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DataPreprocessing

A black and white striped pattern

Description automatically generatedImporting Libraries

In [1]: **import** numpy **as** np

**import** pandas **as** pd

**import** matplotlib.pyplot **as** plt

**import** seaborn **as** sns

Importing Dataset

In [2]: dataset=pd.read\_csv("HR-Employee-Attrition.csv")

In [3]: dataset

Out[3]: Age Attrition BusinessTravel DailyRate Department DistanceFromHome Education EducationField EmployeeCount EmployeeNumber ... RelationshipSatisfaction StandardHour

0 41 Yes Travel\_Rarely 1102 Sales 1 2 Life Sciences 1 1 ... 1 8

1 49 No Travel\_Frequently 279 Research & 8 1 Life Sciences 1 2 ... 4 8

Development

2 37 Yes Travel\_Rarely 1373 Research & 2 2 Other 1 4 ... 2 8

Development

3 33 No Travel\_Frequently 1392 Research & 3 4 Life Sciences 1 5 ... 3 8

Development

4 27 No Travel\_Rarely 591 Research & 2 1 Medical 1 7 ... 4 8

Development

... ... ... ... ... ... ... ... ... ... ... ... ...

1465 36 No Travel\_Frequently 884 Research & 23 2 Medical 1 2061 ... 3 8

Development

1466 39 No Travel\_Rarely 613 Research & 6 1 Medical 1 2062 ... 1 8

Development

1467 27 No Travel\_Rarely 155 Research & 4 3 Life Sciences 1 2064 ... 2 8

Development

1468 49 No Travel\_Frequently 1023 Sales 2 3 Medical 1 2065 ... 4 8

1469 34 No Travel\_Rarely 628 Research & 8 3 Medical 1 2068 ... 1 8

Development

1470 rows × 35 columns

In [4]: dataset.head()

Out[4]: Age Attrition BusinessTravel DailyRate Department DistanceFromHome Education EducationField EmployeeCount EmployeeNumber ... RelationshipSatisfaction StandardHours

0 41 Yes Travel\_Rarely 1102 Sales 1 2 Life Sciences 1 1 ... 1 80

1 49 No Travel\_Frequently 279 Research & 8 1 Life Sciences 1 2 ... 4 80

Development

2 37 Yes Travel\_Rarely 1373 Research & 2 2 Other 1 4 ... 2 80

Development

3 33 No Travel\_Frequently 1392 Research & 3 4 Life Sciences 1 5 ... 3 80

Development

4 27 No Travel\_Rarely 591 Research & 2 1 Medical 1 7 ... 4 80

Development

5 rows × 35 columns

In [5]: dataset.tail()

Out[5]: Age Attrition BusinessTravel DailyRate Department DistanceFromHome Education EducationField EmployeeCount EmployeeNumber ... RelationshipSatisfaction StandardHour

1465 36 No Travel\_Frequently 884 Research & 23 2 Medical 1 2061 ... 3 8

Development

1466 39 No Travel\_Rarely 613 Research & 6 1 Medical 1 2062 ... 1 8

Development

1467 27 No Travel\_Rarely 155 Research & 4 3 Life Sciences 1 2064 ... 2 8

Development

1468 49 No Travel\_Frequently 1023 Sales 2 3 Medical 1 2065 ... 4 8

1469 34 No Travel\_Rarely 628 Research & 8 3 Medical 1 2068 ... 1 8

Development

5 rows × 35 columns

In [6]: dataset.shape

Out[6]: (1470, 35)

In [7]: dataset.info()

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 1470 entries, 0 to 1469

Data columns (total 35 columns):

# Column Non-Null Count Dtype

--- ------ -------------- -----

0 Age 1470 non-null int64

1 Attrition 1470 non-null object

2 BusinessTravel 1470 non-null object

3 DailyRate 1470 non-null int64

4 Department 1470 non-null object

5 DistanceFromHome 1470 non-null int64

6 Education 1470 non-null int64

7 EducationField 1470 non-null object

8 EmployeeCount 1470 non-null int64

9 EmployeeNumber 1470 non-null int64

10 EnvironmentSatisfaction 1470 non-null int64

11 Gender 1470 non-null object

12 HourlyRate 1470 non-null int64

13 JobInvolvement 1470 non-null int64

14 JobLevel 1470 non-null int64

15 JobRole 1470 non-null object

16 JobSatisfaction 1470 non-null int64

17 MaritalStatus 1470 non-null object

18 MonthlyIncome 1470 non-null int64

19 MonthlyRate 1470 non-null int64

20 NumCompaniesWorked 1470 non-null int64

21 Over18 1470 non-null object

22 OverTime 1470 non-null object

23 PercentSalaryHike 1470 non-null int64

24 PerformanceRating 1470 non-null int64

25 RelationshipSatisfaction 1470 non-null int64

26 StandardHours 1470 non-null int64

27 StockOptionLevel 1470 non-null int64

28 TotalWorkingYears 1470 non-null int64

29 TrainingTimesLastYear 1470 non-null int64

30 WorkLifeBalance 1470 non-null int64

31 YearsAtCompany 1470 non-null int64

32 YearsInCurrentRole 1470 non-null int64

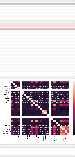
33 YearsSinceLastPromotion 1470 non-null int64

34 YearsWithCurrManager 1470 non-null int64

dtypes: int64(26), object(9)

memory usage: 402.1+ KB

In [8]:



dataset**.**describe()

**Age DailyRate DistanceFromHome Education EmployeeCount EmployeeNumber EnvironmentSatisfaction HourlyRate JobInvolvement JobLevel ... Relationship**

**count** 1470.000000 1470.000000 1470.000000 1470.000000 1470.0 1470.000000 1470.000000 1470.000000 1470.000000 1470.000000 ... 1

**mean** 36.923810 802.485714 9.192517 2.912925 1.0 1024.865306 2.721769 65.891156 2.729932 2.063946 ...

**min** 18.000000 102.000000 1.000000 1.000000 1.0 1.000000 1.000000 30.000000 1.000000 1.000000 ...

**25%** 30.000000 465.000000 2.000000 2.000000 1.0 491.250000 2.000000 48.000000 2.000000 1.000000 ...

**50%** 36.000000 802.000000 7.000000 3.000000 1.0 1020.500000 3.000000 66.000000 3.000000 2.000000 ...

**std** 9.135373 403.509100 8.106864 1.024165 0.0 602.024335 1.093082 20.329428 0.711561 1.106940 ...

**75%** 43.000000 1157.000000 14.000000 4.000000 1.0 1555.750000 4.000000 83.750000 3.000000 3.000000 ...

**max** 60.000000 1499.000000 29.000000 5.000000 1.0 2068.000000 4.000000 100.000000 4.000000 5.000000 ...

8 rows × 26 columns

corr**=**dataset**.**corr()

C:\Users\Admin\AppData\Local\Temp\ipykernel\_916\1091080309.py:1: FutureWarning: The default value of numeric\_only in DataFrame.corr is deprecated.

In a future version, it will default to False. Select only valid columns or specify the value of numeric\_only to silence this warning.

corr

corr=dataset.corr()

**Age DailyRate DistanceFromHome Education EmployeeCount EmployeeNumber EnvironmentSatisfaction HourlyRate JobInvolvement JobLevel ... Rela**

**Age** 1.000000 0.010661 -0.001686 0.208034 NaN -0.010145 0.010146 0.024287 0.029820 0.509604 ...

**DistanceFromHome** -0.001686 -0.004985 1.000000 0.021042 NaN 0.032916 -0.016075 0.031131 0.008783 0.005303 ...

**Education** 0.208034 -0.016806 0.021042 1.000000 NaN 0.042070 -0.027128 0.016775 0.042438 0.101589 ...

**EmployeeNumber** -0.010145 -0.050990 0.032916 0.042070 NaN 1.000000 0.017621 0.035179 -0.006888 -0.018519 ...

**EnvironmentSatisfaction** 0.010146 0.018355 -0.016075 -0.027128 NaN 0.017621 1.000000 -0.049857 -0.008278 0.001212 ...

**DailyRate** 0.010661 1.000000 -0.004985 -0.016806 NaN -0.050990 0.018355 0.023381 0.046135 0.002966 ...

**EmployeeCount** NaN NaN NaN NaN NaN NaN NaN NaN NaN NaN ...

**HourlyRate** 0.024287 0.023381 0.031131 0.016775 NaN 0.035179 -0.049857 1.000000 0.042861 -0.027853 ...

**JobInvolvement** 0.029820 0.046135 0.008783 0.042438 NaN -0.006888 -0.008278 0.042861 1.000000 -0.012630 ...

**JobSatisfaction** -0.004892 0.030571 -0.003669 -0.011296 NaN -0.046247 -0.006784 -0.071335 -0.021476 -0.001944 ...

**MonthlyIncome** 0.497855 0.007707 -0.017014 0.094961 NaN -0.014829 -0.006259 -0.015794 -0.015271 0.950300 ...

**NumCompaniesWorked** 0.299635 0.038153 -0.029251 0.126317 NaN -0.001251 0.012594 0.022157 0.015012 0.142501 ...

**PercentSalaryHike** 0.003634 0.022704 0.040235 -0.011111 NaN -0.012944 -0.031701 -0.009062 -0.017205 -0.034730 ...

**JobLevel** 0.509604 0.002966 0.005303 0.101589 NaN -0.018519 0.001212 -0.027853 -0.012630 1.000000 ...

**MonthlyRate** 0.028051 -0.032182 0.027473 -0.026084 NaN 0.012648 0.037600 -0.015297 -0.016322 0.039563 ...

**PerformanceRating** 0.001904 0.000473 0.027110 -0.024539 NaN -0.020359 -0.029548 -0.002172 -0.029071 -0.021222 ...

**RelationshipSatisfaction** 0.053535 0.007846 0.006557 -0.009118 NaN -0.069861 0.007665 0.001330 0.034297 0.021642 ...

**StockOptionLevel** 0.037510 0.042143 0.044872 0.018422 NaN 0.062227 0.003432 0.050263 0.021523 0.013984 ...

**TotalWorkingYears** 0.680381 0.014515 0.004628 0.148280 NaN -0.014365 -0.002693 -0.002334 -0.005533 0.782208 ...

**TrainingTimesLastYear** -0.019621 0.002453 -0.036942 -0.025100 NaN 0.023603 -0.019359 -0.008548 -0.015338 -0.018191 ...

