

## ▼ Overfitting and Underfitting

[https://scikit-learn.org/stable/auto\\_examples/model\\_selection/plot\\_underfitting\\_overfitting.html](https://scikit-learn.org/stable/auto_examples/model_selection/plot_underfitting_overfitting.html)

## ▼ Program for understanding Overfitting and Underfitting

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import PolynomialFeatures
from sklearn.linear_model import LinearRegression
from sklearn.model_selection import cross_val_score

def true_fun(X):
    return np.cos(1.5 * np.pi * X)

np.random.seed(0)

n_samples = 30
degrees = [1, 4, 15]

X = np.sort(np.random.rand(n_samples))
y = true_fun(X) + np.random.randn(n_samples) * 0.1

plt.figure(figsize=(14, 5))
for i in range(len(degrees)):
    ax = plt.subplot(1, len(degrees), i + 1)
    plt.setp(ax, xticks=(), yticks=())

    polynomial_features = PolynomialFeatures(degree=degrees[i], include_bias=False)
    linear_regression = LinearRegression()
    pipeline = Pipeline([
        ("polynomial_features", polynomial_features),
        ("linear_regression", linear_regression),
    ])
    pipeline.fit(X[:, np.newaxis], y)

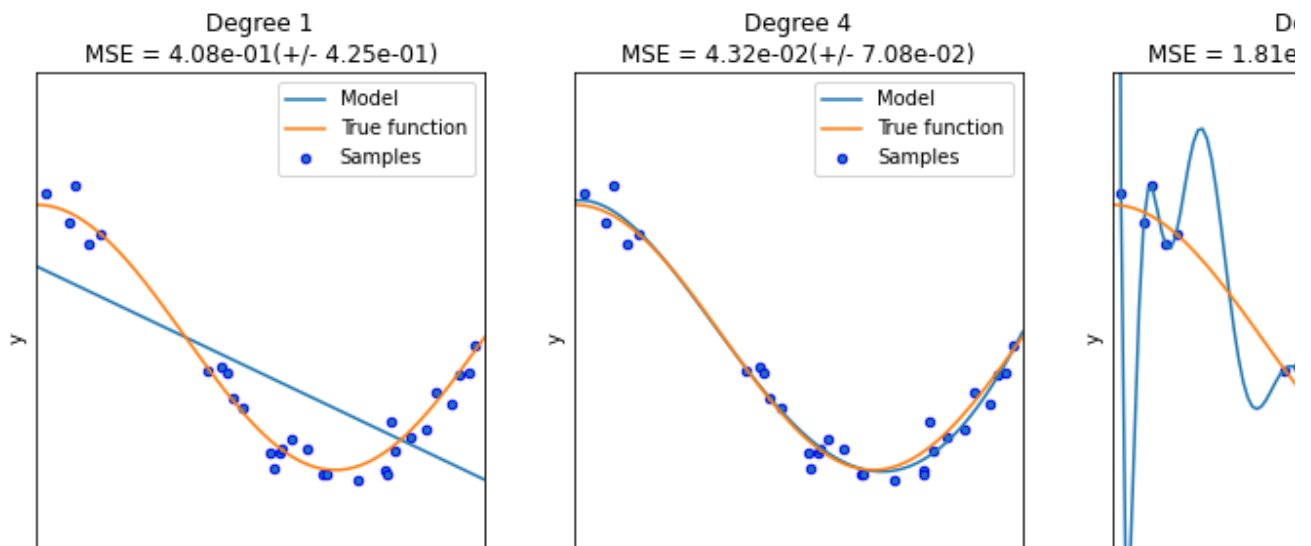
    # Evaluate the models using crossvalidation
    scores = cross_val_score(
        pipeline, X[:, np.newaxis], y, scoring="neg_mean_squared_error", cv=10
```

```

)

X_test = np.linspace(0, 1, 100)
plt.plot(X_test, pipeline.predict(X_test[:, np.newaxis]), label="Model")
plt.plot(X_test, true_fun(X_test), label="True function")
plt.scatter(X, y, edgecolor="b", s=20, label="Samples")
plt.xlabel("x")
plt.ylabel("y")
plt.xlim((0, 1))
plt.ylim((-2, 2))
plt.legend(loc="best")
plt.title(
    "Degree {} \n MSE = {:.2e} (+/- {:.2e})".format(
        degrees[i], -scores.mean(), scores.std()
    )
)
)
plt.show()

```



## ▼ Overfitting (Printing accuracy at different steps)

<https://machinelearningmastery.com/overfitting-machine-learning-models/>

