 1000, crop_gray = False):
    """
    Load training data from local files

    :param loadImage: if it's False, this function will not load original images
    :return: a tuple (images, points, labels)
        if loadImage is False, the 'images' will None. Otherwise its a numpy arr
ay with shape (2500,750,1000,3)
        points is a numpy array with shape (2500, 78, 2)
        labels is a pandas.DataFrame
    """

    face_images_points = read_all_points()

    face_images_ndarr =  read_all_images(height, width, crop_gray, face_images_p
oints) if loadImage else None
    labels = read_labels()

    return face_images_ndarr, face_images_points, labels



def show_image(index, all_images = None):
    """
    Display the (index)th image.
    all_images is passed, the this image numpy array can be easily retrieved fro
m it.
    Otherwise the original images needs to be read from disk

    :param index: the index to specify which image to disply
    :param all_images: the return value of 'read_all_images' function
    """

    if all_images is not None and index < len(all_images):
        face_img_arr = all_images[index].astype('uint8')
        if face_img_arr.shape[2] == 1:
            face_img_arr = face_img_arr.reshape((face_img_arr.shape[0],face_img_
arr.shape[1]))
    else:
        face_img_arr = plt.imread(os.path.join(IMAGE_FOLDER, f"{index:04}.jpg"))
    plt.imshow(face_img_arr, cmap='gray')
    plt.show()
```

In [5]:

```
"""
Read images with 200x200 resolution and facial points, labels
"""
height = 200
width = 200
images, points, labels = load_data(loadImage= False,crop_gray=True, height = hei
ght, width = width)
```

In [6]:

```
if images is not None:
    print("shape of image",images.shape)
    print(f"memory of image ndarray is {sys.getsizeof(images)/1024/1024/1024:.2
f} GB")
if points is not None:
    print("shape of points",points.shape)
```

```
shape of points (2500, 78, 2)
```

Data Preprocessing And Data Featuring

In [12]:

```
"""
Preprocessing
"""

X_distances = np.zeros((2500, 3003))
for i in range(2500):
    current = points[i]
    X_distances[i,] = pdist(current)


X_points = points.reshape((points.shape[0], -1))

y = labels['emotion_idx'].values - 1

print(X_distances.shape,X_points.shape, y.shape)
```

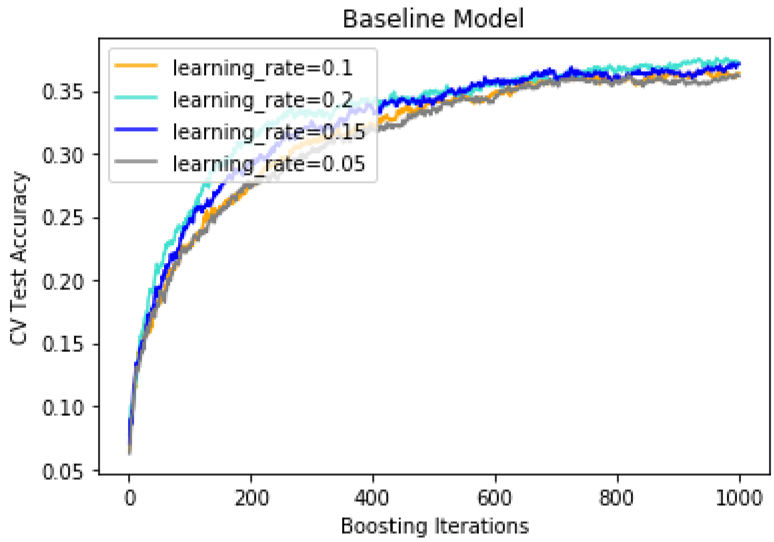
```
(2500, 3003) (2500, 156) (2500,)
```

Baseline Model

In [21]:

```
X = X_distances
Y = labels['emotion_idx']
plt.figure()
original_params = {'n_estimators': 1000, 'max_features': 1, 'max_depth': 1,
                   'learning_rate': 0.1}
for label, color, setting in [('learning_rate=0.1','orange',
                                {'learning_rate':0.1}),
                               ('learning_rate=0.2','turquoise',
                                {'learning_rate':0.2}),
                               ('learning_rate=0.15','blue',
                                {'learning_rate':0.15}),
                               ('learning_rate=0.05','gray',
                                {'learning_rate':0.1})]:
    start_time = time.time()
    skf = StratifiedKFold(n_splits = 5, random_state = 666)
    params = dict(original_params)
    base_score = np.zeros((5,params['n_estimators']), dtype=np.float64)
    params.update(setting)
    clf = ensemble.GradientBoostingClassifier(**params)

    for j, (train_index, test_index) in zip(range(5), skf.split(X, Y)):
        X_train, Y_train = X[train_index], Y[train_index]
        X_test, Y_test = X[test_index], Y[test_index]
        clf.fit(X_train, Y_train)

        for i, Y_pred in enumerate(clf.staged_predict(X_test)):
            base_score[j,i] = accuracy_score(Y_test, Y_pred)

    score = [mean(base_score[:,i]) for i in range(1000)]
    plt.plot(range(1, 1001), score, color=color, label=label)
    print("###### Time: %f" % (time.time() - start_time) + "s ######")

plt.legend(loc='upper left')
plt.xlabel('Boosting Iterations')
plt.ylabel('CV Test Accuracy')
plt.title('Baseline Model')
plt.show()
```

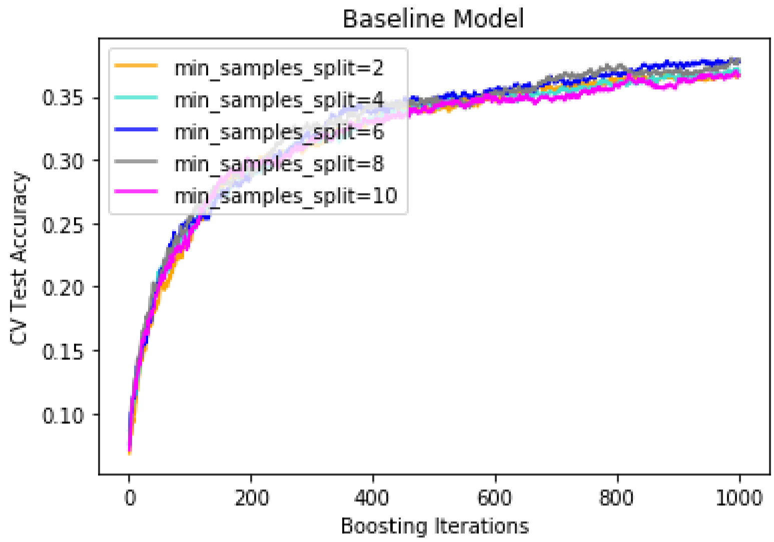
```
###### Time: 94.284029s ######
###### Time: 95.914360s ######
###### Time: 97.368861s ######
###### Time: 94.959776s ######
```



In [37]:

```
plt.figure()
original_params.update({'learning_rate':0.2})
for label, color, setting in [('min_samples_split=2','orange',
                               {'min_samples_split':2}),
                              ('min_samples_split=4','turquoise',
                               {'min_samples_split':4}),
                              ('min_samples_split=6','blue',
                               {'min_samples_split':6}),
                              ('min_samples_split=8','gray',
                               {'min_samples_split':8}),
                             ('min_samples_split=10','magenta',
                               {'min_samples_split':10})]:
    start_time = time.time()
    skf = StratifiedKFold(n_splits = 5, random_state = 666)
    params = dict(original_params)
    base_score = np.zeros((5,params['n_estimators']), dtype=np.float64)
    params.update(setting)
    clf = ensemble.GradientBoostingClassifier(**params)

    for j, (train_index, test_index) in zip(range(5), skf.split(X, Y)):
        X_train, Y_train = X[train_index], Y[train_index]
        X_test, Y_test = X[test_index], Y[test_index]
        clf.fit(X_train, Y_train)

        for i, Y_pred in enumerate(clf.staged_predict(X_test)):
            base_score[j,i] = accuracy_score(Y_test, Y_pred)

    score = [mean(base_score[:,i]) for i in range(1000)]
    plt.plot(range(1, 1001), score, color=color, label=label)
    print("###### Time: %f" % (time.time() - start_time) + "s ######")

plt.legend(loc='upper left')
plt.xlabel('Boosting Iterations')
plt.ylabel('CV Test Accuracy')
plt.title('Baseline Model')
plt.show()
```

```
###### Time: 93.063822s ######
###### Time: 105.025655s ######
###### Time: 106.438205s ######
###### Time: 105.194551s ######
###### Time: 98.242049s ######
```



In [ ]:

```
plt.figure()
original_params.update({'min_samples_split':4})
for label, color, setting in [('min_samples_leaf=1','orange',
                               {'min_samples_leaf':1}),
                              ('min_samples_leaf=2','turquoise',
                               {'min_samples_leaf':2}),
                              ('min_samples_leaf=3','blue',
                               {'min_samples_leaf':3}),
                              ('min_samples_leaf=4','gray',
                               {'min_samples_leaf':4}),
                             ('min_samples_leaf=5','magenta',
                               {'min_samples_leaf':5})]:
    start_time = time.time()
    skf = StratifiedKFold(n_splits = 5, random_state = 666)
    params = dict(original_params)
    base_score = np.zeros((5,params['n_estimators']), dtype=np.float64)
    params.update(setting)
    clf = ensemble.GradientBoostingClassifier(**params)

    for j, (train_index, test_index) in zip(range(5), skf.split(X, Y)):
        X_train, Y_train = X[train_index], Y[train_index]
        X_test, Y_test = X[test_index], Y[test_index]
        clf.fit(X_train, Y_train)

        for i, Y_pred in enumerate(clf.staged_predict(X_test)):
            base_score[j,i] = accuracy_score(Y_test, Y_pred)

    score = [mean(base_score[:,i]) for i in range(1000)]
    plt.plot(range(1, 1001), score, color=color, label=label)
    print("###### CV Score: %f" % max(score))
    print("###### Time: %f" % (time.time() - start_time) + "s ######")

plt.legend(loc='upper left')
plt.xlabel('Boosting Iterations')
plt.ylabel('CV Test Accuracy')
plt.title('Baseline Model')
plt.show()
```

In [ ]:

```
start_time = time.time()
chosen_params = {'min_samples_leaf':1, 'min_samples_split':4, 'learning_rate':0.
2,
                'n_estimators':10000, 'max_features':1, 'max_depth':1}
chosen_baseline = ensemble.GradientBoostingClassifier(**chosen_params)
chosen_baseline.fit(X,Y)
print("###### Model Training Time: %f" % (time.time() - start_time) + "s ######"
)
```

In [ ]:

```
emotion_cat = {x[0]:x[1] for x in labels.values}
emotion_type = {x[0]:x[2] for x in labels.values}

def baseline_predict(Xtest, Ytest = None, output = True):
    clf = chosen_baseline
    Ypred = clf.predict(Xtest)
    if Ytest is not None:
        score = accuracy_score(Ytest, Ypred)
        print("###### Accuracy: %f" % score + " ######")
    if output:
        d = {'emotion_idx':Ypred, 'emotion_cat':[emotion_cat.get(key) for key in
Ypred],
             'type':[emotion_type.get(key) for key in Ypred]}
        #cat = [emotion_cat.get(key) for key in Ypred]
        #type = [emotion_type.get(key) for key in Ypred]
        df = pd.DataFrame(data = d)
        df.to_csv('../output/baseline_prediction.csv')
```

Improved Model - Logistic Regression

In [92]:

```
def k_fold_validation(model, X, y, fold = 5, random_state = RANDOM_SEED):
    """
    k-fold cross validation of sklearn classifier using X and y

    :param model: sklearn-compatible classifier with fit and score methods
    :param X: the feature matrix
    :param y: the target
    :param fold: the number of fold
    :param random_state: random seed for k-fold splitting

    :return: average accuracy for the model
    """

    kfold = StratifiedKFold(n_splits=fold, shuffle=True, random_state=random_sta
te)

    avg_accuracy = 0
    for train_index, val_index in kfold.split(X, y):

        # split traning set and validation set
        X_train = X[train_index]
        y_train = y[train_index]

        X_test = X[val_index]
        y_test = y[val_index]

        # standardize
        scaler = StandardScaler()
        X_train = scaler.fit_transform(X_train)
        X_test =scaler.transform(X_test)

        # fit
        model.fit(X_train, y_train)

        avg_accuracy += model.score(X_test, y_test)

    return avg_accuracy / fold


def draw_plot(X, y, title, xlabel, ylabel):
    """
    Draw a plain plot graph
    """
    plt.plot(X,y)
    plt.title(title)
    plt.xlabel(xlabel)
    plt.ylabel(ylabel)
    plt.show()
```

In [111]:

```
penalties = [0.1,1, 10,50,100]

# 1. points coordinates
log_points_accuracies = []
for C in penalties:
    model = LogisticRegression(multi_class='auto', solver='lbfgs', max_iter=5000
, random_state=RANDOM_SEED, C = C, n_jobs = 6)
    log_point_acc = k_fold_validation(model,X_points, y)
    print(f"Average accuracy with C={C}: ", log_point_acc)
    log_points_accuracies.append(log_point_acc)

print("=============================================")

log_distances_accuracies = []
# 2.distances
for C in penalties:
    model = LogisticRegression(multi_class='auto', solver='lbfgs', max_iter=5000
, random_state=RANDOM_SEED, C = C, n_jobs = 6)
    log_dist_acc = k_fold_validation(model,X_distances, y)
    print(f"Average accuracy with C={C}: ", log_dist_acc)
    log_distances_accuracies.append(log_dist_acc)
```

In [ ]:

```
draw_plot(penalties, log_points_accuracies, 'Accuracy For Logistic Regression(Co
ordinates Input)', 'Penalty C', 'Accuracy')
```

In [ ]:

```
best_logistic_model = LogisticRegression(multi_class='auto', solver='lbfgs', max
_iter=5000, random_state=RANDOM_SEED, C = 50, n_jobs = 6)
%time acc = k_fold_validation(best_logistic_model,X_points, y)
```

Summarizing Running Time

- Baseline Mode:
  - Time For 5-fold Cros Validation:
    - Total time: 469s
- Improved Model:
  - Time For 5-fold Cros Validation:
    - Wall time: 41 s