**StandardHours** NaN NaN NaN NaN NaN NaN NaN NaN NaN NaN ...

**WorkLifeBalance** -0.021490 -0.037848 -0.026556 0.009819 NaN 0.010309 0.027627 -0.004607 -0.014617 0.037818 ...

**YearsAtCompany** 0.311309 -0.034055 0.009508 0.069114 NaN -0.011240 0.001458 -0.019582 -0.021355 0.534739 ...

**YearsInCurrentRole** 0.212901 0.009932 0.018845 0.060236 NaN -0.008416 0.018007 -0.024106 0.008717 0.389447 ...

**YearsSinceLastPromotion** 0.216513 -0.033229 0.010029 0.054254 NaN -0.009019 0.016194 -0.026716 -0.024184 0.353885 ...

**YearsWithCurrManager** 0.202089 -0.026363 0.014406 0.069065 NaN -0.009197 -0.004999 -0.020123 0.025976 0.375281 ...

26 rows × 26 columns

plt**.**subplots(figsize**=**(20,15))

sns**.**heatmap(corr,annot**=True**)

<Axes: >

dataset**.**Attrition**.**value\_counts()

*#Attrition is independent variable*

No 1233

Yes 237

Name: Attrition, dtype: int64

Handling Null Values

dataset**.**isnull()**.**any()

Out[8]:

In [9]:

Out[9]:

In [10]:

Out[10]:

In [11]:

Out[11]:

In [12]:

Out[12]: Age False

Attrition False

BusinessTravel False

DailyRate False

Department False

DistanceFromHome False

Education False

EducationField False

EmployeeCount False

EmployeeNumber False

EnvironmentSatisfaction False

Gender False

HourlyRate False

JobInvolvement False

JobLevel False

JobRole False

JobSatisfaction False

MaritalStatus False

MonthlyIncome False

MonthlyRate False

NumCompaniesWorked False

Over18 False

OverTime False

PercentSalaryHike False

PerformanceRating False

RelationshipSatisfaction False

StandardHours False

StockOptionLevel False

TotalWorkingYears False

TrainingTimesLastYear False

WorkLifeBalance False

YearsAtCompany False

YearsInCurrentRole False



dataset**.**isnull()**.**sum()

YearsSinceLastPromotion False

YearsWithCurrManager False

dtype: bool

In [13]:

Out[13]: Age 0

Attrition 0

BusinessTravel 0

DailyRate 0

Department 0

DistanceFromHome 0

Education 0

EducationField 0

EmployeeCount 0

EmployeeNumber 0

EnvironmentSatisfaction 0

Gender 0

HourlyRate 0

JobInvolvement 0

JobLevel 0

JobRole 0

JobSatisfaction 0

MaritalStatus 0

MonthlyIncome 0

MonthlyRate 0

NumCompaniesWorked 0

Over18 0

OverTime 0

PercentSalaryHike 0

PerformanceRating 0

RelationshipSatisfaction 0

StandardHours 0

StockOptionLevel 0

TotalWorkingYears 0

TrainingTimesLastYear 0

WorkLifeBalance 0

YearsAtCompany 0

YearsInCurrentRole 0

YearsSinceLastPromotion 0

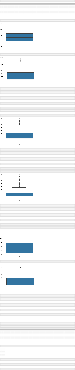
YearsWithCurrManager 0

dtype: int64

there are no NULL values in dataset thus no need to handle null values

Outlier Detection

In [14]:



dataset**.**head()

**Age Attrition BusinessTravel DailyRate Department DistanceFromHome Education EducationField EmployeeCount EmployeeNumber ... RelationshipSatisfaction StandardHours**

**0** 41 Yes Travel\_Rarely 1102 Sales 1 2 Life Sciences 1 1 ... 1 80

**1** 49 No Travel\_Frequently 279 Research & 8 1 Life Sciences 1 2 ... 4 80

Development

**2** 37 Yes Travel\_Rarely 1373 Research & 2 2 Other 1 4 ... 2 80

Development

**3** 33 No Travel\_Frequently 1392 Research & 3 4 Life Sciences 1 5 ... 3 80

Development

**4** 27 No Travel\_Rarely 591 Research & 2 1 Medical 1 7 ... 4 80

Development

5 rows × 35 columns

sns**.**boxplot(dataset**.**Age)

<Axes: >

Outliers not present in Age column

sns**.**boxplot(dataset**.**MonthlyIncome)

<Axes: >

There are outliers in Monthly Income columns above Upper limit

q1 **=** dataset**.**MonthlyIncome**.**quantile(0.25)

IQR **=** q3**-**q1

5468.0

upper\_limit **=** q3 **+** 1.5 **\***IQR

upper\_limit

q3 **=** dataset**.**MonthlyIncome**.**quantile(0.75)

IQR

16581.0

dataset['MonthlyIncome']**.**median()

4919.0

dataset['MonthlyIncome'] **=** np**.**where(dataset['MonthlyIncome'] **>** upper\_limit ,4919.0, dataset['MonthlyIncome'])

dataset**.**shape

(1470, 35)

sns**.**boxplot(dataset**.**TotalWorkingYears)

<Axes: >

There are outliers in Total Working Years columns above Upper limit

q1 **=** dataset**.**TotalWorkingYears**.**quantile(0.25)

q3 **=** dataset**.**TotalWorkingYears**.**quantile(0.75)

IQR **=** q3**-**q1

9.0

upper\_limit **=** q3 **+** 1.5 **\***IQR

28.5

dataset['TotalWorkingYears']**.**median()

10.0

dataset['TotalWorkingYears'] **=** np**.**where(dataset['TotalWorkingYears'] **>** upper\_limit ,10, dataset['TotalWorkingYears'])

sns**.**boxplot(dataset**.**YearsAtCompany)

<Axes: >

IQR

upper\_limit

There are outliers in Years At Company columns above Upper limit

q1 **=** dataset**.**YearsAtCompany**.**quantile(0.25)

q3 **=** dataset**.**YearsAtCompany**.**quantile(0.75)

IQR **=** q3**-**q1

6.0

upper\_limit **=** q3 **+** 1.5 **\***IQR

18.0

dataset['YearsAtCompany']**.**mean()

7.0081632653061225

dataset['YearsAtCompany'] **=** np**.**where(dataset['YearsAtCompany'] **>** upper\_limit ,7.0081632653061225, dataset['YearsAtCompany'])

sns**.**boxplot(dataset**.**DistanceFromHome)

<Axes: >

IQR

upper\_limit

No outliers present in Distance From Home column

sns**.**boxplot(dataset**.**YearsWithCurrManager)

<Axes: >

There are outliers in Years With CurrManager columns above Upper limit

q1 **=** dataset**.**YearsWithCurrManager**.**quantile(0.25)

q3 **=** dataset**.**YearsWithCurrManager**.**quantile(0.75)

IQR **=** q3**-**q1

IQR

5.0

upper\_limit **=** q3 **+** 1.5 **\***IQR

14.5

dataset['YearsWithCurrManager']**.**median()

3.0

upper\_limit

dataset['YearsWithCurrManager'] **=** np**.**where(dataset['YearsWithCurrManager'] **>** upper\_limit ,3, dataset['YearsWithCurrManager'])

Seperate Dependent and Independent Variables

Now we will perform encoding

x **=** dataset**.**iloc[:, dataset**.**columns **!=** "Attrition"]

x**.**head()

**Age BusinessTravel DailyRate Department DistanceFromHome Education EducationField EmployeeCount EmployeeNumber EnvironmentSatisfaction ... RelationshipSatisfaction**

**0** 41 Travel\_Rarely 1102 Sales 1 2 Life Sciences 1 1 2 ... 1

y **=** dataset**.**iloc[:,1:2]

**1** 49 Travel\_Frequently 279 Research & 8 1 Life Sciences 1 2 3 ... 4

Development

**2** 37 Travel\_Rarely 1373 Research & 2 2 Other 1 4 4 ... 2

Development

**3** 33 Travel\_Frequently 1392 Research & 3 4 Life Sciences 1 5 4 ... 3

Development

**4** 27 Travel\_Rarely 591 Research & 2 1 Medical 1 7 1 ... 4

Development

5 rows × 34 columns

y**.**head()

**Attrition**

**0** Yes

**1** No

**2** Yes

**3** No

**4** No

dataset**.**shape

(1470, 35)

x**.**shape

(1470, 34)

y**.**shape

Out[14]:

In [15]:

Out[15]:

In [16]:

Out[16]:

In [17]:

In [18]:

Out[18]:

In [19]:

Out[19]:

In [20]:

Out[20]:

In [21]:

In [22]:

Out[22]:

In [23]:

Out[23]:

In [24]:

In [25]:

Out[25]:

In [26]:

Out[26]:

In [27]:

Out[27]:

In [28]:

In [29]:

Out[29]:

In [30]:

In [31]:

Out[31]:

In [32]:

Out[32]:

In [33]:

Out[33]:

In [34]:

In [35]:

Out[35]:

In [36]:

Out[36]:

In [37]:

In [38]:

Out[38]:

In [39]:

Out[39]:

In [40]:

Out[40]:

In [41]:

In [42]:

In [43]:

Out[43]:

In [44]:

Out[44]:

In [45]:

Out[45]:

In [46]:

Out[46]:

In [47]:

Out[47]: (1470, 1)

Encoding

Nominal One hot encoding

A black and white rectangular object with white lines

Description automatically generatedBusinessTravel column

In [48]: BusinessTravel=pd.get\_dummies(x["BusinessTravel"],drop\_first=True)

BusinessTravel

Out[48]: **Travel\_Frequently Travel\_Rarely**

**0** 0 1

**1** 1 0

**2** 0 1

**3** 1 0

**4** 0 1

**...** ... ...

**1465** 1 0

**1466** 0 1

**1467** 0 1

**1468** 1 0

**1469** 0 1

1470 rows × 2 columns

In [49]: x=pd.concat([x,BusinessTravel],axis=1)

In [50]: x.drop(["BusinessTravel"],axis=1,inplace=True)

Department column

In [51]: Department=pd.get\_dummies(x["Department"],drop\_first=True)

Department

Out[51]: **Research & Development Sales**

**0** 0 1

**1** 1 0

**2** 1 0

**3** 1 0

**4** 1 0

**...** ... ...

1465 1 0

1466 1 0

1467 1 0

1468 0 1

1469 1 0

1470 rows × 2 columns

In [52]: x=pd.concat([x,Department],axis=1)

x.drop(["Department"],axis=1,inplace=True)

In [53]: x.head()

Out[53]: Age DailyRate DistanceFromHome Education EducationField EmployeeCount EmployeeNumber EnvironmentSatisfaction Gender HourlyRate ... TrainingTimesLastYear WorkLifeBala

0 41 1102 1 2 Life Sciences 1 1 2 Female 94 ... 0

1 49 279 8 1 Life Sciences 1 2 3 Male 61 ... 3

2 37 1373 2 2 Other 1 4 4 Male 92 ... 3

3 33 1392 3 4 Life Sciences 1 5 4 Female 56 ... 3

4 27 591 2 1 Medical 1 7 1 Male 40 ... 3

5 rows × 36 columns

EducationField column

In [54]: EducationField=pd.get\_dummies(x["EducationField"],drop\_first=True)

EducationField

Out[54]: Life Sciences Marketing Medical Other Technical Degree

**0** 1 0 0 0 0

**1** 1 0 0 0 0

**2** 0 0 0 1 0

**3** 1 0 0 0 0

**4** 0 0 1 0 0

**...** ... ... ... ... ...

**1465** 0 0 1 0 0

**1466** 0 0 1 0 0

**1467** 1 0 0 0 0

**1468** 0 0 1 0 0

**1469** 0 0 1 0 0

1470 rows × 5 columns

In [55]: x=pd.concat([x,EducationField],axis=1)

x.drop(["EducationField"],axis=1,inplace=True)

Gender column

In [56]: Gender=pd.get\_dummies(x["Gender"],drop\_first=True)

Gender

Out[56]: **Male**

0 0

1 1

2 1

3 0

4 1

**...** ...

1465 1

1466 1

1467 1

1468 1

1469 1

1470 rows × 1 columns

In [57]: x=pd.concat([x,Gender],axis=1)

x.drop(["Gender"],axis=1,inplace=True)

JobRole column

In [58]: JobRole=pd.get\_dummies(x["JobRole"],drop\_first=True)

JobRole

Out[58]: Human Resources Laboratory Technician Manager Manufacturing Director Research Director Research Scientist Sales Executive Sales Representative

0 0 0 0 0 0 0 1 0

1 0 0 0 0 0 1 0 0

2 0 1 0 0 0 0 0 0

3 0 0 0 0 0 1 0 0

4 0 1 0 0 0 0 0 0

... ... ... ... ... ... ... ... ...

1465 0 1 0 0 0 0 0 0

1466 0 0 0 0 0 0 0 0

1467 0 0 0 1 0 0 0 0

1468 0 0 0 0 0 0 1 0

1469 0 1 0 0 0 0 0 0

1470 rows × 8 columns

In [59]: x=pd.concat([x,JobRole],axis=1)

x.drop(["JobRole"],axis=1,inplace=True)

In [60]: x.shape

Out[60]: (1470, 47)

MaritalStatus column

In [61]: MaritalStatus=pd.get\_dummies(x["MaritalStatus"],drop\_first=True)

MaritalStatus

Out[61]: **Married Single**

**0** 0 1

**1** 1 0

**2** 0 1

**3** 1 0

**4** 1 0

**...** ... ...

**1465** 1 0

**1466** 1 0

**1467** 1 0

**1468** 1 0

**1469** 1 0

1470 rows × 2 columns

In [62]: x=pd.concat([x,MaritalStatus],axis=1)

x.drop(["MaritalStatus"],axis=1,inplace=True)

In [63]: x.shape

Out[63]: (1470, 48)

Over18 column

In [64]: Over18=pd.get\_dummies(x["Over18"],drop\_first=True)

Over18

Out[64]:

0

1

2

3

4

...

1465

1466

1467

1468

1469

1470 rows × 0 columns

In [65]: x=pd.concat([x,MaritalStatus],axis=1)

x.drop(["Over18"],axis=1,inplace=True)

OverTime column

In [66]: OverTime=pd.get\_dummies(x["OverTime"],drop\_first=True)

OverTime

Out[66]: **Yes**

0 1

1 0

2 1

3 1

4 0

**...** ...

1465 0

1466 0

1467 1

1468 0

1469 0

1470 rows × 1 columns

In [67]: x=pd.concat([x,OverTime],axis=1)

x.drop(["OverTime"],axis=1,inplace=True)

Attrition column

In [68]: Attrition=pd.get\_dummies(y["Attrition"],drop\_first=True)

Attrition

Out[68]: **Yes**

0 1

1 0

2 1

3 0

4 0

**...** ...

1465 0

1466 0

1467 0

1468 0

1469 0

1470 rows × 1 columns

In [69]: y=pd.concat([y,Attrition],axis=1)

y.drop(["Attrition"],axis=1,inplace=True)

In [70]: y.head()

Out[70]: **Yes**

0 1

1 0

2 1

3 0

4 0

Ordinal Label Encoding

In [71]: **from** sklearn.preprocessing **import** LabelEncoder

In [72]: le=LabelEncoder()

Education column

In [73]: x["Education"]=le.fit\_transform(x["Education"])

x["Education"]

Out[73]: 0 1

1 0

2 1

3 3

4 0

..

1465 1

1466 0

1467 2

1468 2

1469 2

Name: Education, Length: 1470, dtype: int64

EnvironmentSatisfaction column

In [74]:



x["EnvironmentSatisfaction"]**=**le**.**fit\_transform(x["EnvironmentSatisfaction"])

*# JobInvolvement column*

x["JobInvolvement"]**=**le**.**fit\_transform(x["JobInvolvement"])

*# JobSatisfaction column*

x["JobSatisfaction"]**=**le**.**fit\_transform(x["JobSatisfaction"])

*# PerformanceRating column*

*# RelationshipSatisfaction column*

x["RelationshipSatisfaction"]**=**le**.**fit\_transform(x["RelationshipSatisfaction"])

x["PerformanceRating"]**=**le**.**fit\_transform(x["PerformanceRating"])

x**.**head()

**Age DailyRate DistanceFromHome Education EmployeeCount EmployeeNumber EnvironmentSatisfaction HourlyRate JobInvolvement JobLevel ... Manufacturing Research Resear**

**Director Director Scient**

**0** 41 1102 1 1 1 1 1 94 2 2 ... 0 0

**1** 49 279 8 0 1 2 2 61 1 2 ... 0 0

**2** 37 1373 2 1 1 4 3 92 1 1 ... 0 0

**3** 33 1392 3 3 1 5 3 56 2 1 ... 0 0

**4** 27 591 2 0 1 7 0 40 2 1 ... 0 0

5 rows × 49 columns

x**.**info()

In [75]:

In [76]:

In [77]:

In [78]:

In [79]:

Out[79]:

In [80]:

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 1470 entries, 0 to 1469

Data columns (total 49 columns):

# Column Non-Null Count Dtype

--- ------ -------------- -----

0 Age 1470 non-null int64

1 DailyRate 1470 non-null int64

2 DistanceFromHome 1470 non-null int64

3 Education 1470 non-null int64

4 EmployeeCount 1470 non-null int64

5 EmployeeNumber 1470 non-null int64

6 EnvironmentSatisfaction 1470 non-null int64

7 HourlyRate 1470 non-null int64

8 JobInvolvement 1470 non-null int64

9 JobLevel 1470 non-null int64

10 JobSatisfaction 1470 non-null int64

11 MonthlyIncome 1470 non-null float64

12 MonthlyRate 1470 non-null int64

13 NumCompaniesWorked 1470 non-null int64

14 PercentSalaryHike 1470 non-null int64

15 PerformanceRating 1470 non-null int64

16 RelationshipSatisfaction 1470 non-null int64

17 StandardHours 1470 non-null int64

18 StockOptionLevel 1470 non-null int64

19 TotalWorkingYears 1470 non-null int64

20 TrainingTimesLastYear 1470 non-null int64

21 WorkLifeBalance 1470 non-null int64

22 YearsAtCompany 1470 non-null float64

23 YearsInCurrentRole 1470 non-null int64

24 YearsSinceLastPromotion 1470 non-null int64

25 YearsWithCurrManager 1470 non-null int64

26 Travel\_Frequently 1470 non-null uint8

27 Travel\_Rarely 1470 non-null uint8

28 Research & Development 1470 non-null uint8

29 Sales 1470 non-null uint8

30 Life Sciences 1470 non-null uint8

31 Marketing 1470 non-null uint8

32 Medical 1470 non-null uint8

33 Other 1470 non-null uint8

34 Technical Degree 1470 non-null uint8

35 Male 1470 non-null uint8

36 Human Resources 1470 non-null uint8

37 Laboratory Technician 1470 non-null uint8

38 Manager 1470 non-null uint8

39 Manufacturing Director 1470 non-null uint8

40 Research Director 1470 non-null uint8

41 Research Scientist 1470 non-null uint8

42 Sales Executive 1470 non-null uint8

43 Sales Representative 1470 non-null uint8

44 Married 1470 non-null uint8

45 Single 1470 non-null uint8

46 Married 1470 non-null uint8

47 Single 1470 non-null uint8

48 Yes 1470 non-null uint8

dtypes: float64(2), int64(24), uint8(23)

memory usage: 331.7 KB

We can see that all the columns have been encoded

Splitting Training and Testing DataSet

In [81]:



**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,random\_state**=**0)

x\_train**.**shape,x\_test**.**shape,y\_train**.**shape,y\_test**.**shape

((1029, 49), (441, 49), (1029, 1), (441, 1))

Feature Scaling

**from** sklearn.preprocessing **import** StandardScaler

sc**=**StandardScaler()

x\_train**=**sc**.**fit\_transform(x\_train)

x\_test**=**sc**.**fit\_transform(x\_test)

x\_train

In [82]:

Out[82]:

In [83]:

In [84]:

In [85]:

Out[85]: array([[-0.75016842, -0.58244694, -0.51036458, ..., -0.90267093,

-0.69784971, -0.61441846],

[-0.41863372, -1.12354988, -0.51036458, ..., -0.90267093,

1.43297329, 1.62755527],

[ 0.90750511, -0.04626313, 1.84630474, ..., -0.90267093,

1.43297329, -0.61441846],

...,

[ 0.68648197, 0.91542436, -0.88247026, ..., 1.10782342,

-0.69784971, 1.62755527],

[ 0.13392413, -1.3252337 , -0.88247026, ..., 1.10782342,



x\_test

-0.69784971, 1.62755527],

[ 0.35494726, -0.36600577, 0.10981156, ..., -0.90267093,

-0.69784971, -0.61441846]])

In [86]:

Out[86]: array([[-0.13313793, -0.3978601 , 0.07634069, ..., -0.95780546,

1.52177182, -0.66066791],

[-0.45515161, -0.54952521, 1.90602783, ..., -0.95780546,

1.52177182, -0.66066791],

[-0.24047582, -0.32961081, 1.05217383, ..., 1.04405335,

-0.65712874, 1.51361976],

...,

[ 0.29621364, 0.76237796, 2.27196526, ..., -0.95780546,

-0.65712874, -0.66066791],

[ 1.58426835, -1.19662966, -0.77751331, ..., 1.04405335,

-0.65712874, 1.51361976],

[-0.45515161, -1.46457135, -0.28959674, ..., 1.04405335,

-0.65712874, -0.66066791]])

Model Building using Logistic Regression

In [87]:



**from** sklearn.linear\_model **import** LogisticRegression

model**=**LogisticRegression()

model**.**fit(x\_train,y\_train)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\utils\validation.py:1184: DataConversionWarning: A column-vector y was passed when a 1d array wa

s expected. Please change the shape of y to (n\_samples, ), for example using ravel().

▾ LogisticRegression

LogisticRegression()

y = column\_or\_1d(y, warn=True)

pred**=**model**.**predict(x\_test)

pred

In [88]:

Out[88]:

In [89]:

In [90]:

Out[90]: array([0, 0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0,

1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0,

0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1,

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0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0], dtype=uint8)

In [91]:



y\_test

**442** 0

**1091** 0

**981** 1

**Yes**

**785** 0

**1332** 1

**817** 0

**399** 0

**...** ...

**458** 0

**406** 0

**590** 0

441 rows × 1 columns

Evaluation of Classification Model

**from** sklearn.metrics **import** accuracy\_score,confusion\_matrix,classification\_report,roc\_auc\_score,roc\_curve

accuracy\_score(y\_test,pred)

0.8866213151927438

confusion\_matrix(y\_test,pred)

array([[362, 9],

[ 41, 29]], dtype=int64)

print(classification\_report(y\_test,pred))

Out[91]:

In [92]:

In [93]:

Out[93]:

In [94]:

Out[94]:

In [95]:

precision recall f1-score support

0 0.90 0.98 0.94 371

1 0.76 0.41 0.54 70

accuracy 0.89 441

macro avg 0.83 0.70 0.74 441

weighted avg 0.88 0.89 0.87 441

In [96]:



probability**=**model**.**predict\_proba(x\_test)[:,1]

probability

Out[96]: array([9.78796690e-02, 6.49693921e-02, 6.07481146e-01, 1.83162250e-01,

8.31084648e-01, 5.36392103e-02, 4.32850819e-01, 3.14266433e-02,

4.44634741e-04, 6.01649262e-01, 2.00126658e-02, 1.72875273e-01,

1.35432484e-02, 6.13546704e-01, 5.48696953e-02, 1.25074596e-02,

1.17401377e-01, 4.61662962e-02, 3.34247564e-02, 2.93915157e-01,

1.68598420e-01, 8.37652504e-03, 1.21719673e-02, 6.32241866e-02,

7.75894857e-01, 4.74787345e-01, 5.33696627e-02, 3.79406056e-02,

6.67224841e-01, 4.77326470e-02, 5.10200006e-03, 2.57723249e-01,

3.44646694e-02, 2.16176812e-01, 2.21640011e-02, 3.05570340e-03,

1.49171594e-01, 4.32273605e-02, 2.40340735e-02, 1.25059338e-01,

1.00460399e-01, 9.20489402e-03, 6.70928324e-04, 1.03062961e-02,

6.68856203e-03, 5.77491219e-01, 4.31402098e-01, 1.21367756e-03,

4.05592771e-01, 3.79607455e-01, 3.81580646e-02, 8.49277879e-01,

2.95953756e-02, 4.85176455e-01, 4.23160010e-01, 2.66465926e-01,

8.72672403e-03, 4.32518565e-01, 1.67403507e-02, 3.57052308e-01,

1.31315939e-02, 1.96567213e-01, 8.61257435e-02, 5.48437472e-02,

9.60323031e-02, 2.20585134e-02, 2.87914859e-01, 1.80117569e-01,

9.74594292e-02, 1.85851697e-01, 4.06587491e-02, 1.51033053e-01,

6.43832781e-02, 3.53040608e-02, 1.08767146e-01, 4.32579625e-02,

3.77016174e-02, 1.83059419e-01, 4.61556301e-01, 2.14908949e-02,

1.25883864e-03, 2.60234237e-02, 2.69275940e-01, 1.46485917e-02,

1.61445485e-02, 8.53742071e-02, 4.95616689e-03, 1.55530770e-02,

1.40747973e-02, 7.08803509e-02, 1.01528686e-01, 9.44966673e-02,

3.35931374e-01, 1.39668465e-01, 5.48641117e-04, 9.41450016e-02,

4.77921886e-01, 6.06499153e-01, 6.58457434e-02, 9.30497362e-02,

1.68660449e-01, 5.05528660e-01, 4.46602572e-01, 6.26135722e-03,

1.72756707e-01, 6.06200602e-03, 9.94495564e-02, 2.35511586e-01,

2.50353979e-02, 2.24177879e-01, 2.65882117e-02, 1.47976461e-02,

3.15372416e-03, 3.21640113e-01, 2.15467440e-02, 4.26902651e-02,

1.17230640e-02, 2.52517047e-02, 1.55271978e-03, 7.37535894e-03,

1.22702270e-01, 2.11512579e-02, 7.37084448e-02, 8.80911304e-01,

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2.05660422e-01, 1.28212586e-02, 1.19466645e-03, 2.54336966e-01,

6.83862689e-01, 2.74020557e-01, 5.41900291e-02, 2.13125260e-01,

5.93265178e-01, 3.35349938e-01, 2.38722275e-01, 4.30977268e-01,

2.08287637e-02, 4.32312196e-02, 3.65855261e-02, 1.87818891e-01,

5.53619885e-01, 3.34527076e-02, 1.96485980e-01, 6.48546577e-03,

5.02024421e-02, 1.65555812e-01, 3.75738415e-03, 1.01466331e-01,

6.49887183e-02, 5.08421286e-02, 5.21376626e-02, 2.67089375e-02,

4.01450235e-02, 3.11310492e-01, 4.22448598e-03, 9.33124086e-03,

7.81418490e-01, 2.59763563e-03, 4.99285495e-02, 9.46891747e-01,

1.25249803e-02, 2.81150057e-01, 2.12055192e-01, 1.10252018e-01,

3.17055605e-02, 5.08137486e-04, 1.00498329e-01, 5.66290109e-02,

5.16883408e-02, 1.28910757e-01, 9.02804220e-03, 6.23858003e-02,

4.21165422e-02, 5.30222528e-02, 3.99641445e-02, 2.63812209e-02,

2.10250011e-02, 2.22732621e-01, 9.62804687e-03, 8.95772250e-01,

7.61117948e-02, 9.18558307e-02, 6.20870224e-01, 1.44456104e-02,

5.61108036e-01, 2.23627428e-01, 2.77306814e-01, 2.85548561e-01,

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2.57466513e-02, 8.91412850e-03, 2.94503157e-01, 1.53149284e-02,

3.97068258e-01, 2.50381556e-01, 7.74802139e-01, 2.98550538e-02,

9.79176976e-02, 1.13594343e-02, 4.04736156e-01, 1.95442644e-03,

2.75447795e-01, 1.63009364e-02, 6.01083903e-02, 3.18333647e-01,

5.00362374e-02, 3.28783645e-01, 1.57176748e-01, 4.25288050e-03,

5.75574998e-03, 5.17405788e-02, 2.36732531e-02, 1.28804020e-01,

1.34302982e-01, 4.39618611e-01, 5.22066102e-01, 1.19250826e-01,

2.40717554e-01, 4.02557421e-03, 9.58923312e-02, 2.90979957e-01,

7.56914230e-01, 7.06421081e-02, 5.57090442e-02, 2.49241355e-01,

3.14683680e-02, 3.10204624e-02, 1.53733673e-01, 1.27604748e-01,

3.63699825e-01, 1.06125879e-03, 7.70865077e-02, 6.89991745e-03,

1.55922866e-01, 1.92337152e-01, 6.17429844e-03, 1.76374883e-01,

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7.90772087e-02, 5.86356412e-02, 2.94634475e-01, 1.02183392e-01,

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1.82859002e-03, 6.94124038e-01, 6.88418695e-01, 3.77702931e-01,

1.60408349e-01, 3.73438153e-02, 2.55822094e-01, 7.35121303e-02,

5.77759036e-02, 8.82445083e-02, 1.12495644e-03, 3.97007877e-01,

5.37660814e-01, 4.64528704e-02, 3.72755709e-02, 1.58323255e-02,

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3.30098041e-02, 8.86162342e-02, 3.36876695e-04, 1.25967516e-01,

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4.78772831e-01, 6.33881559e-02, 9.33838870e-01, 6.11375300e-03,

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1.13511249e-03, 3.18788110e-02, 3.53982173e-01, 1.39866017e-02,

1.17292351e-01, 6.69597602e-02, 1.05365545e-01, 1.66076320e-01,

7.47401091e-02, 6.15752530e-02, 5.60925232e-02, 5.18658274e-03,

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3.88023847e-02, 1.70753340e-02, 2.35969324e-01, 1.33024417e-01,

2.43234850e-03, 1.46446371e-02, 1.53939632e-02, 2.35216731e-01,

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3.15199536e-02, 5.59383981e-03, 9.44886352e-02, 2.13266413e-01,

9.68401104e-03, 8.49517283e-02, 1.08099557e-02, 2.73906824e-01,

6.25214570e-02, 1.65044989e-01, 6.53722879e-02, 4.78455216e-03,

6.42388765e-02, 8.99104148e-02, 3.79332993e-03, 2.70835292e-01,

4.96742383e-03, 4.29077834e-03, 1.08815311e-02, 2.21587385e-03,

2.23421522e-01, 6.47147717e-02, 2.00641849e-03, 4.30790071e-01,

1.51268070e-02, 8.23374179e-02, 4.78748775e-03, 5.55329137e-01,

1.17147513e-02, 4.36125499e-02, 4.55052186e-01, 3.26172268e-01,

6.64959011e-03, 2.04738377e-02, 7.47671150e-01, 1.09558095e-01,

2.51037501e-01, 2.81302949e-02, 3.34975318e-02, 6.02059546e-02,

1.20560672e-03, 7.72182819e-01, 4.81119258e-04, 2.82029097e-01,

9.17385752e-03, 8.31867948e-02, 3.85578733e-02, 6.84097282e-01,

3.83505730e-02, 6.46943487e-02, 8.06682328e-01, 1.64778495e-02,

7.83417589e-02, 5.66998055e-01, 9.46883610e-03, 3.76385423e-02,

7.48120581e-01, 3.22493646e-02, 2.16143874e-02, 3.64865854e-02,

5.36704416e-02, 5.82953030e-03, 1.72080662e-01, 5.07316544e-02,

1.61265576e-02, 1.75292136e-03, 2.79114759e-01, 1.61827033e-02,

2.10847532e-02, 4.47978489e-01, 4.52640047e-01, 3.42846902e-01,

2.80919776e-02, 3.56562691e-01, 8.66195889e-02, 3.08977895e-02,

2.19886880e-01, 9.84291161e-02, 4.95304390e-02, 2.03314116e-03,

1.86101979e-03, 2.03859038e-02, 1.03879381e-01, 8.55390066e-02,

2.59636309e-01, 6.97127835e-03, 1.21093498e-01, 2.16623712e-01,

6.77560665e-03, 1.35869166e-01, 1.54017661e-01, 1.19158489e-01,

1.23249508e-02, 1.54454121e-01, 6.15739824e-02, 4.12836693e-03,

4.58878117e-04])

In [97]:



fpr,tpr,threshsholds **=** roc\_curve(y\_test,probability)

plt**.**plot(fpr,tpr)

plt**.**xlabel('FPR')

plt**.**ylabel('TPR')

plt**.**title('ROC CURVE')

plt**.**show()

Decision Tree

**from** sklearn.tree **import** DecisionTreeClassifier

dtc**.**fit(x\_train,y\_train)

▾ DecisionTreeClassifier

DecisionTreeClassifier()

pred**=**dtc**.**predict(x\_test)

dtc**=**DecisionTreeClassifier()

pred

In [98]:

In [99]:

In [100…

Out[100]:

In [101…

Out[101]: array([0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,

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0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0,

0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0,

0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 1, 1, 0, 1, 0,

0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 1,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0,

0], dtype=uint8)

In [102…



y\_test

**Yes**

**442** 0

**1091** 0

**981** 1

**785** 0

**1332** 1

**...** ...

**817** 0

**399** 0

**458** 0

**406** 0

**590** 0

441 rows × 1 columns

Evaluation of Classification model

**from** sklearn.metrics **import** accuracy\_score,confusion\_matrix,classification\_report,roc\_auc\_score,roc\_curve

accuracy\_score(y\_test,pred)

0.7868480725623582

confusion\_matrix(y\_test,pred)

array([[321, 50],

print(classification\_report(y\_test,pred))

[ 44, 26]], dtype=int64)

Out[102]:

In [103…

In [104…

Out[104]:

In [105…

Out[105]:

In [106…

precision recall f1-score support

0 0.88 0.87 0.87 371

1 0.34 0.37 0.36 70

accuracy 0.79 441

macro avg 0.61 0.62 0.61 441

weighted avg 0.79 0.79 0.79 441

ROC-AUC Curve

In [107…



probability**=**dtc**.**predict\_proba(x\_test)[:,1]

probability

Out[107]: array([0., 0., 0., 0., 1., 1., 1., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 1., 0., 0., 0., 1., 0.,

0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 1., 1., 0.,

0., 1., 0., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 1., 0., 0., 0., 0., 1., 0.,

0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,

1., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 1.,

0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0.,

0., 0., 0., 0., 0., 0., 0., 1., 0., 1., 1., 0., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 1., 0., 0., 0.,

0., 0., 0., 1., 1., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 1., 0.,

0., 0., 1., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 1., 0.,

1., 1., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 1., 0., 0., 1., 0.,

0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,

0., 0., 1., 0., 1., 0., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 0., 1., 1., 0., 1., 0., 0., 1., 0., 0., 0.,

0., 1., 1., 0., 0., 0., 0., 0., 0., 1., 0., 1., 0., 0., 0., 0., 0.,

0., 0., 0., 1., 0., 0., 0., 0., 1., 0., 0., 0., 1., 0., 0., 0., 0.,

1., 1., 0., 1., 1., 0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0.,

0., 1., 0., 1., 0., 0., 0., 0., 0., 1., 0., 1., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 1., 0., 0., 1., 0., 0.,

1., 1., 0., 1., 0., 0., 1., 0., 0., 0., 0., 0., 1., 0., 0., 0., 0.,

0., 0., 0., 0., 1., 1., 1., 0., 0., 1., 0., 0., 0., 0., 0., 0., 0.,

0., 0., 0., 0., 0., 1., 0., 0., 0., 0., 1., 0., 0., 0., 0., 0.])

In [108…



fpr,tpr,threshsholds **=** roc\_curve(y\_test,probability)

plt**.**plot(fpr,tpr)

plt**.**xlabel('FPR')

plt**.**ylabel('TPR')

plt**.**title('ROC CURVE')

plt**.**show()

Performing Hyperparameter Tuning

**from** sklearn **import** tree

tree**.**plot\_tree(dtc,filled**=True**)

plt**.**figure(figsize**=**(25,15))

In [109…

In [110…

Out[110]: [Text(0.5181215347782258, 0.9642857142857143, 'x[48] <= 0.507\ngini = 0.272\nsamples = 1029\nvalue = [862, 167]'),

Text(0.22764931955645162, 0.8928571428571429, 'x[22] <= -1.115\ngini = 0.191\nsamples = 747\nvalue = [667, 80]'),

Text(0.08870967741935484, 0.8214285714285714, 'x[0] <= -0.584\ngini = 0.397\nsamples = 110\nvalue = [80, 30]'),

Text(0.04435483870967742, 0.75, 'x[26] <= 0.804\ngini = 0.499\nsamples = 46\nvalue = [24, 22]'),

Text(0.036290322580645164, 0.6785714285714286, 'x[1] <= -1.14\ngini = 0.473\nsamples = 39\nvalue = [24, 15]'),

Text(0.016129032258064516, 0.6071428571428571, 'x[11] <= -1.361\ngini = 0.245\nsamples = 7\nvalue = [1, 6]'),

Text(0.008064516129032258, 0.5357142857142857, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.024193548387096774, 0.5357142857142857, 'gini = 0.0\nsamples = 6\nvalue = [0, 6]'),

Text(0.056451612903225805, 0.6071428571428571, 'x[21] <= -0.355\ngini = 0.404\nsamples = 32\nvalue = [23, 9]'),

Text(0.04032258064516129, 0.5357142857142857, 'x[18] <= 0.823\ngini = 0.42\nsamples = 10\nvalue = [3, 7]'),

Text(0.03225806451612903, 0.4642857142857143, 'gini = 0.0\nsamples = 7\nvalue = [0, 7]'),

Text(0.04838709677419355, 0.4642857142857143, 'gini = 0.0\nsamples = 3\nvalue = [3, 0]'),

Text(0.07258064516129033, 0.5357142857142857, 'x[0] <= -0.695\ngini = 0.165\nsamples = 22\nvalue = [20, 2]'),

Text(0.06451612903225806, 0.4642857142857143, 'gini = 0.0\nsamples = 19\nvalue = [19, 0]'),

Text(0.08064516129032258, 0.4642857142857143, 'x[2] <= -0.076\ngini = 0.444\nsamples = 3\nvalue = [1, 2]'),

Text(0.07258064516129033, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.08870967741935484, 0.39285714285714285, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.05241935483870968, 0.6785714285714286, 'gini = 0.0\nsamples = 7\nvalue = [0, 7]'),

Text(0.13306451612903225, 0.75, 'x[6] <= -1.134\ngini = 0.219\nsamples = 64\nvalue = [56, 8]'),

Text(0.11290322580645161, 0.6785714285714286, 'x[13] <= 0.697\ngini = 0.457\nsamples = 17\nvalue = [11, 6]'),

Text(0.0967741935483871, 0.6071428571428571, 'x[27] <= -0.464\ngini = 0.18\nsamples = 10\nvalue = [9, 1]'),

Text(0.08870967741935484, 0.5357142857142857, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.10483870967741936, 0.5357142857142857, 'gini = 0.0\nsamples = 9\nvalue = [9, 0]'),

Text(0.12903225806451613, 0.6071428571428571, 'x[10] <= 0.709\ngini = 0.408\nsamples = 7\nvalue = [2, 5]'),

Text(0.12096774193548387, 0.5357142857142857, 'gini = 0.0\nsamples = 5\nvalue = [0, 5]'),

Text(0.13709677419354838, 0.5357142857142857, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.1532258064516129, 0.6785714285714286, 'x[12] <= -1.512\ngini = 0.081\nsamples = 47\nvalue = [45, 2]'),

Text(0.14516129032258066, 0.6071428571428571, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.16129032258064516, 0.6071428571428571, 'x[12] <= 1.684\ngini = 0.043\nsamples = 46\nvalue = [45, 1]'),

Text(0.1532258064516129, 0.5357142857142857, 'gini = 0.0\nsamples = 45\nvalue = [45, 0]'),

Text(0.1693548387096774, 0.5357142857142857, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.3665889616935484, 0.8214285714285714, 'x[10] <= -1.119\ngini = 0.145\nsamples = 637\nvalue = [587, 50]'),

Text(0.2600806451612903, 0.75, 'x[18] <= -0.354\ngini = 0.265\nsamples = 121\nvalue = [102, 19]'),

Text(0.21370967741935484, 0.6785714285714286, 'x[16] <= 0.754\ngini = 0.393\nsamples = 52\nvalue = [38, 14]'),

Text(0.2056451612903226, 0.6071428571428571, 'x[13] <= -0.487\ngini = 0.475\nsamples = 36\nvalue = [22, 14]'),

Text(0.18548387096774194, 0.5357142857142857, 'x[34] <= 1.429\ngini = 0.332\nsamples = 19\nvalue = [15, 4]'),

Text(0.1774193548387097, 0.4642857142857143, 'x[24] <= 3.369\ngini = 0.208\nsamples = 17\nvalue = [15, 2]'),

Text(0.1693548387096774, 0.39285714285714285, 'x[21] <= -1.741\ngini = 0.117\nsamples = 16\nvalue = [15, 1]'),

Text(0.16129032258064516, 0.32142857142857145, 'x[2] <= -0.448\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.1532258064516129, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.1693548387096774, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.1774193548387097, 0.32142857142857145, 'gini = 0.0\nsamples = 14\nvalue = [14, 0]'),

Text(0.18548387096774194, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.1935483870967742, 0.4642857142857143, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.22580645161290322, 0.5357142857142857, 'x[2] <= -0.82\ngini = 0.484\nsamples = 17\nvalue = [7, 10]'),

Text(0.20967741935483872, 0.4642857142857143, 'x[11] <= -0.731\ngini = 0.375\nsamples = 8\nvalue = [6, 2]'),

Text(0.20161290322580644, 0.39285714285714285, 'x[23] <= 0.086\ngini = 0.444\nsamples = 3\nvalue = [1, 2]'),

Text(0.1935483870967742, 0.32142857142857145, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.20967741935483872, 0.32142857142857145, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.21774193548387097, 0.39285714285714285, 'gini = 0.0\nsamples = 5\nvalue = [5, 0]'),

Text(0.24193548387096775, 0.4642857142857143, 'x[21] <= -1.741\ngini = 0.198\nsamples = 9\nvalue = [1, 8]'),

Text(0.23387096774193547, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.25, 0.39285714285714285, 'gini = 0.0\nsamples = 8\nvalue = [0, 8]'),

Text(0.2217741935483871, 0.6071428571428571, 'gini = 0.0\nsamples = 16\nvalue = [16, 0]'),

Text(0.3064516129032258, 0.6785714285714286, 'x[43] <= 1.964\ngini = 0.134\nsamples = 69\nvalue = [64, 5]'),

Text(0.29838709677419356, 0.6071428571428571, 'x[0] <= -0.253\ngini = 0.111\nsamples = 68\nvalue = [64, 4]'),

Text(0.2903225806451613, 0.5357142857142857, 'x[11] <= -0.076\ngini = 0.238\nsamples = 29\nvalue = [25, 4]'),

Text(0.27419354838709675, 0.4642857142857143, 'x[6] <= -1.134\ngini = 0.095\nsamples = 20\nvalue = [19, 1]'),

Text(0.2661290322580645, 0.39285714285714285, 'x[25] <= -0.437\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.25806451612903225, 0.32142857142857145, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.27419354838709675, 0.32142857142857145, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.28225806451612906, 0.39285714285714285, 'gini = 0.0\nsamples = 18\nvalue = [18, 0]'),

Text(0.3064516129032258, 0.4642857142857143, 'x[1] <= 0.13\ngini = 0.444\nsamples = 9\nvalue = [6, 3]'),

Text(0.29838709677419356, 0.39285714285714285, 'x[19] <= -0.114\ngini = 0.48\nsamples = 5\nvalue = [2, 3]'),

Text(0.2903225806451613, 0.32142857142857145, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.3064516129032258, 0.32142857142857145, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.31451612903225806, 0.39285714285714285, 'gini = 0.0\nsamples = 4\nvalue = [4, 0]'),

Text(0.3064516129032258, 0.5357142857142857, 'gini = 0.0\nsamples = 39\nvalue = [39, 0]'),

Text(0.31451612903225806, 0.6071428571428571, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.47309727822580644, 0.75, 'x[1] <= -1.7\ngini = 0.113\nsamples = 516\nvalue = [485, 31]'),

Text(0.4332157258064516, 0.6785714285714286, 'x[0] <= -0.253\ngini = 0.5\nsamples = 4\nvalue = [2, 2]'),

Text(0.4251512096774194, 0.6071428571428571, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.4412802419354839, 0.6071428571428571, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.5129788306451613, 0.6785714285714286, 'x[11] <= 0.612\ngini = 0.107\nsamples = 512\nvalue = [483, 29]'),

Text(0.4574092741935484, 0.6071428571428571, 'x[19] <= -0.432\ngini = 0.077\nsamples = 400\nvalue = [384, 16]'),

Text(0.4067540322580645, 0.5357142857142857, 'x[13] <= 0.697\ngini = 0.155\nsamples = 154\nvalue = [141, 13]'),

Text(0.3538306451612903, 0.4642857142857143, 'x[25] <= -1.036\ngini = 0.085\nsamples = 135\nvalue = [129, 6]'),

Text(0.33064516129032256, 0.39285714285714285, 'x[11] <= -0.822\ngini = 0.408\nsamples = 7\nvalue = [5, 2]'),

Text(0.3225806451612903, 0.32142857142857145, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.3387096774193548, 0.32142857142857145, 'gini = 0.0\nsamples = 5\nvalue = [5, 0]'),

Text(0.37701612903225806, 0.39285714285714285, 'x[11] <= -1.048\ngini = 0.061\nsamples = 128\nvalue = [124, 4]'),

Text(0.3548387096774194, 0.32142857142857145, 'x[46] <= 0.103\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.3467741935483871, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.3629032258064516, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.39919354838709675, 0.32142857142857145, 'x[24] <= 1.188\ngini = 0.046\nsamples = 126\nvalue = [123, 3]'),

Text(0.3790322580645161, 0.25, 'x[0] <= -1.69\ngini = 0.032\nsamples = 124\nvalue = [122, 2]'),

Text(0.3629032258064516, 0.17857142857142858, 'x[15] <= 0.956\ngini = 0.278\nsamples = 6\nvalue = [5, 1]'),

Text(0.3548387096774194, 0.10714285714285714, 'gini = 0.0\nsamples = 5\nvalue = [5, 0]'),

Text(0.3709677419354839, 0.10714285714285714, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.3951612903225806, 0.17857142857142858, 'x[13] <= 0.302\ngini = 0.017\nsamples = 118\nvalue = [117, 1]'),

Text(0.3870967741935484, 0.10714285714285714, 'gini = 0.0\nsamples = 112\nvalue = [112, 0]'),

Text(0.4032258064516129, 0.10714285714285714, 'x[25] <= -0.288\ngini = 0.278\nsamples = 6\nvalue = [5, 1]'),

Text(0.3951612903225806, 0.03571428571428571, 'gini = 0.0\nsamples = 5\nvalue = [5, 0]'),

Text(0.4112903225806452, 0.03571428571428571, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.41935483870967744, 0.25, 'x[16] <= -0.623\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.4112903225806452, 0.17857142857142858, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.4274193548387097, 0.17857142857142858, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.4596774193548387, 0.4642857142857143, 'x[1] <= 1.373\ngini = 0.465\nsamples = 19\nvalue = [12, 7]'),

Text(0.45161290322580644, 0.39285714285714285, 'x[0] <= -0.584\ngini = 0.375\nsamples = 16\nvalue = [12, 4]'),

Text(0.4435483870967742, 0.32142857142857145, 'x[1] <= 0.334\ngini = 0.5\nsamples = 8\nvalue = [4, 4]'),

Text(0.43548387096774194, 0.25, 'gini = 0.0\nsamples = 4\nvalue = [0, 4]'),

Text(0.45161290322580644, 0.25, 'gini = 0.0\nsamples = 4\nvalue = [4, 0]'),

Text(0.4596774193548387, 0.32142857142857145, 'gini = 0.0\nsamples = 8\nvalue = [8, 0]'),

Text(0.46774193548387094, 0.39285714285714285, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.5080645161290323, 0.5357142857142857, 'x[0] <= 1.626\ngini = 0.024\nsamples = 246\nvalue = [243, 3]'),

Text(0.49193548387096775, 0.4642857142857143, 'x[25] <= -0.737\ngini = 0.009\nsamples = 221\nvalue = [220, 1]'),

Text(0.4838709677419355, 0.39285714285714285, 'x[37] <= 0.878\ngini = 0.091\nsamples = 21\nvalue = [20, 1]'),

Text(0.47580645161290325, 0.32142857142857145, 'gini = 0.0\nsamples = 18\nvalue = [18, 0]'),

Text(0.49193548387096775, 0.32142857142857145, 'x[2] <= -0.386\ngini = 0.444\nsamples = 3\nvalue = [2, 1]'),

Text(0.4838709677419355, 0.25, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.5, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.5, 0.39285714285714285, 'gini = 0.0\nsamples = 200\nvalue = [200, 0]'),

Text(0.5241935483870968, 0.4642857142857143, 'x[11] <= -0.943\ngini = 0.147\nsamples = 25\nvalue = [23, 2]'),

Text(0.5161290322580645, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.532258064516129, 0.39285714285714285, 'x[8] <= -1.733\ngini = 0.08\nsamples = 24\nvalue = [23, 1]'),

Text(0.5241935483870968, 0.32142857142857145, 'x[29] <= 0.438\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.5161290322580645, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.532258064516129, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.5403225806451613, 0.32142857142857145, 'gini = 0.0\nsamples = 22\nvalue = [22, 0]'),

Text(0.5685483870967742, 0.6071428571428571, 'x[1] <= -1.619\ngini = 0.205\nsamples = 112\nvalue = [99, 13]'),

Text(0.5483870967741935, 0.5357142857142857, 'x[22] <= 1.728\ngini = 0.375\nsamples = 4\nvalue = [1, 3]'),

Text(0.5403225806451613, 0.4642857142857143, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.5564516129032258, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.5887096774193549, 0.5357142857142857, 'x[14] <= -1.017\ngini = 0.168\nsamples = 108\nvalue = [98, 10]'),

Text(0.5725806451612904, 0.4642857142857143, 'x[24] <= 1.967\ngini = 0.397\nsamples = 22\nvalue = [16, 6]'),

Text(0.5645161290322581, 0.39285714285714285, 'x[2] <= -0.944\ngini = 0.266\nsamples = 19\nvalue = [16, 3]'),

Text(0.5564516129032258, 0.32142857142857145, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.5725806451612904, 0.32142857142857145, 'x[19] <= 1.876\ngini = 0.198\nsamples = 18\nvalue = [16, 2]'),

Text(0.5645161290322581, 0.25, 'x[2] <= 0.668\ngini = 0.111\nsamples = 17\nvalue = [16, 1]'),

Text(0.5564516129032258, 0.17857142857142858, 'gini = 0.0\nsamples = 16\nvalue = [16, 0]'),

Text(0.5725806451612904, 0.17857142857142858, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.5806451612903226, 0.25, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.5806451612903226, 0.39285714285714285, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.6048387096774194, 0.4642857142857143, 'x[11] <= 0.633\ngini = 0.089\nsamples = 86\nvalue = [82, 4]'),

Text(0.5967741935483871, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.6129032258064516, 0.39285714285714285, 'x[0] <= 1.294\ngini = 0.068\nsamples = 85\nvalue = [82, 3]'),

Text(0.6048387096774194, 0.32142857142857145, 'gini = 0.0\nsamples = 62\nvalue = [62, 0]'),

Text(0.6209677419354839, 0.32142857142857145, 'x[11] <= 1.562\ngini = 0.227\nsamples = 23\nvalue = [20, 3]'),

Text(0.6129032258064516, 0.25, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.6290322580645161, 0.25, 'x[12] <= 1.488\ngini = 0.091\nsamples = 21\nvalue = [20, 1]'),

Text(0.6209677419354839, 0.17857142857142858, 'gini = 0.0\nsamples = 20\nvalue = [20, 0]'),

Text(0.6370967741935484, 0.17857142857142858, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.80859375, 0.8928571428571429, 'x[11] <= -0.434\ngini = 0.427\nsamples = 282\nvalue = [195, 87]'),

Text(0.7250504032258065, 0.8214285714285714, 'x[8] <= 1.094\ngini = 0.493\nsamples = 109\nvalue = [48, 61]'),

Text(0.6839717741935484, 0.75, 'x[0] <= -1.137\ngini = 0.474\nsamples = 96\nvalue = [37, 59]'),

Text(0.6411290322580645, 0.6785714285714286, 'x[24] <= -0.214\ngini = 0.204\nsamples = 26\nvalue = [3, 23]'),

Text(0.625, 0.6071428571428571, 'x[11] <= -0.599\ngini = 0.083\nsamples = 23\nvalue = [1, 22]'),

Text(0.6169354838709677, 0.5357142857142857, 'gini = 0.0\nsamples = 21\nvalue = [0, 21]'),

Text(0.6330645161290323, 0.5357142857142857, 'x[8] <= -0.319\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.625, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.6411290322580645, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.657258064516129, 0.6071428571428571, 'x[12] <= -0.971\ngini = 0.444\nsamples = 3\nvalue = [2, 1]'),

Text(0.6491935483870968, 0.5357142857142857, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.6653225806451613, 0.5357142857142857, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.7268145161290323, 0.6785714285714286, 'x[1] <= 0.807\ngini = 0.5\nsamples = 70\nvalue = [34, 36]'),

Text(0.7036290322580645, 0.6071428571428571, 'x[14] <= 0.898\ngini = 0.468\nsamples = 51\nvalue = [19, 32]'),

Text(0.6814516129032258, 0.5357142857142857, 'x[0] <= -0.142\ngini = 0.497\nsamples = 39\nvalue = [18, 21]'),

Text(0.6612903225806451, 0.4642857142857143, 'x[0] <= -0.916\ngini = 0.434\nsamples = 22\nvalue = [7, 15]'),

Text(0.6451612903225806, 0.39285714285714285, 'x[18] <= 2.001\ngini = 0.32\nsamples = 5\nvalue = [4, 1]'),

Text(0.6370967741935484, 0.32142857142857145, 'gini = 0.0\nsamples = 4\nvalue = [4, 0]'),

Text(0.6532258064516129, 0.32142857142857145, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.6774193548387096, 0.39285714285714285, 'x[14] <= 0.077\ngini = 0.291\nsamples = 17\nvalue = [3, 14]'),

Text(0.6693548387096774, 0.32142857142857145, 'x[36] <= 2.455\ngini = 0.124\nsamples = 15\nvalue = [1, 14]'),

Text(0.6612903225806451, 0.25, 'gini = 0.0\nsamples = 13\nvalue = [0, 13]'),

Text(0.6774193548387096, 0.25, 'x[5] <= 0.589\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.6693548387096774, 0.17857142857142858, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.6854838709677419, 0.17857142857142858, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.6854838709677419, 0.32142857142857145, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.7016129032258065, 0.4642857142857143, 'x[19] <= -1.069\ngini = 0.457\nsamples = 17\nvalue = [11, 6]'),

Text(0.6935483870967742, 0.39285714285714285, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.7096774193548387, 0.39285714285714285, 'x[5] <= 0.13\ngini = 0.337\nsamples = 14\nvalue = [11, 3]'),

Text(0.7016129032258065, 0.32142857142857145, 'gini = 0.0\nsamples = 9\nvalue = [9, 0]'),

Text(0.717741935483871, 0.32142857142857145, 'x[2] <= -0.634\ngini = 0.48\nsamples = 5\nvalue = [2, 3]'),

Text(0.7096774193548387, 0.25, 'gini = 0.0\nsamples = 2\nvalue = [2, 0]'),

Text(0.7258064516129032, 0.25, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.7258064516129032, 0.5357142857142857, 'x[11] <= -0.459\ngini = 0.153\nsamples = 12\nvalue = [1, 11]'),

Text(0.717741935483871, 0.4642857142857143, 'gini = 0.0\nsamples = 11\nvalue = [0, 11]'),

Text(0.7338709677419355, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.75, 0.6071428571428571, 'x[6] <= -1.134\ngini = 0.332\nsamples = 19\nvalue = [15, 4]'),

Text(0.7419354838709677, 0.5357142857142857, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.7580645161290323, 0.5357142857142857, 'x[5] <= -1.467\ngini = 0.117\nsamples = 16\nvalue = [15, 1]'),

Text(0.75, 0.4642857142857143, 'x[7] <= -0.598\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.7419354838709677, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.7580645161290323, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.7661290322580645, 0.4642857142857143, 'gini = 0.0\nsamples = 14\nvalue = [14, 0]'),

Text(0.7661290322580645, 0.75, 'x[11] <= -1.111\ngini = 0.26\nsamples = 13\nvalue = [11, 2]'),

Text(0.7580645161290323, 0.6785714285714286, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.7741935483870968, 0.6785714285714286, 'x[26] <= 0.804\ngini = 0.153\nsamples = 12\nvalue = [11, 1]'),

Text(0.7661290322580645, 0.6071428571428571, 'gini = 0.0\nsamples = 11\nvalue = [11, 0]'),

Text(0.782258064516129, 0.6071428571428571, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.8921370967741935, 0.8214285714285714, 'x[47] <= 0.368\ngini = 0.255\nsamples = 173\nvalue = [147, 26]'),

Text(0.8407258064516129, 0.75, 'x[12] <= 1.46\ngini = 0.123\nsamples = 121\nvalue = [113, 8]'),

Text(0.8185483870967742, 0.6785714285714286, 'x[25] <= -1.036\ngini = 0.085\nsamples = 113\nvalue = [108, 5]'),

Text(0.7983870967741935, 0.6071428571428571, 'x[10] <= 0.709\ngini = 0.42\nsamples = 10\nvalue = [7, 3]'),

Text(0.7903225806451613, 0.5357142857142857, 'x[28] <= -0.326\ngini = 0.375\nsamples = 4\nvalue = [1, 3]'),

Text(0.782258064516129, 0.4642857142857143, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.7983870967741935, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.8064516129032258, 0.5357142857142857, 'gini = 0.0\nsamples = 6\nvalue = [6, 0]'),

Text(0.8387096774193549, 0.6071428571428571, 'x[2] <= 2.404\ngini = 0.038\nsamples = 103\nvalue = [101, 2]'),

Text(0.8225806451612904, 0.5357142857142857, 'x[8] <= -1.733\ngini = 0.02\nsamples = 101\nvalue = [100, 1]'),

Text(0.8145161290322581, 0.4642857142857143, 'x[0] <= -0.142\ngini = 0.32\nsamples = 5\nvalue = [4, 1]'),

Text(0.8064516129032258, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.8225806451612904, 0.39285714285714285, 'gini = 0.0\nsamples = 4\nvalue = [4, 0]'),

Text(0.8306451612903226, 0.4642857142857143, 'gini = 0.0\nsamples = 96\nvalue = [96, 0]'),

Text(0.8548387096774194, 0.5357142857142857, 'x[27] <= -0.464\ngini = 0.5\nsamples = 2\nvalue = [1, 1]'),

Text(0.8467741935483871, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.8629032258064516, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.8629032258064516, 0.6785714285714286, 'x[6] <= -0.221\ngini = 0.469\nsamples = 8\nvalue = [5, 3]'),

Text(0.8548387096774194, 0.6071428571428571, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.8709677419354839, 0.6071428571428571, 'gini = 0.0\nsamples = 5\nvalue = [5, 0]'),

Text(0.9435483870967742, 0.75, 'x[42] <= 0.67\ngini = 0.453\nsamples = 52\nvalue = [34, 18]'),

Text(0.9032258064516129, 0.6785714285714286, 'x[5] <= -1.454\ngini = 0.252\nsamples = 27\nvalue = [23, 4]'),

Text(0.8870967741935484, 0.6071428571428571, 'x[14] <= -0.743\ngini = 0.444\nsamples = 3\nvalue = [1, 2]'),

Text(0.8790322580645161, 0.5357142857142857, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.8951612903225806, 0.5357142857142857, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.9193548387096774, 0.6071428571428571, 'x[24] <= 1.188\ngini = 0.153\nsamples = 24\nvalue = [22, 2]'),

Text(0.9112903225806451, 0.5357142857142857, 'gini = 0.0\nsamples = 21\nvalue = [21, 0]'),

Text(0.9274193548387096, 0.5357142857142857, 'x[21] <= 1.031\ngini = 0.444\nsamples = 3\nvalue = [1, 2]'),

Text(0.9193548387096774, 0.4642857142857143, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.9354838709677419, 0.4642857142857143, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.9838709677419355, 0.6785714285714286, 'x[24] <= -0.214\ngini = 0.493\nsamples = 25\nvalue = [11, 14]'),

Text(0.9758064516129032, 0.6071428571428571, 'x[8] <= 1.094\ngini = 0.457\nsamples = 17\nvalue = [11, 6]'),

Text(0.967741935483871, 0.5357142857142857, 'x[11] <= 0.811\ngini = 0.337\nsamples = 14\nvalue = [11, 3]'),

Text(0.9516129032258065, 0.4642857142857143, 'x[2] <= -0.944\ngini = 0.165\nsamples = 11\nvalue = [10, 1]'),

Text(0.9435483870967742, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]'),

Text(0.9596774193548387, 0.39285714285714285, 'gini = 0.0\nsamples = 10\nvalue = [10, 0]'),

Text(0.9838709677419355, 0.4642857142857143, 'x[14] <= 0.351\ngini = 0.444\nsamples = 3\nvalue = [1, 2]'),

Text(0.9758064516129032, 0.39285714285714285, 'gini = 0.0\nsamples = 1\nvalue = [1, 0]'),

Text(0.9919354838709677, 0.39285714285714285, 'gini = 0.0\nsamples = 2\nvalue = [0, 2]'),

Text(0.9838709677419355, 0.5357142857142857, 'gini = 0.0\nsamples = 3\nvalue = [0, 3]'),

Text(0.9919354838709677, 0.6071428571428571, 'gini = 0.0\nsamples = 8\nvalue = [0, 8]')]

In [111…



**from** sklearn.model\_selection **import** GridSearchCV

parameter**=**{

'criterion':['gini','entropy'],

'splitter':['best','random'],

'max\_depth':[1,2,3,4,5],

'max\_features':['auto', 'sqrt', 'log2']

}

grid\_search**=**GridSearchCV(estimator**=**dtc,param\_grid**=**parameter,cv**=**5,scoring**=**"accuracy")

grid\_search**.**fit(x\_train,y\_train)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\model\_selection\\_validation.py:425: FitFailedWarning:

100 fits failed out of a total of 300.

The score on these train-test partitions for these parameters will be set to nan.

Below are more details about the failures:

100 fits failed with the following error:

If these failures are not expected, you can try to debug them by setting error\_score='raise'.

Traceback (most recent call last):

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\model\_selection\\_validation.py", line 732, in \_fit\_and\_score

estimator.fit(X\_train, y\_train, \*\*fit\_params)

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py", line 1144, in wrapper

estimator.\_validate\_params()

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py", line 637, in \_validate\_params

validate\_parameter\_constraints(

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\utils\\_param\_validation.py", line 95, in validate\_parameter\_constraints

raise InvalidParameterError(

sklearn.utils.\_param\_validation.InvalidParameterError: The 'max\_features' parameter of DecisionTreeClassifier must be an int in the range [1, inf),

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\model\_selection\\_search.py:976: UserWarning: One or more of the test scores are non-finite: [

nan nan 0.83478096 0.83770779 0.83770779 0.83770779

a float in the range (0.0, 1.0], a str among {'log2', 'sqrt'} or None. Got 'auto' instead.

warnings.warn(some\_fits\_failed\_message, FitFailedWarning)

nan nan 0.84159129 0.83770779 0.82897466 0.83770779

nan nan 0.83965427 0.83284869 0.8513095 0.83769832

nan nan 0.84353777 0.83966375 0.82990765 0.83576604

nan nan 0.83770779 0.83770779 0.83770779 0.83770779

nan nan 0.81923277 0.82992186 0.83672744 0.82022259

nan nan 0.83185413 0.83479517 0.83770779 0.83478096

nan nan 0.83479517 0.83866919 0.83576131 0.83576604

nan nan 0.84354724 0.8396448 0.84741179 0.84253848

▸ **GridSearchCV**

▸ **estimator: DecisionTreeClassifier**

▸ DecisionTreeClassifier

nan nan 0.82703291 0.83089273 0.83673692 0.83284395]

warnings.warn(

grid\_search**.**best\_params\_

{'criterion': 'gini',

'max\_features': 'log2',

'max\_depth': 3,

'splitter': 'best'}

dtc\_cv**=**DecisionTreeClassifier(criterion**=** 'entropy',

max\_depth**=**3,

dtc\_cv**.**fit(x\_train,y\_train)

▾ DecisionTreeClassifier

DecisionTreeClassifier(criterion='entropy', max\_depth=3, max\_features='sqrt')

pred**=**dtc\_cv**.**predict(x\_test)

print(classification\_report(y\_test,pred))

max\_features**=**'sqrt',

splitter**=**'best')

In [112…

In [114…

Out[114]:

In [115…

Out[115]:

In [116…

Out[116]:

In [117…

In [118…

precision recall f1-score support

0 0.87 0.96 0.91 371

1 0.52 0.21 0.30 70

accuracy 0.84 441

macro avg 0.69 0.59 0.61 441

weighted avg 0.81 0.84 0.82 441

We can notice that our accuracy have improved after performing hyperparameter tuning

Random Forest

In [119… from sklearn.ensemble import RandomForestClassifier

rfc=RandomForestClassifier()

In [120… forest\_params = [{'max\_depth': list(range(10, 15)), 'max\_features': list(range(0,14))}]

In [121… rfc\_cv= GridSearchCV(rfc,param\_grid=forest\_params,cv=10,scoring="accuracy")

In [122… rfc\_cv.fit(x\_train,y\_train)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

Please change the shape of y to (n\_samples,), for example using ravel().

return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

Please change the shape of y to (n\_samples,), for example using ravel().

return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

Please change the shape of y to (n\_samples,), for example using ravel().

return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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return fit\_method(estimator, \*args, \*\*kwargs)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\model\_selection\\_validation.py:425: FitFailedWarning:

50 fits failed out of a total of 700.

The score on these train-test partitions for these parameters will be set to nan.

If these failures are not expected, you can try to debug them by setting error\_score='raise'.

Below are more details about the failures:

50 fits failed with the following error:

Traceback (most recent call last):

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\model\_selection\\_validation.py", line 732, in \_fit\_and\_score

estimator.fit(X\_train, y\_train, \*\*fit\_params)

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py", line 1144, in wrapper

estimator.\_validate\_params()

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py", line 637, in \_validate\_params

validate\_parameter\_constraints(

File "C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\utils\\_param\_validation.py", line 95, in validate\_parameter\_constraints

raise InvalidParameterError(

sklearn.utils.\_param\_validation.InvalidParameterError: The 'max\_features' parameter of RandomForestClassifier must be an int in the range [1, inf),

a float in the range (0.0, 1.0], a str among {'log2', 'sqrt'} or None. Got 0 instead.

warnings.warn(some\_fits\_failed\_message, FitFailedWarning)

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\model\_selection\\_search.py:976: UserWarning: One or more of the test scores are non-finite: [

nan 0.84353703 0.84936227 0.85031411 0.85227489 0.85130402

0.85034266 0.84934323 0.84935275 0.85907101 0.85420712 0.85130402

0.85322673 0.85031411 nan 0.84743004 0.84548829 0.85033314

0.85227489 0.85227489 0.85519703 0.85130402 0.85421664 0.85518751

0.85227489 0.85032362 0.85130402 0.85908053 nan 0.84353703

0.8483914 0.85422616 0.8532648 0.85033314 0.85713878 0.85517799

0.85227489 0.85421664 0.85712926 0.847411 0.85227489 0.85127546

nan 0.84451742 0.84743004 0.85228441 0.85324576 0.85324576

0.85034266 0.85420712 0.85422616 0.85324576 0.85033314 0.85228441

0.85324576 0.85130402 nan 0.84547877 0.85227489 0.84840091

0.85228441 0.85422616 0.85420712 0.85032362 0.85033314 0.8512945

0.85128498 0.85227489 0.85033314 0.85615839]

warnings.warn(

C:\Users\Admin\anaconda3\Lib\site-packages\sklearn\base.py:1151: DataConversionWarning: A column-vector y was passed when a 1d array was expected.

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return fit\_method(estimator, \*args, \*\*kwargs)

Out[122]: ▸ **GridSearchCV**

▸ estimator: RandomForestClassifier

▸ RandomForestClassifier

In [123… pred=rfc\_cv.predict(x\_test)

In [124… print(classification\_report(y\_test,pred))

precision recall f1-score support

0 0.86 0.98 0.92 371

1 0.67 0.17 0.27 70

accuracy 0.85 441

macro avg 0.76 0.58 0.60 441

weighted avg 0.83 0.85 0.82 441

In [125…



rfc\_cv**.**best\_params\_

{'max\_depth': 11, 'max\_features': 13}

Out[125]:

In [ ]: