

# 01 - Supervised Learning - Classification - AdaBoost(Solution)\_st122097\_thantham

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## 1 Programming for Data Science and Artificial Intelligence

### 1.1 Classification - AdaBoost

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#### 1.3.1 ===Task===

Your work: Let's modify the above scratch code: - Notice that if  $\text{err} = 0$ , then  $\alpha$  will be undefined, thus attempt to fix this by adding some very small value to the lower term - Notice that sklearn version of AdaBoost has a parameter `learning_rate`. This is in fact the  $\frac{1}{2}$  in front of the  $\alpha$  calculation. Attempt to change this  $\frac{1}{2}$  into a parameter called `eta`, and try different values of it and see whether accuracy is improved. Note that sklearn default this value to 1. - Observe that we are actually using sklearn `DecisionTreeClassifier`. If we take a look at it closely, it is actually using weighted gini index, instead of weighted errors that we learn above. Attempt to write your own class of class `Stump` that actually uses weighted errors, instead of weighted gini index - Put everything into a class

```
[1]: from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
import numpy as np

X, y = make_classification(n_samples=500, random_state=0)
y = np.where(y==0,-1,1) #change our y to be -1 if it is 0, otherwise 1

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.3, random_state=42)
```

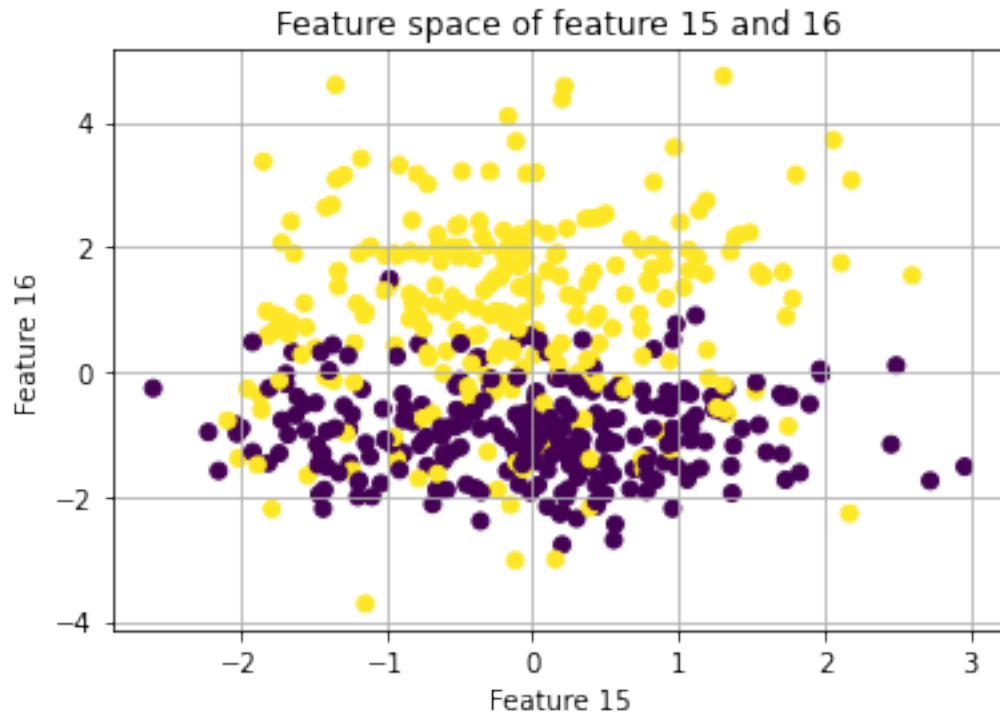
Show the scatter of dataset before for imagining the dataset looks like. However, the dataset was 20 dimension features, we therefore just show it simply first and last feature combination

```
[2]: import matplotlib.pyplot as plt

plt.scatter(X[:,15], X[:, 16], c=y)
plt.title('Feature space of feature 15 and 16')
plt.xlabel('Feature 15')
```

```
plt.ylabel('Feature 16')
plt.grid()
plt.show()

print('Shape of dataset: ',X.shape)
```



Shape of dataset: (500, 20)

### 1.3.2 TASK 3: Stump class

Actually, we have to put stump class may be into inner class, but we personally have separated class called **StumpClassifier** to further use separately for different approach.

This is also make the **Adaboost** class being more feasible to be used for different kinds of classifier

```
[3]: class StumpClassifier:

    def __init__(self):
        self.polarity = 1
        self.feature_index = None
        self.threshold = None

    def fit(self, X, y):
```

```

self.min_err = np.inf
m,n = X.shape
W = np.full(m, 1/m) # init equal weight

for feature in range(n): # looping for all features

    feature_vals = np.sort(np.unique(X[:, feature])) # get sorted
    ↪ features
    thresholds = (feature_vals[:-1] + feature_vals[1:])/2 # get all
    ↪ of thresholds in features

    for threshold in thresholds: # looping for each threshold

        for polarity in [1, -1]: # check for polarity twice

            yhat = np.ones(len(y)) # init all answers as 1

            # change the answer into -1 if the feature value that
            ↪ less than threshold in current polarity
            yhat[polarity * X[:, feature] < polarity * threshold] =
            ↪ -1

            # evaluate error
            err = W[(yhat != y)].sum()

            # if error is less than before -> define current
            ↪ feature_idx and threshold of splitting
            if err < self.min_err:
                self.polarity = polarity
                self.threshold = threshold
                self.feature_index = feature
                self.min_err = err

            # if further feature splitting gives more less of error ->
            ↪ define that feature for feature split

def predict(self, X):
    m, n = X.shape

    pred = np.ones(m) # init all answer as 1

    # change the answer into -1 if the feature value that less than
    ↪ threshold in current polarity

```

```

        pred[self.polarity * X[:,self.feature_index] < self.polarity * self.
→threshold] = -1

    return pred # return sign of the answer

```

### 1.3.3 TASK 4: Put every thing into a class (Include task 1)

I made this class similar to the way of sklearn do. we can put any classifier into the this class.

```

[4]: from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC

class AdaBoost:

    def __init__(self, estimator = None, n_estimators=20, model_params={},
→eta=0.5):

        self.n_estimators = n_estimators
        self.model_params = model_params
        self.eps = 1e-10 # < ===== TASK 1: Epsilon
        self.eta = eta # < ===== TASK 2: Adding learning rate
→(ETA)

        if estimator == None:
            raise ValueError('No Classifier Implemented')
        # init estimator classifiers set following the predefined params
        self.models = [estimator(**self.model_params) for _ in range(self.
→n_estimators)]

    def fit(self, X_train, y_train):

        m, n = X_train.shape

        self.W = np.full(m, 1/m) # init weak learner weights of samples
        self.err = np.zeros(self.n_estimators)
        self.alpha = np.zeros(self.n_estimators) # init alpha of each classifier

        for i, model in enumerate(self.models): # looping each model in modelset

            model.fit(X_train, y_train) # simply fit
            yhat = model.predict(X_train) #simply predict

            self.err[i] = np.sum(self.W[(y_train != yhat)])# evaluate error of
→current model

            # calculate alpha (voting power) of current model

```

```

        self.alpha[i] = np.log ((1 - self.err[i]) / (self.err[i] + self.
→eps)) * self.eta

        # calculate Weaker learner weights of each samples
        self.W = (self.W * np.exp(-1 * self.alpha[i] * y_train * yhat))
        self.W = self.W / sum (self.W)

    def predict(self, X_test):

        H_X = 0

        for i, model in enumerate(self.models): # looping for each model in
→modelset

            yhat = model.predict(X_test) # simply predict
            H_X += self.alpha[i] * yhat # weight the answers

        return np.sign(H_X) # just give the sign of answers

```

To show up the model class, I put **StumpClassifier** for estimator and keep it default number of estimators

```

[5]: model = AdaBoost(estimator=StumpClassifier, n_estimators=10, model_params={},
→eta=0.5)
      model.fit(X_train, y_train)
      model.alpha

```

```

[5]: array([ 8.18560670e-01,  2.07019513e-10,  3.99680289e-15, -6.66133815e-16,
            -4.44089210e-16, -4.44089210e-16, -3.33066907e-16,  1.11022302e-16,
            -3.33066907e-16,  1.11022302e-16])

```

As we known, lets predict the result of training

```

[6]: y_pred = model.predict(X_test)

```

The result is also being the same as set of  $\{-1, +1\}$  following therotical

```

[7]: y_pred[:20]

```

```

[7]: array([-1., -1., -1.,  1., -1., -1., -1., -1.,  1., -1., -1., -1.,  1.,
            1., -1.,  1., -1., -1.,  1.,  1.])