```

# evaluate decision tree performance on train and test sets with different tree depths
from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
from sklearn.tree import DecisionTreeClassifier
from matplotlib import pyplot

# define dataset
X, y = make_classification(n_samples=10000, n_features=20, n_informative=5, n_redundant=15)
# summarize the dataset
print(X.shape, y.shape)

(10000, 20) (10000,)

```

```
# split into train test sets
from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
# summarize the shape of the train and test sets
print(X_train.shape, X_test.shape, y_train.shape, y_test.shape)
```

```
(7000, 20) (3000, 20) (7000,) (3000,)
```

```
train_scores, test_scores = list(), list()
```

```
# define the tree depths to evaluate
values = [i for i in range(1, 31)]
```

```
# evaluate a decision tree for each depth
for i in values:
```

```
    # configure the model
    model = DecisionTreeClassifier(max_depth=i)
    # fit model on the training dataset
    model.fit(X_train, y_train)
    # evaluate on the train dataset
    train_yhat = model.predict(X_train)
    train_acc = accuracy_score(y_train, train_yhat)
    train_scores.append(train_acc)
    # evaluate on the test dataset
    test_yhat = model.predict(X_test)
    test_acc = accuracy_score(y_test, test_yhat)
    test_scores.append(test_acc)
    # summarize progress
    print('>%d, train: %.3f, test: %.3f' % (i, train_acc, test_acc))
```

```
>1, train: 0.763, test: 0.767
>2, train: 0.804, test: 0.805
>3, train: 0.871, test: 0.868
>4, train: 0.906, test: 0.890
>5, train: 0.924, test: 0.901
>6, train: 0.937, test: 0.912
>7, train: 0.947, test: 0.917
>8, train: 0.956, test: 0.914
>9, train: 0.966, test: 0.917
>10, train: 0.975, test: 0.911
>11, train: 0.981, test: 0.913
>12, train: 0.985, test: 0.909
>13, train: 0.990, test: 0.909
>14, train: 0.993, test: 0.907
>15, train: 0.995, test: 0.905
>16, train: 0.996, test: 0.910
>17, train: 0.997, test: 0.908
>18, train: 0.998, test: 0.904
>19, train: 0.999, test: 0.905
>20, train: 0.999, test: 0.903
>21, train: 1.000, test: 0.902
>22, train: 1.000, test: 0.905
>23, train: 1.000, test: 0.903
```

```

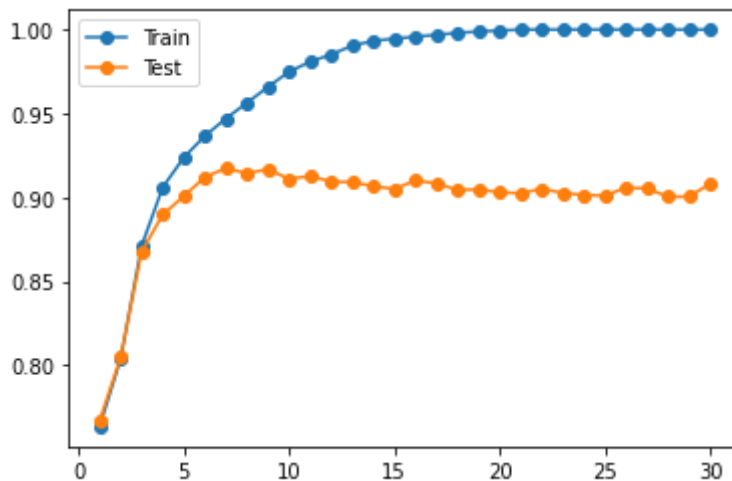
>24, train: 1.000, test: 0.901
>25, train: 1.000, test: 0.901
>26, train: 1.000, test: 0.906
>27, train: 1.000, test: 0.905
>28, train: 1.000, test: 0.900
>29, train: 1.000, test: 0.900
>30, train: 1.000, test: 0.908

```

```

# plot of train and test scores vs tree depth
pyplot.plot(values, train_scores, '-o', label='Train')
pyplot.plot(values, test_scores, '-o', label='Test')
pyplot.legend()
pyplot.show()

```



```

from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
from sklearn.neighbors import KNeighborsClassifier
from matplotlib import pyplot
# create dataset
X, y = make_classification(n_samples=10000, n_features=20, n_informative=5, n_redundant=15)
# split into train test sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
# define lists to collect scores
train_scores, test_scores = list(), list()
# define the tree depths to evaluate
values = [i for i in range(1, 51)]
# evaluate a decision tree for each depth
for i in values:
    # configure the model
    model = KNeighborsClassifier(n_neighbors=i)
    # fit model on the training dataset
    model.fit(X_train, y_train)
    # evaluate on the train dataset
    train_yhat = model.predict(X_train)
    train_acc = accuracy_score(y_train, train_yhat)
    train_scores.append(train_acc)
    # evaluate on the test dataset
    test_yhat = model.predict(X_test)
    test_acc = accuracy_score(y_test, test_yhat)

```

```
    test_scores.append(test_acc)
    # summarize progress
    print('>%d, train: %.3f, test: %.3f' % (i, train_acc, test_acc))
# plot of train and test scores vs number of neighbors
pyplot.plot(values, train_scores, '-o', label='Train')
pyplot.plot(values, test_scores, '-o', label='Test')
pyplot.legend()
pyplot.show()
```

```

>1, train: 1.000, test: 0.917
>2, train: 0.963, test: 0.914
>3, train: 0.961, test: 0.924
>4, train: 0.955, test: 0.930
>5, train: 0.955, test: 0.932
>6, train: 0.953, test: 0.930
>7, train: 0.950, test: 0.933
>8, train: 0.950, test: 0.935
>9, train: 0.949, test: 0.935
>10, train: 0.947, test: 0.932
>11, train: 0.946, test: 0.933
>12, train: 0.947, test: 0.934
>13, train: 0.944, test: 0.932
>14, train: 0.946, test: 0.933
>15, train: 0.945, test: 0.930

```

---



---

```

>22, train: 0.942, test: 0.929

```

## ▼ Cross-validation

[https://scikit-learn.org/stable/modules/cross\\_validation.html](https://scikit-learn.org/stable/modules/cross_validation.html)

```

>30, train: 0.941, test: 0.926
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn import datasets
from sklearn import svm

X, y = datasets.load_iris(return_X_y=True)
X.shape, y.shape

```

```

((150, 4), (150,))
>42, train: 0.936, test: 0.921

```

## ▼ Basic method to compute score

```

>46, train: 0.936, test: 0.921

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.4, random_state=0)

X_train.shape, y_train.shape

X_test.shape, y_test.shape

clf = svm.SVC(kernel='linear', C=1).fit(X_train, y_train)
clf.score(X_test, y_test)

```

0.9666666666666667



- ▼ Estimate the accuracy by splitting the data, computing the score 5 consecutive times (with different splits each time)

```
from sklearn.model_selection import cross_val_score
clf = svm.SVC(kernel='linear', C=1, random_state=42)
scores = cross_val_score(clf, X, y, cv=5)
scores
```

```
array([0.96666667, 1.          , 0.96666667, 0.96666667, 1.          ])
```

```
print("%.2f accuracy with a standard deviation of %.2f" % (scores.mean(), scores.std()))
```

```
0.98 accuracy with a standard deviation of 0.02
```

- ▼ Using the different scoring parameter

```
from sklearn import metrics

scores = cross_val_score(
    clf, X, y, cv=5, scoring='f1_macro')
scores
```

```
array([0.96658312, 1.          , 0.96658312, 0.96658312, 1.          ])
```

- ▼ Specified multiple metrics of predefined scorer names

```
from sklearn.model_selection import cross_validate
from sklearn.metrics import recall_score

scoring = ['precision_macro', 'recall_macro']
clf = svm.SVC(kernel='linear', C=1, random_state=0)
scores = cross_validate(clf, X, y, scoring=scoring)
sorted(scores.keys())

scores['test_recall_macro']
```

```
array([0.96666667, 1.          , 0.96666667, 0.96666667, 1.          ])
```

- ▼ Calculate cross validation score by passing a cross validation iterator

```

from sklearn.model_selection import ShuffleSplit
n_samples = X.shape[0]
cv = ShuffleSplit(n_splits=5, test_size=0.3, random_state=0)
cross_val_score(clf, X, y, cv=cv)

array([0.97777778, 0.97777778, 1.          , 0.95555556, 1.          ])

```

## ▼ Use an iterable yielding (train, test) splits as arrays of indices

```

def custom_cv_2folds(X):
    n = X.shape[0]
    i = 1
    while i <= 2:
        idx = np.arange(n * (i - 1) / 2, n * i / 2, dtype=int)
        yield idx, idx
        i += 1

custom_cv = custom_cv_2folds(X)
cross_val_score(clf, X, y, cv=custom_cv)

array([1.          , 0.97333333])

from sklearn import preprocessing
X_train, X_test, y_train, y_test = train_test_split(
X, y, test_size=0.4, random_state=0)
scaler = preprocessing.StandardScaler().fit(X_train)
X_train_transformed = scaler.transform(X_train)
clf = svm.SVC(C=1).fit(X_train_transformed, y_train)
X_test_transformed = scaler.transform(X_test)
clf.score(X_test_transformed, y_test)

0.9333333333333333

from sklearn.pipeline import make_pipeline
clf = make_pipeline(preprocessing.StandardScaler(), svm.SVC(C=1))
cross_val_score(clf, X, y, cv=cv)

array([0.97777778, 0.93333333, 0.95555556, 0.93333333, 0.97777778])

```

## ▼ Different type of Cross validation iterators

### ▼ K-fold

```

import numpy as np
from sklearn.model_selection import KFold

```



```
X = ["a", "b", "c", "d"]
kf = KFold(n_splits=2)
for train, test in kf.split(X):
    print("%s %s" % (train, test))
```

```
[2 3] [0 1]
[0 1] [2 3]
```

## ▼ Repeated K-Fold

```
import numpy as np
from sklearn.model_selection import RepeatedKFold
X = np.array([[1, 2], [3, 4], [1, 2], [3, 4]])
random_state = 12883823
rkf = RepeatedKFold(n_splits=2, n_repeats=2, random_state=random_state)
for train, test in rkf.split(X):
    print("%s %s" % (train, test))
```

```
[2 3] [0 1]
[0 1] [2 3]
[0 2] [1 3]
[1 3] [0 2]
```

## ▼ Leave One Out (LOO)

```
from sklearn.model_selection import LeaveOneOut

X = [1, 2, 3, 4]
loo = LeaveOneOut()
for train, test in loo.split(X):
    print("%s %s" % (train, test))
```

```
[1 2 3] [0]
[0 2 3] [1]
[0 1 3] [2]
[0 1 2] [3]
```

## ▼ Leave P Out (LPO)

```
from sklearn.model_selection import LeavePOut
X = np.ones(4)
lpo = LeavePOut(p=2)
```

```
for train, test in lpo.split(X):
    print("%s %s" % (train, test))
```

```
[2 3] [0 1]
[1 3] [0 2]
[1 2] [0 3]
[0 3] [1 2]
[0 2] [1 3]
```

## ▼ Shuffle & Split

```
from sklearn.model_selection import ShuffleSplit
X = np.arange(10)
ss = ShuffleSplit(n_splits=5, test_size=0.25, random_state=0)
for train_index, test_index in ss.split(X):
    print("%s %s" % (train_index, test_index))
```

```
[9 1 6 7 3 0 5] [2 8 4]
[2 9 8 0 6 7 4] [3 5 1]
[4 5 1 0 6 9 7] [2 3 8]
[2 7 5 8 0 3 4] [6 1 9]
[4 1 0 6 8 9 3] [5 2 7]
```

## ▼ Stratified k-fold

```
from sklearn.model_selection import StratifiedKFold, KFold
import numpy as np
X, y = np.ones((50, 1)), np.hstack(([0] * 45, [1] * 5))
skf = StratifiedKFold(n_splits=3)
for train, test in skf.split(X, y):
    print('train - {} | test - {}'.format(
        np.bincount(y[train]), np.bincount(y[test])))
```

```
↳ train - [30 3] | test - [15 2]
   train - [30 3] | test - [15 2]
   train - [30 4] | test - [15 1]
```

```
kf = KFold(n_splits=3)
for train, test in kf.split(X, y):
    print('train - {} | test - {}'.format(
        np.bincount(y[train]), np.bincount(y[test])))
```

```
train - [28 5] | test - [17]
train - [28 5] | test - [17]
train - [34] | test - [11 5]
```

## ▸ Validation curve

[https://keeeto.github.io/blog/bias\\_variance/](https://keeeto.github.io/blog/bias_variance/)

[https://scikit-learn.org/stable/modules/learning\\_curve.html](https://scikit-learn.org/stable/modules/learning_curve.html)

```
import pandas as pd
import numpy as np

import matplotlib.pyplot as plt

from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.model_selection import cross_val_score, learning_curve, validation_curve

from google.colab import drive
drive.mount('/content/drive')

Mounted at /content/drive

df_train = pd.read_csv('/content/drive/MyDrive/ML Assingments/Data For Validation Curve/tr
df_test = pd.read_csv('/content/drive/MyDrive/ML Assingments/Data For Validation Curve/tes
df_comb = df_train.append(df_test)

X = pd.DataFrame()

def encode_sex(x):
    return 1 if x == 'female' else 0

def family_size(x):
    size = x.SibSp + x.Parch
    return 4 if size > 3 else size

X['Sex'] = df_comb.Sex.map(encode_sex)
X['Pclass'] = df_comb.Pclass
X['FamilySize'] = df_comb.apply(family_size, axis=1)

fare_median = df_train.groupby(['Sex', 'Pclass']).Fare.median()
fare_median.name = 'FareMedian'

age_mean = df_train.groupby(['Sex', 'Pclass']).Age.mean()
age_mean.name = 'AgeMean'
```

```

def join(df, stat):
    return pd.merge(df, stat.to_frame(), left_on=['Sex', 'Pclass'], right_index=True, how=

X['Fare'] = df_comb.Fare.fillna(join(df_comb, fare_median).FareMedian)
X['Age'] = df_comb.Age.fillna(join(df_comb, age_mean).AgeMean)

def quantiles(series, num):
    return pd.qcut(series, num, retbins=True)[1]

def discretize(series, bins):
    return pd.cut(series, bins, labels=range(len(bins)-1), include_lowest=True)

X['Fare'] = discretize(X.Fare, quantiles(df_comb.Fare, 10))
X['Age'] = discretize(X.Age, quantiles(df_comb.Age, 10))

X_train = X.iloc[:df_train.shape[0]]
X_test = X.iloc[df_train.shape[0]:]

y_train = df_train.Survived

clf_1 = RandomForestClassifier(n_estimators=100, bootstrap=True, random_state=0)
clf_1.fit(X_train, y_train)
# Number of folds for cross validation
num_folds = 7

def plot_curve(ticks, train_scores, test_scores):
    train_scores_mean = -1 * np.mean(train_scores, axis=1)
    train_scores_std = -1 * np.std(train_scores, axis=1)
    test_scores_mean = -1 * np.mean(test_scores, axis=1)
    test_scores_std = -1 * np.std(test_scores, axis=1)

    plt.figure()
    plt.fill_between(ticks,
                     train_scores_mean - train_scores_std,
                     train_scores_mean + train_scores_std, alpha=0.1, color="b")
    plt.fill_between(ticks,
                     test_scores_mean - test_scores_std,
                     test_scores_mean + test_scores_std, alpha=0.1, color="r")
    plt.plot(ticks, train_scores_mean, 'b-', label='Training score')
    plt.plot(ticks, test_scores_mean, 'r-', label='Validation score')
    plt.legend(fancybox=True, facecolor='w')

    return plt.gca()

def plot_validation_curve(clf, X, y, param_name, param_range, scoring='roc_auc'):
    plt.xkcd()
    ax = plot_curve(param_range, *validation_curve(clf, X, y, cv=num_folds,

```

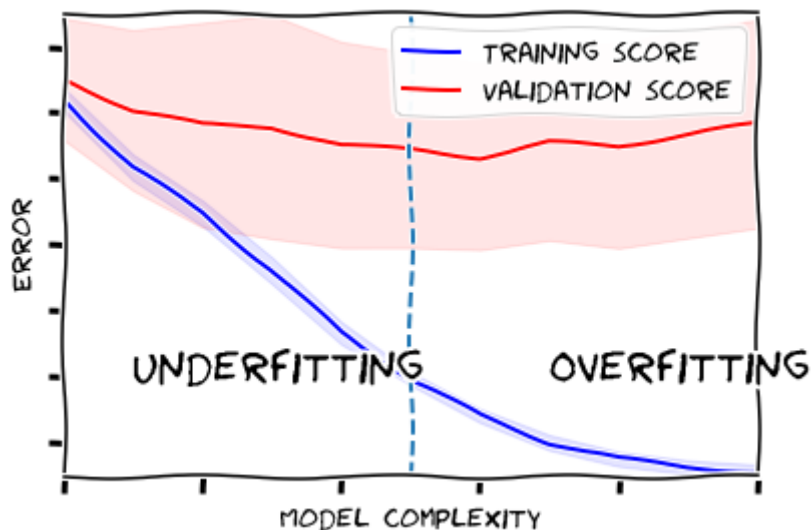
```

scoring=scoring,
param_name=param_name,
param_range=param_range, n_jobs=-1))

ax.set_title('')
ax.set_xticklabels([])
ax.set_yticklabels([])
ax.set_xlim(2,12)
ax.set_ylim(-0.97, -0.83)
ax.set_ylabel('Error')
ax.set_xlabel('Model complexity')
ax.text(9, -0.94, 'Overfitting', fontsize=22)
ax.text(3, -0.94, 'Underfitting', fontsize=22)
ax.axvline(7, ls='--')
plt.tight_layout()

```

```
plot_validation_curve(clf_1, X_train, y_train, param_name='max_depth', param_range=range(2
```



## ▼ ROC

<https://www.statology.org/plot-roc-curve-python/>

```

import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression

```

```

from sklearn import metrics

#import dataset from CSV file on Github
url = "https://raw.githubusercontent.com/Statology/Python-Guides/main/default.csv"
data = pd.read_csv(url)

#define the predictor variables and the response variable
X = data[['student', 'balance', 'income']]
y = data['default']

#split the dataset into training (70%) and testing (30%) sets
X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.3,random_state=0)

#instantiate the model
log_regression = LogisticRegression()

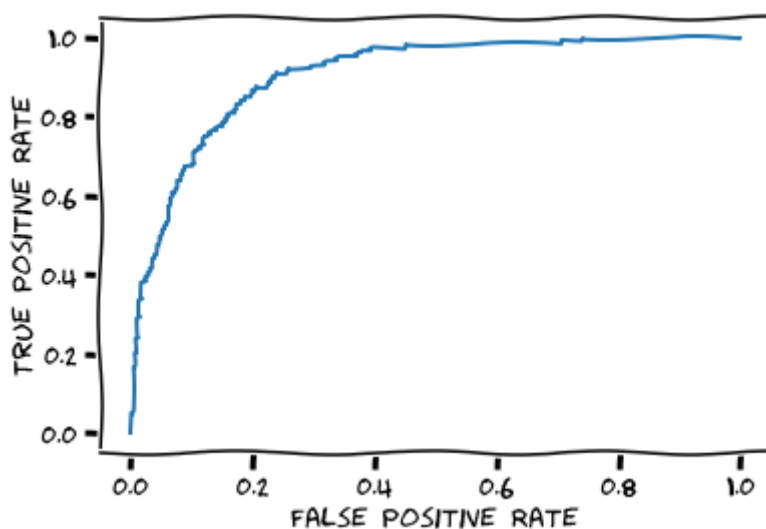
#fit the model using the training data
log_regression.fit(X_train,y_train)

LogisticRegression()

#define metrics
y_pred_proba = log_regression.predict_proba(X_test)[::,1]
fpr, tpr, _ = metrics.roc_curve(y_test, y_pred_proba)

#create ROC curve
plt.plot(fpr,tpr)
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()

```



Task 1: Perform all of the above codes of Overfitting, Cross Validation, etc. with the help of the given reference link.

Task 2: Explain your analysis of the code. Make a detailed analysis that can also cover the following questions:  
(Submit the PDF of Report)

- 1) According to you, why do overfitting and underfitting occur, and how resolve them? What is the difference between them?
- 2) What kind of pattern did you analyze in the Train and Test score while running the code of overfitting?
- 3) What is cross-validation, and what did you analyze in a different type of validation that you performed?
- 4) Explain the analysis from generated ROC and validation curve and what they represent?

Task 3: Using the given Cross Validation iterators perform all types of Cross Validations we did in the task :

- 1) K-fold
- 2) Repeated K-Fold
- 3) Leave One Out (LOO)

Apart from this three, try to perform validation using three new iterators.

Task 4: With the help of the given code and references complete all of the following step:

- 1) Choose one new dataset. Train a overfitted model with the help of any machine learning technique, such as KNN, classification, regression.
- 2) Try to resolve the overfitting.
- 3) Calculate the Validation score by any two or three given techniques and Validation iterators.

- 4) Generate the validation curve
- 5) Predict the output of testing data.
- 6) Generate the ROC curve using the predicted data and actual data.

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