```

Finally, examine the classification report

```

[8]: from sklearn.metrics import classification_report

      print(classification_report(y_test, y_pred))

```

	precision	recall	f1-score	support
-1	0.79	0.84	0.81	73
1	0.84	0.79	0.81	77
accuracy			0.81	150
macro avg	0.81	0.81	0.81	150
weighted avg	0.81	0.81	0.81	150

### 1.3.4 Try different eta (Task 2)

```
[9]: model = AdaBoost(estimator=StumpClassifier, n_estimators=10, model_params={},
    ↪eta=0.01)
model.fit(X_train, y_train)

print(classification_report(y_test, model.predict(X_test)))
```

	precision	recall	f1-score	support
-1	0.79	0.84	0.81	73
1	0.84	0.79	0.81	77
accuracy			0.81	150
macro avg	0.81	0.81	0.81	150
weighted avg	0.81	0.81	0.81	150

```
[10]: model.alpha
```

```
[10]: array([0.01637121, 0.01604379, 0.01572291, 0.01540846, 0.01510029,
    0.01479828, 0.01450231, 0.01421227, 0.01392802, 0.01364946])
```

**Discussion of eta:** The implementation of different eta is mainly focused on the change of alpha in each model. The much more eta indicates that there will be a huge change through the adjustment of alpha among Weak Learner weights.

When we use the every less eta, it will be giving small differences of voting power in each model. However, the big difference in term of accuracy is very difficult to indicate due to the adjustment of weak learner sample weights after a few further models.

Therefore, big eta will give the overshooting of alpha and weak learner weights adjustment. the small eta will indicate small change between voting power of each submodel. So, we have to consider this and choose the balanced eta to reach optimal alpha of each model

### 1.3.5 Adaboost Alternative Usage

Lets try implementing different way of **Adaboost**: KNN, SVM, DecisionTree

```
[11]: ada_knn = AdaBoost(estimator=KNeighborsClassifier, n_estimators=10,
    ↪model_params={'n_neighbors': 5}, eta=0.5)
ada_knn.fit(X_train, y_train)
print(classification_report(y_test, ada_knn.predict(X_test)))
```

	precision	recall	f1-score	support
-1	0.78	0.79	0.79	73
1	0.80	0.79	0.80	77
accuracy			0.79	150
macro avg	0.79	0.79	0.79	150
weighted avg	0.79	0.79	0.79	150

```
[12]: ada_svm = AdaBoost(estimator=SVC, n_estimators=5, model_params={}, eta=0.5)
ada_svm.fit(X_train, y_train)
print(classification_report(y_test, ada_svm.predict(X_test)))
```

	precision	recall	f1-score	support
-1	0.77	0.92	0.84	73
1	0.90	0.74	0.81	77
accuracy			0.83	150
macro avg	0.84	0.83	0.83	150
weighted avg	0.84	0.83	0.83	150

```
[13]: ada_dt = AdaBoost(estimator=DecisionTreeClassifier, n_estimators=5,
    ↪model_params={'max_depth': 3}, eta=0.5)
ada_dt.fit(X_train, y_train)
print(classification_report(y_test, ada_dt.predict(X_test)))
```

	precision	recall	f1-score	support
-1	0.78	0.96	0.86	73
1	0.95	0.74	0.83	77
accuracy			0.85	150
macro avg	0.86	0.85	0.85	150
weighted avg	0.87	0.85	0.85	150

**StumpClassifier Usage** For show up the usage of Stump classifier

```
[14]: stump = StumpClassifier()
stump.fit(X_train, y_train)
```

```
print(classification_report(y_test, stump.predict(X_test)))

print('Feature to split: ', stump.feature_index)
print('Feature threshold: ', stump.threshold)
print('Min error: ', stump.min_err)
```

	precision	recall	f1-score	support
-1	0.79	0.84	0.81	73
1	0.84	0.79	0.81	77
accuracy			0.81	150
macro avg	0.81	0.81	0.81	150
weighted avg	0.81	0.81	0.81	150

```
Feature to split: 16
Feature threshold: -0.2323816980491494
Min error: 0.16285714285714287
```

[ ]: