الجمهورية اليمنية

جامعة إب

كلية العلوم

قسم علوم الحاسوب وتقنية المعلومات

تكليف مقرر

تنقيب بيانات - عملي

Data Mining

المحاضرة الثامنة

عمل الطالب :

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إشراف :

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2024 - 2025

import Library

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.feature_selection import SelectKBest , f_classif
from sklearn.model_selection import train_test_split as tts
from sklearn.preprocessing import MinMaxScaler
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import
accuracy_score,recall_score,f1_score,confusion_matrix,precision_score
from sklearn.tree import plot_tree,export_text
import numpy as np
import pickle as pk
```

Read Data

```
dataset = pd.read_csv('diabetes.csv')
```

Know My Data

```
dataset.shape
```

```
(768, 9)
```

```
dataset.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 768 entries, 0 to 767
Data columns (total 9 columns):
 #   Column                    Non-Null Count  Dtype
---  ------                    --------------  -----
 0   Pregnancies               768 non-null    float64
 1   Glucose                   768 non-null    int64
 2   BloodPressure             768 non-null    int64
 3   SkinThickness             768 non-null    int64
 4   Insulin                   768 non-null    int64
 5   BMI                       768 non-null    float64
 6   DiabetesPedigreeFunction  768 non-null    float64
 7   Age                       768 non-null    int64
 8   Outcome                   768 non-null    int64
dtypes: float64(3), int64(6)
memory usage: 54.1 KB
```

```
dataset.describe()
```

```
       Pregnancies     Glucose  BloodPressure  SkinThickness
Insulin  \
count   768.000000  768.000000     768.000000     768.000000
768.000000
mean      3.845052  120.894531      69.105469      20.536458
79.799479
std       3.369578   31.972618      19.355807      15.952218
115.244002
min       0.000000    0.000000       0.000000       0.000000
0.000000
25%       1.000000   99.000000      62.000000       0.000000
0.000000
50%       3.000000  117.000000      72.000000      23.000000
30.500000
75%       6.000000  140.250000      80.000000      32.000000
127.250000
max      17.000000  199.000000     122.000000      99.000000
846.000000

              BMI  DiabetesPedigreeFunction         Age     Outcome
count  768.000000                768.000000  768.000000  768.000000
mean    31.992578                  0.471876   33.240885    0.348958
std      7.884160                  0.331329   11.760232    0.476951
min      0.000000                  0.078000   21.000000    0.000000
25%     27.300000                  0.243750   24.000000    0.000000
50%     32.000000                  0.372500   29.000000    0.000000
75%     36.600000                  0.626250   41.000000    1.000000
max     67.100000                  2.420000   81.000000    1.000000

dataset.head()

   Pregnancies  Glucose  BloodPressure  SkinThickness  Insulin
BMI  \
0          6.0      148             72             35        0  33.6

1          1.0       85             66             29        0  26.6

2          8.0      183             64              0        0  23.3

3          1.0       89             66             23       94  28.1

4          0.0      137             40             35      168  43.1


   DiabetesPedigreeFunction  Age  Outcome
0                     0.627   50        1
1                     0.351   31        0
2                     0.672   32        1
3                     0.167   21        0
4                     2.288   33        1
```

```
dataset.tail()
```

```
     Pregnancies  Glucose  BloodPressure  SkinThickness  Insulin   BMI
\
763         10.0      101             76             48      180  32.9

764          2.0      122             70             27        0  36.8

765          5.0      121             72             23      112  26.2

766          1.0      126             60              0        0  30.1

767          1.0       93             70             31        0  30.4


     DiabetesPedigreeFunction  Age  Outcome
763                     0.171   63        0
764                     0.340   27        0
765                     0.245   30        0
766                     0.349   47        1
767                     0.315   23        0
```

```
dataset.columns
```

```
Index(['Pregnancies', 'Glucose', 'BloodPressure', 'SkinThickness',
'Insulin',
       'BMI', 'DiabetesPedigreeFunction', 'Age', 'Outcome'],
      dtype='object')
```

```
dataset.isna().sum()
```

```
Pregnancies                 0
Glucose                     0
BloodPressure               0
SkinThickness               0
Insulin                     0
BMI                         0
DiabetesPedigreeFunction    0
Age                         0
Outcome                     0
dtype: int64
```

```
dataset.Pregnancies.unique()
```

```
array([ 6.,  1.,  8.,  0.,  5.,  3., 10.,  2.,  4.,  7.,  9., 11.,
13.,
       15., 17., 12., 14.])
```

```
dataset.Glucose.unique()
```

```
array([148,  85, 183,  89, 137, 116,  78, 115, 197, 125, 110, 168,
139,
```

```
       189, 166, 100, 118, 107, 103, 126,  99, 196, 119, 143, 147,
97,
       145, 117, 109, 158,  88,  92, 122, 138, 102,  90, 111, 180,
133,
       106, 171, 159, 146,  71, 105, 101, 176, 150,  73, 187,  84,
44,
       141, 114,  95, 129,  79,   0,  62, 131, 112, 113,  74,  83,
136,
        80, 123,  81, 134, 142, 144,  93, 163, 151,  96, 155,  76,
160,
       124, 162, 132, 120, 173, 170, 128, 108, 154,  57, 156, 153,
188,
       152, 104,  87,  75, 179, 130, 194, 181, 135, 184, 140, 177,
164,
        91, 165,  86, 193, 191, 161, 167,  77, 182, 157, 178,  61,
98,
       127,  82,  72, 172,  94, 175, 195,  68, 186, 198, 121,  67,
174,
       199,  56, 169, 149,  65, 190], dtype=int64)
```

```
dataset.BloodPressure.unique()
```

```
array([ 72,  66,  64,  40,  74,  50,   0,  70,  96,  92,  80,  60,
84,
        30,  88,  90,  94,  76,  82,  75,  58,  78,  68, 110,  56,
62,
        85,  86,  48,  44,  65, 108,  55, 122,  54,  52,  98, 104,
95,
        46, 102, 100,  61,  24,  38, 106, 114], dtype=int64)
```

```
dataset.SkinThickness.unique()
```

```
array([35, 29,  0, 23, 32, 45, 19, 47, 38, 30, 41, 33, 26, 15, 36, 11,
31,
       37, 42, 25, 18, 24, 39, 27, 21, 34, 10, 60, 13, 20, 22, 28, 54,
40,
       51, 56, 14, 17, 50, 44, 12, 46, 16,  7, 52, 43, 48,  8, 49, 63,
99],
      dtype=int64)
```

```
dataset.Insulin.unique()
```

```
array([  0,  94, 168,  88, 543, 846, 175, 230,  83,  96, 235, 146,
115,
       140, 110, 245,  54, 192, 207,  70, 240,  82,  36,  23, 300,
342,
       304, 142, 128,  38, 100,  90, 270,  71, 125, 176,  48,  64,
228,
        76, 220,  40, 152,  18, 135, 495,  37,  51,  99, 145, 225,
49,
        50,  92, 325,  63, 284, 119, 204, 155, 485,  53, 114, 105,
```

```
285,
       156,  78, 130,  55,  58, 160, 210, 318,  44, 190, 280,  87,
271,
       129, 120, 478,  56,  32, 744, 370,  45, 194, 680, 402, 258,
375,
       150,  67,  57, 116, 278, 122, 545,  75,  74, 182, 360, 215,
184,
        42, 132, 148, 180, 205,  85, 231,  29,  68,  52, 255, 171,
73,
       108,  43, 167, 249, 293,  66, 465,  89, 158,  84,  72,  59,
81,
       196, 415, 275, 165, 579, 310,  61, 474, 170, 277,  60,  14,
95,
       237, 191, 328, 250, 480, 265, 193,  79,  86, 326, 188, 106,
65,
       166, 274,  77, 126, 330, 600, 185,  25,  41, 272, 321, 144,
15,
       183,  91,  46, 440, 159, 540, 200, 335, 387,  22, 291, 392,
178,
       127, 510,  16, 112], dtype=int64)
```

```
dataset.BMI.unique()
```

```
array([33.6, 26.6, 23.3, 28.1, 43.1, 25.6, 31. , 35.3, 30.5,  0. ,
37.6,
       38. , 27.1, 30.1, 25.8, 30. , 45.8, 29.6, 43.3, 34.6, 39.3,
35.4,
       39.8, 29. , 36.6, 31.1, 39.4, 23.2, 22.2, 34.1, 36. , 31.6,
24.8,
       19.9, 27.6, 24. , 33.2, 32.9, 38.2, 37.1, 34. , 40.2, 22.7,
45.4,
       27.4, 42. , 29.7, 28. , 39.1, 19.4, 24.2, 24.4, 33.7, 34.7, 23.
,
       37.7, 46.8, 40.5, 41.5, 25. , 25.4, 32.8, 32.5, 42.7, 19.6,
28.9,
       28.6, 43.4, 35.1, 32. , 24.7, 32.6, 43.2, 22.4, 29.3, 24.6,
48.8,
       32.4, 38.5, 26.5, 19.1, 46.7, 23.8, 33.9, 20.4, 28.7, 49.7, 39.
,
       26.1, 22.5, 39.6, 29.5, 34.3, 37.4, 33.3, 31.2, 28.2, 53.2,
34.2,
       26.8, 55. , 42.9, 34.5, 27.9, 38.3, 21.1, 33.8, 30.8, 36.9,
39.5,
       27.3, 21.9, 40.6, 47.9, 50. , 25.2, 40.9, 37.2, 44.2, 29.9,
31.9,
       28.4, 43.5, 32.7, 67.1, 45. , 34.9, 27.7, 35.9, 22.6, 33.1,
30.4,
       52.3, 24.3, 22.9, 34.8, 30.9, 40.1, 23.9, 37.5, 35.5, 42.8,
42.6,
       41.8, 35.8, 37.8, 28.8, 23.6, 35.7, 36.7, 45.2, 44. , 46.2, 35.
```

```
,
       43.6, 44.1, 18.4, 29.2, 25.9, 32.1, 36.3, 40. , 25.1, 27.5,
45.6,
       27.8, 24.9, 25.3, 37.9, 27. , 26. , 38.7, 20.8, 36.1, 30.7,
32.3,
       52.9, 21. , 39.7, 25.5, 26.2, 19.3, 38.1, 23.5, 45.5, 23.1,
39.9,
       36.8, 21.8, 41. , 42.2, 34.4, 27.2, 36.5, 29.8, 39.2, 38.4,
36.2,
       48.3, 20. , 22.3, 45.7, 23.7, 22.1, 42.1, 42.4, 18.2, 26.4,
45.3,
       37. , 24.5, 32.2, 59.4, 21.2, 26.7, 30.2, 46.1, 41.3, 38.8,
35.2,
       42.3, 40.7, 46.5, 33.5, 37.3, 30.3, 26.3, 21.7, 36.4, 28.5,
26.9,
       38.6, 31.3, 19.5, 20.1, 40.8, 23.4, 28.3, 38.9, 57.3, 35.6,
49.6,
       44.6, 24.1, 44.5, 41.2, 49.3, 46.3])
```

```
dataset.DiabetesPedigreeFunction.unique()
```

```
array([0.627, 0.351, 0.672, 0.167, 2.288, 0.201, 0.248, 0.134, 0.158,
       0.232, 0.191, 0.537, 1.441, 0.398, 0.587, 0.484, 0.551, 0.254,
       0.183, 0.529, 0.704, 0.388, 0.451, 0.263, 0.205, 0.257, 0.487,
       0.245, 0.337, 0.546, 0.851, 0.267, 0.188, 0.512, 0.966, 0.42 ,
       0.665, 0.503, 1.39 , 0.271, 0.696, 0.235, 0.721, 0.294, 1.893,
       0.564, 0.586, 0.344, 0.305, 0.491, 0.526, 0.342, 0.467, 0.718,
       0.962, 1.781, 0.173, 0.304, 0.27 , 0.699, 0.258, 0.203, 0.855,
       0.845, 0.334, 0.189, 0.867, 0.411, 0.583, 0.231, 0.396, 0.14 ,
       0.391, 0.37 , 0.307, 0.102, 0.767, 0.237, 0.227, 0.698, 0.178,
       0.324, 0.153, 0.165, 0.443, 0.261, 0.277, 0.761, 0.255, 0.13 ,
       0.323, 0.356, 0.325, 1.222, 0.179, 0.262, 0.283, 0.93 , 0.801,
       0.207, 0.287, 0.336, 0.247, 0.199, 0.543, 0.192, 0.588, 0.539,
       0.22 , 0.654, 0.223, 0.759, 0.26 , 0.404, 0.186, 0.278, 0.496,
       0.452, 0.403, 0.741, 0.361, 1.114, 0.457, 0.647, 0.088, 0.597,
       0.532, 0.703, 0.159, 0.268, 0.286, 0.318, 0.272, 0.572, 0.096,
       1.4  , 0.218, 0.085, 0.399, 0.432, 1.189, 0.687, 0.137, 0.637,
       0.833, 0.229, 0.817, 0.204, 0.368, 0.743, 0.722, 0.256, 0.709,
       0.471, 0.495, 0.18 , 0.542, 0.773, 0.678, 0.719, 0.382, 0.319,
       0.19 , 0.956, 0.084, 0.725, 0.299, 0.244, 0.745, 0.615, 1.321,
       0.64 , 0.142, 0.374, 0.383, 0.578, 0.136, 0.395, 0.187, 0.905,
       0.15 , 0.874, 0.236, 0.787, 0.407, 0.605, 0.151, 0.289, 0.355,
       0.29 , 0.375, 0.164, 0.431, 0.742, 0.514, 0.464, 1.224, 1.072,
       0.805, 0.209, 0.666, 0.101, 0.198, 0.652, 2.329, 0.089, 0.645,
       0.238, 0.394, 0.293, 0.479, 0.686, 0.831, 0.582, 0.446, 0.402,
       1.318, 0.329, 1.213, 0.427, 0.282, 0.143, 0.38 , 0.284, 0.249,
       0.926, 0.557, 0.092, 0.655, 1.353, 0.612, 0.2  , 0.226, 0.997,
       0.933, 1.101, 0.078, 0.24 , 1.136, 0.128, 0.422, 0.251, 0.677,
       0.296, 0.454, 0.744, 0.881, 0.28 , 0.259, 0.619, 0.808, 0.34 ,
       0.434, 0.757, 0.613, 0.692, 0.52 , 0.412, 0.84 , 0.839, 0.156,
```

```
       0.215, 0.326, 1.391, 0.875, 0.313, 0.433, 0.626, 1.127, 0.315,
       0.345, 0.129, 0.527, 0.197, 0.731, 0.148, 0.123, 0.127, 0.122,
       1.476, 0.166, 0.932, 0.343, 0.893, 0.331, 0.472, 0.673, 0.389,
       0.485, 0.349, 0.279, 0.346, 0.252, 0.243, 0.58 , 0.559, 0.302,
       0.569, 0.378, 0.385, 0.499, 0.306, 0.234, 2.137, 1.731, 0.545,
       0.225, 0.816, 0.528, 0.509, 1.021, 0.821, 0.947, 1.268, 0.221,
       0.66 , 0.239, 0.949, 0.444, 0.463, 0.803, 1.6  , 0.944, 0.196,
       0.241, 0.161, 0.135, 0.376, 1.191, 0.702, 0.674, 1.076, 0.534,
       1.095, 0.554, 0.624, 0.219, 0.507, 0.561, 0.421, 0.516, 0.264,
       0.328, 0.233, 0.108, 1.138, 0.147, 0.727, 0.435, 0.497, 0.23 ,
       0.955, 2.42 , 0.658, 0.33 , 0.51 , 0.285, 0.415, 0.381, 0.832,
       0.498, 0.212, 0.364, 1.001, 0.46 , 0.733, 0.416, 0.705, 1.022,
       0.269, 0.6  , 0.571, 0.607, 0.17 , 0.21 , 0.126, 0.711, 0.466,
       0.162, 0.419, 0.63 , 0.365, 0.536, 1.159, 0.629, 0.292, 0.145,
       1.144, 0.174, 0.547, 0.163, 0.738, 0.314, 0.968, 0.409, 0.297,
       0.525, 0.154, 0.771, 0.107, 0.493, 0.717, 0.917, 0.501, 1.251,
       0.735, 0.804, 0.661, 0.549, 0.825, 0.423, 1.034, 0.16 , 0.341,
       0.68 , 0.591, 0.3  , 0.121, 0.502, 0.401, 0.601, 0.748, 0.338,
       0.43 , 0.892, 0.813, 0.693, 0.575, 0.371, 0.206, 0.417, 1.154,
       0.925, 0.175, 1.699, 0.682, 0.194, 0.4  , 0.1  , 1.258, 0.482,
       0.138, 0.593, 0.878, 0.157, 1.282, 0.141, 0.246, 1.698, 1.461,
       0.347, 0.362, 0.393, 0.144, 0.732, 0.115, 0.465, 0.649, 0.871,
       0.149, 0.695, 0.303, 0.61 , 0.73 , 0.447, 0.455, 0.133, 0.155,
       1.162, 1.292, 0.182, 1.394, 0.217, 0.631, 0.88 , 0.614, 0.332,
       0.366, 0.181, 0.828, 0.335, 0.856, 0.886, 0.439, 0.253, 0.598,
       0.904, 0.483, 0.565, 0.118, 0.177, 0.176, 0.295, 0.441, 0.352,
       0.826, 0.97 , 0.595, 0.317, 0.265, 0.646, 0.426, 0.56 , 0.515,
       0.453, 0.785, 0.734, 1.174, 0.488, 0.358, 1.096, 0.408, 1.182,
       0.222, 1.057, 0.766, 0.171])
```

```
dataset.Age.unique()
```

```
array([50, 31, 32, 21, 33, 30, 26, 29, 53, 54, 34, 57, 59, 51, 27, 41,
43,
       22, 38, 60, 28, 45, 35, 46, 56, 37, 48, 40, 25, 24, 58, 42, 44,
39,
       36, 23, 61, 69, 62, 55, 65, 47, 52, 66, 49, 63, 67, 72, 81, 64,
70,
       68], dtype=int64)
```

```
dataset.Outcome.unique()
```

```
array([1, 0], dtype=int64)
```

```
dataset.duplicated().sum()
```

```
0
```

Split Data to Features and Target

```
X = dataset.iloc[:,:-1]
Y = dataset.iloc[:,-1]

Y.unique()
```

```
array([1, 0], dtype=int64)
```

```
value_counts = Y.value_counts()

value_counts
```

```
Outcome
0    500
1    268
Name: count, dtype: int64
```

colors = ['#4ECDC4','#FF6B6B'] plt.bar(value_counts.index,value_counts.values,color=colors) plt.title('Employee Classes') plt.xlabel('Classes') plt.xticks(ticks=[0, 1],labels=['Class 0', 'Class 1'],fontsize=12) plt.ylabel('Count') plt.show()

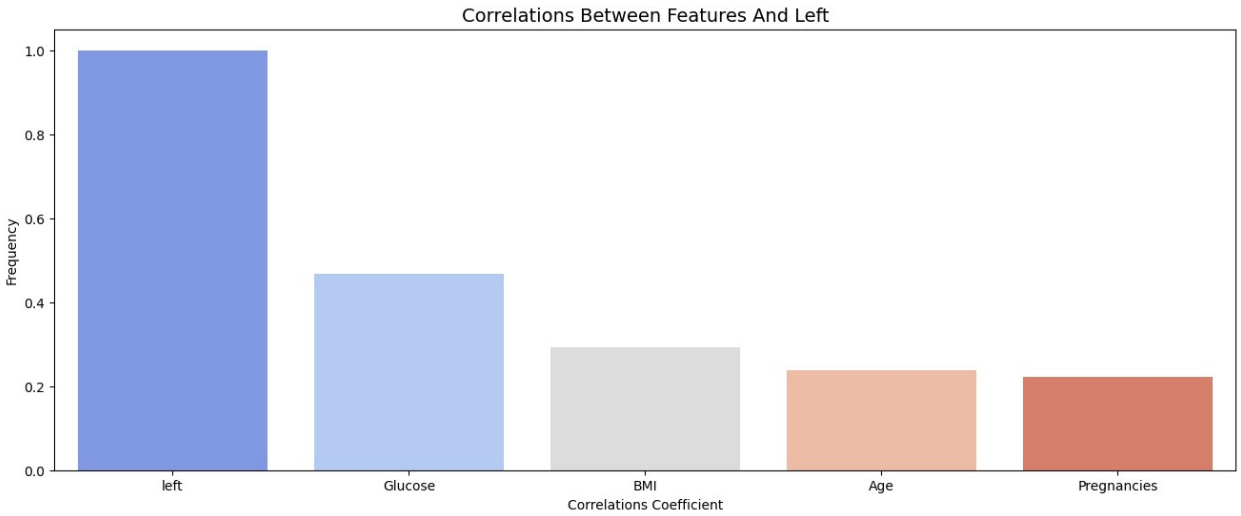
Feature Selection

```
select = SelectKBest(score_func=f_classif,k=4)
best_features = select.fit_transform(X,Y)
best_features = pd.DataFrame(best_features,columns =
X.columns[select.get_support()])
best_features.head()
```

```
   Pregnancies  Glucose   BMI   Age
0          6.0    148.0  33.6  50.0
1          1.0     85.0  26.6  31.0
2          8.0    183.0  23.3  32.0
3          1.0     89.0  28.1  21.0
4          0.0    137.0  43.1  33.0
```

```
mydata = best_features.copy()
mydata['left'] = Y
correlation_matrix = mydata.corr()
correlation_matrix_left =
correlation_matrix.left.sort_values(ascending = False)
plt.figure(figsize = (16,6))
sns.barplot(x = correlation_matrix_left.index,y =
correlation_matrix_left. values,palette =  'coolwarm'  ,hue =
correlation_matrix_left.index,legend = False)
plt.title('Correlations Between Features And Left',fontsize=14)
plt.xlabel("Correlations Coefficient")
```

```
plt.ylabel('Frequency')
plt.show()
```



Split Dataset Train and Test

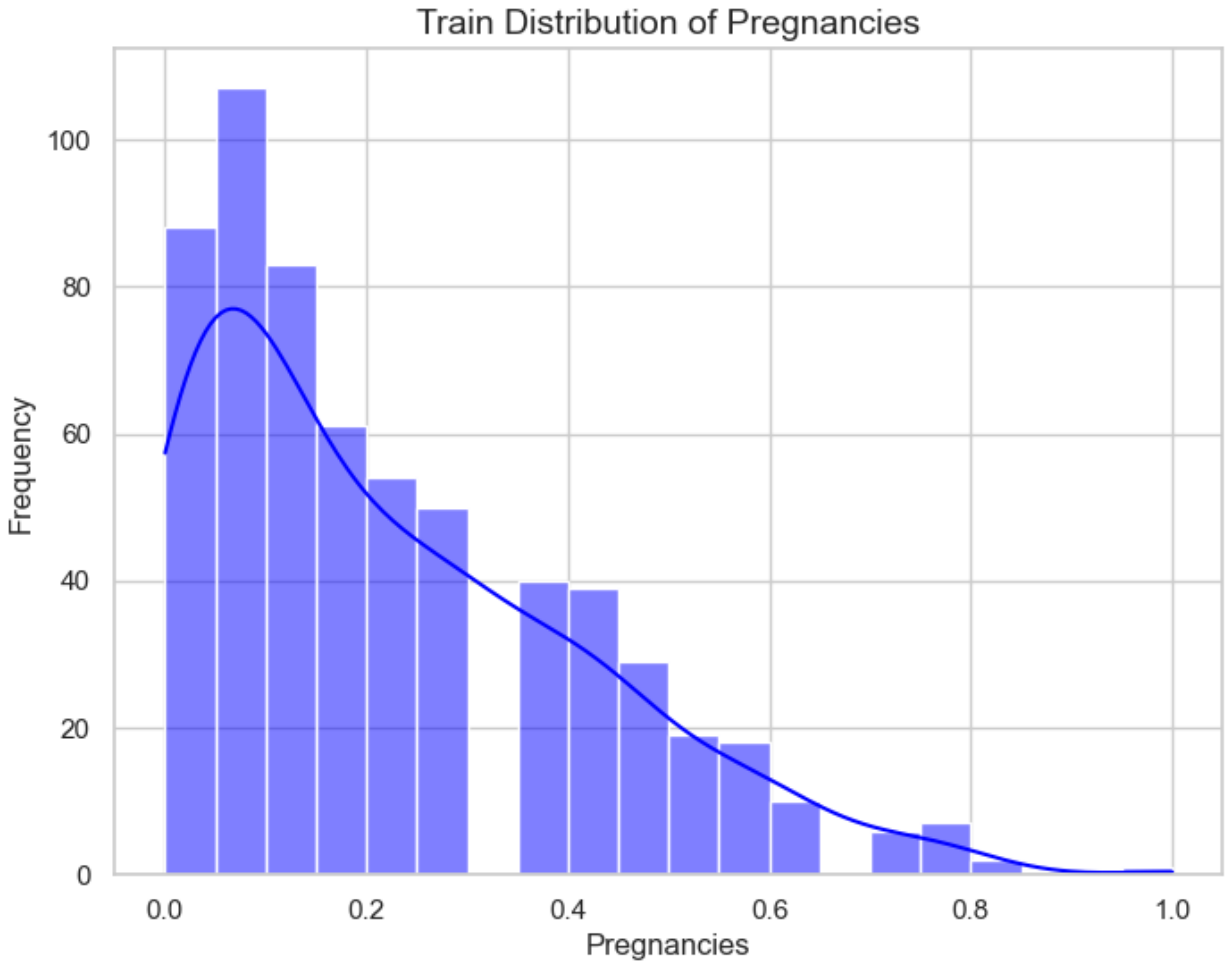
```
x_train,x_test,y_train,y_test=tts(best_features,Y,test_size=.20,random
_state=30,shuffle=True)
```

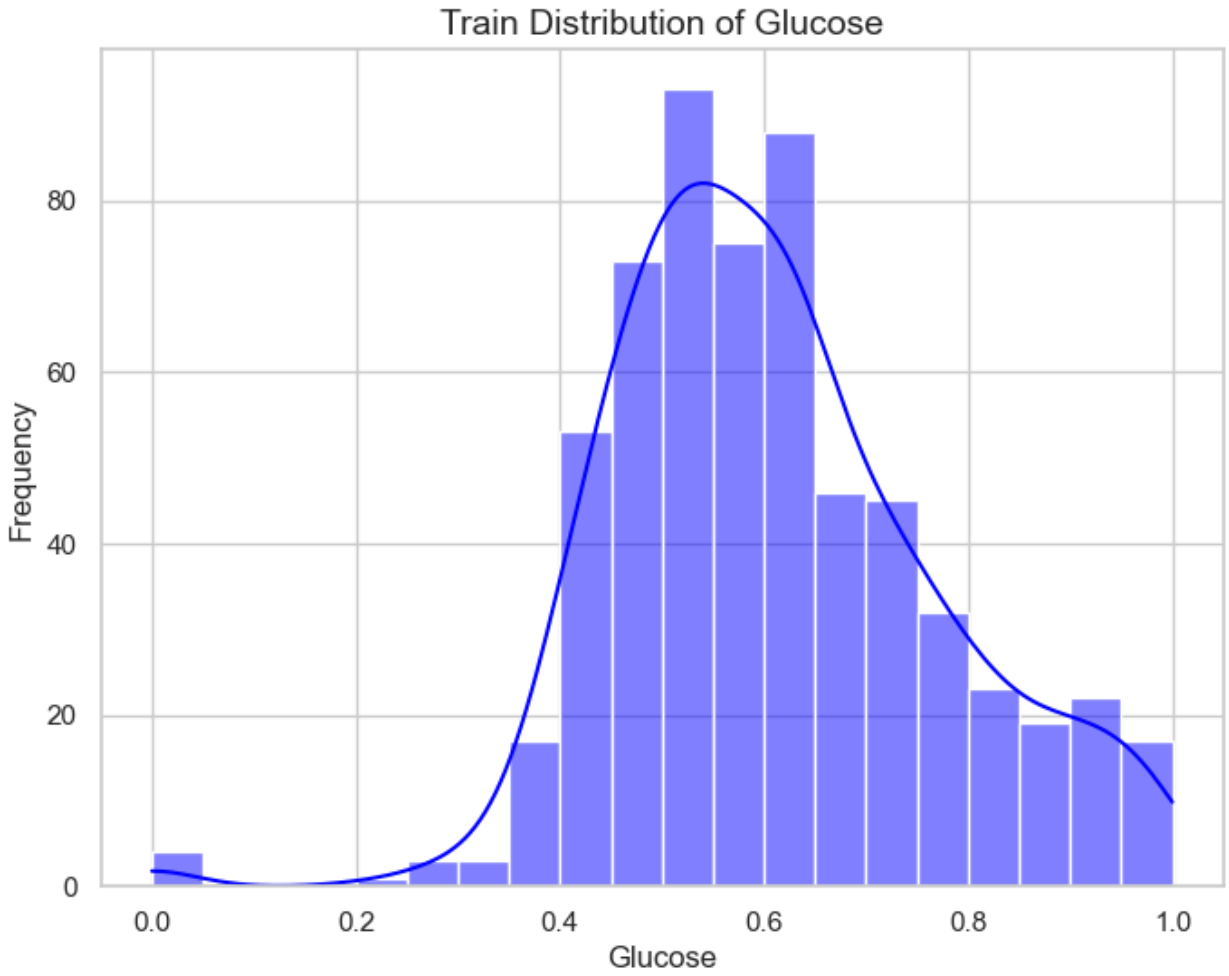
Feature Scaling

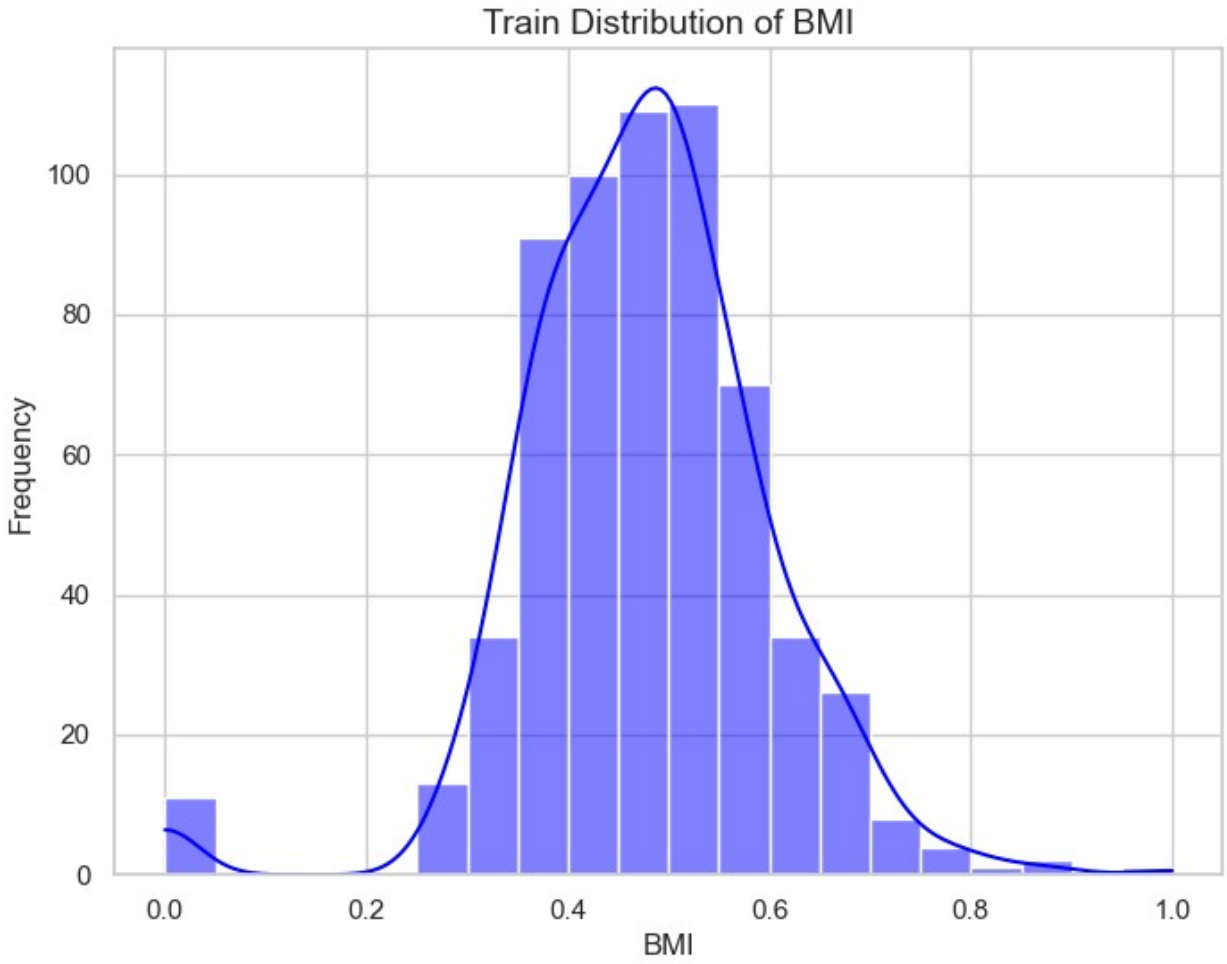
```
scaler=MinMaxScaler(feature_range=(0,1))
x_train_scalled=scaler.fit_transform(x_train)
x_test_scalled=scaler.fit_transform(x_test)
x_train_scalled=pd.DataFrame(x_train_scalled,columns=X.columns[select.
get_support()])
x_test_scalled=pd.DataFrame(x_test_scalled,columns=X.columns[select.ge
t_support()])
```

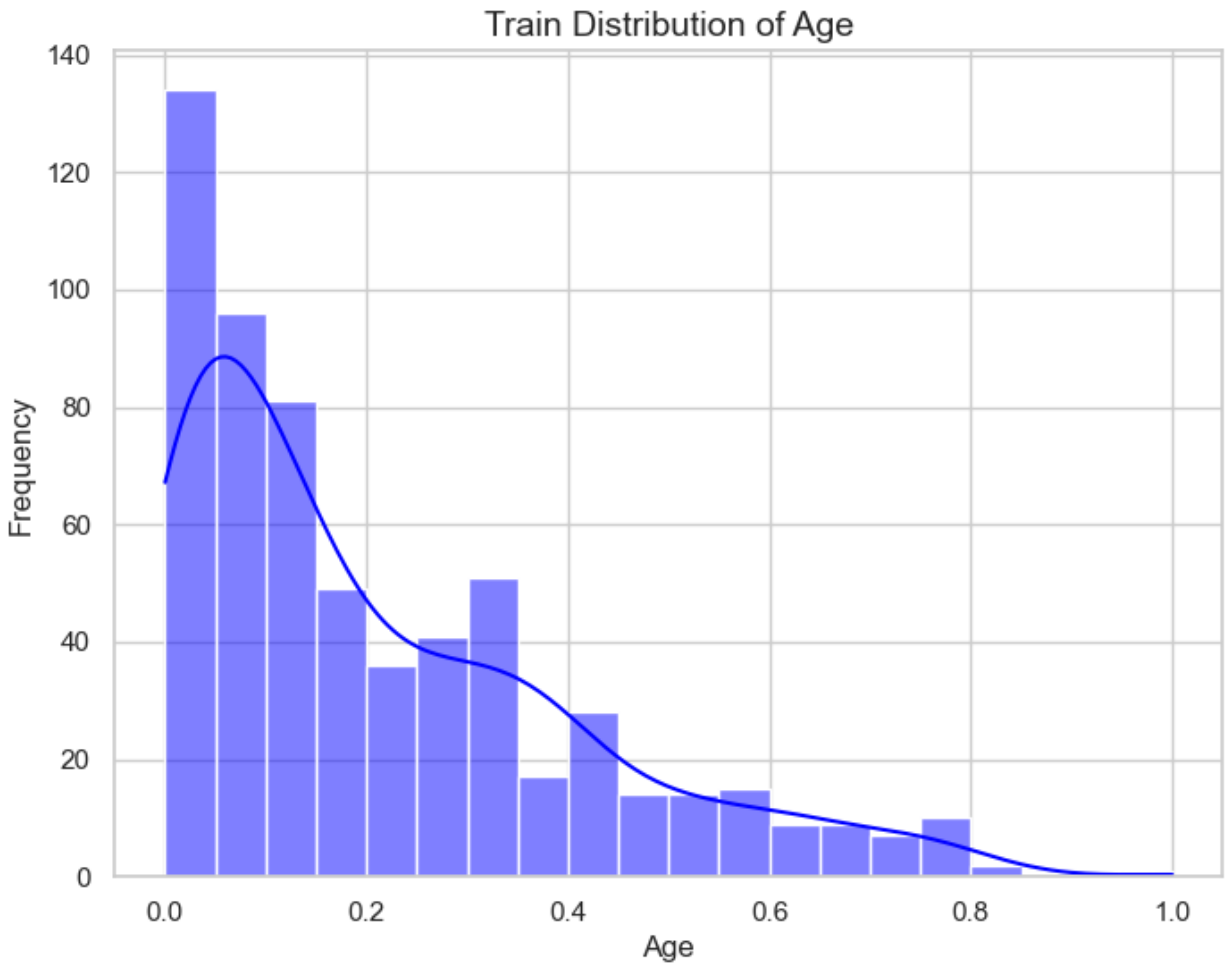
Data Columns Visualization

```
sns.set(style='whitegrid')
for column in x_train_scalled.columns:
   plt.figure(figsize=(8,6))
   sns.histplot(x_train_scalled[column],kde=True,bins=20,color='blue')
   plt.title(f'Train Distribution of {column}',fontsize=14)
   plt.xlabel(column)
   plt.ylabel('Frequency')
   plt.show()
```

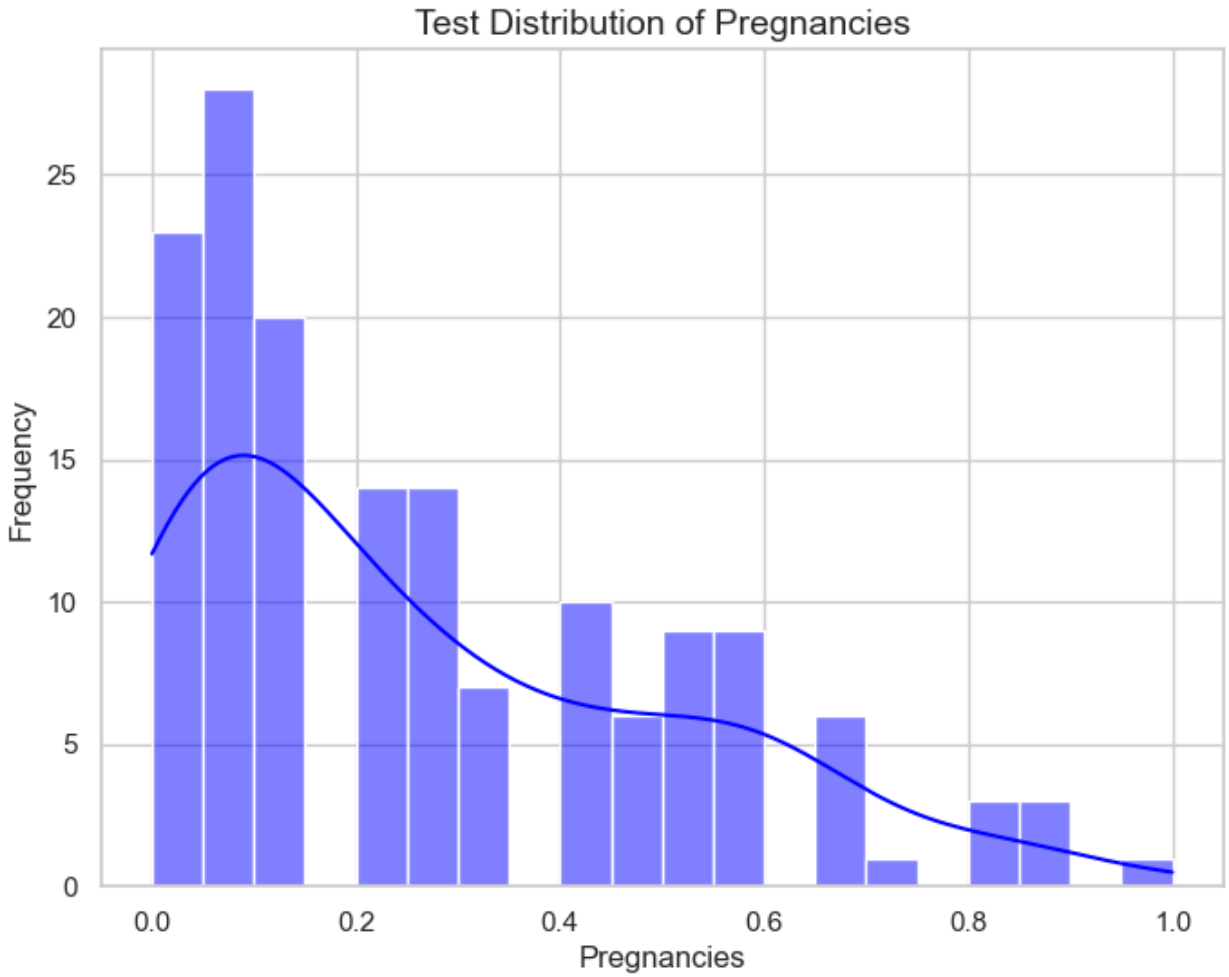

Train Distribution of Pregnancies
Frequency
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
Pregnancies

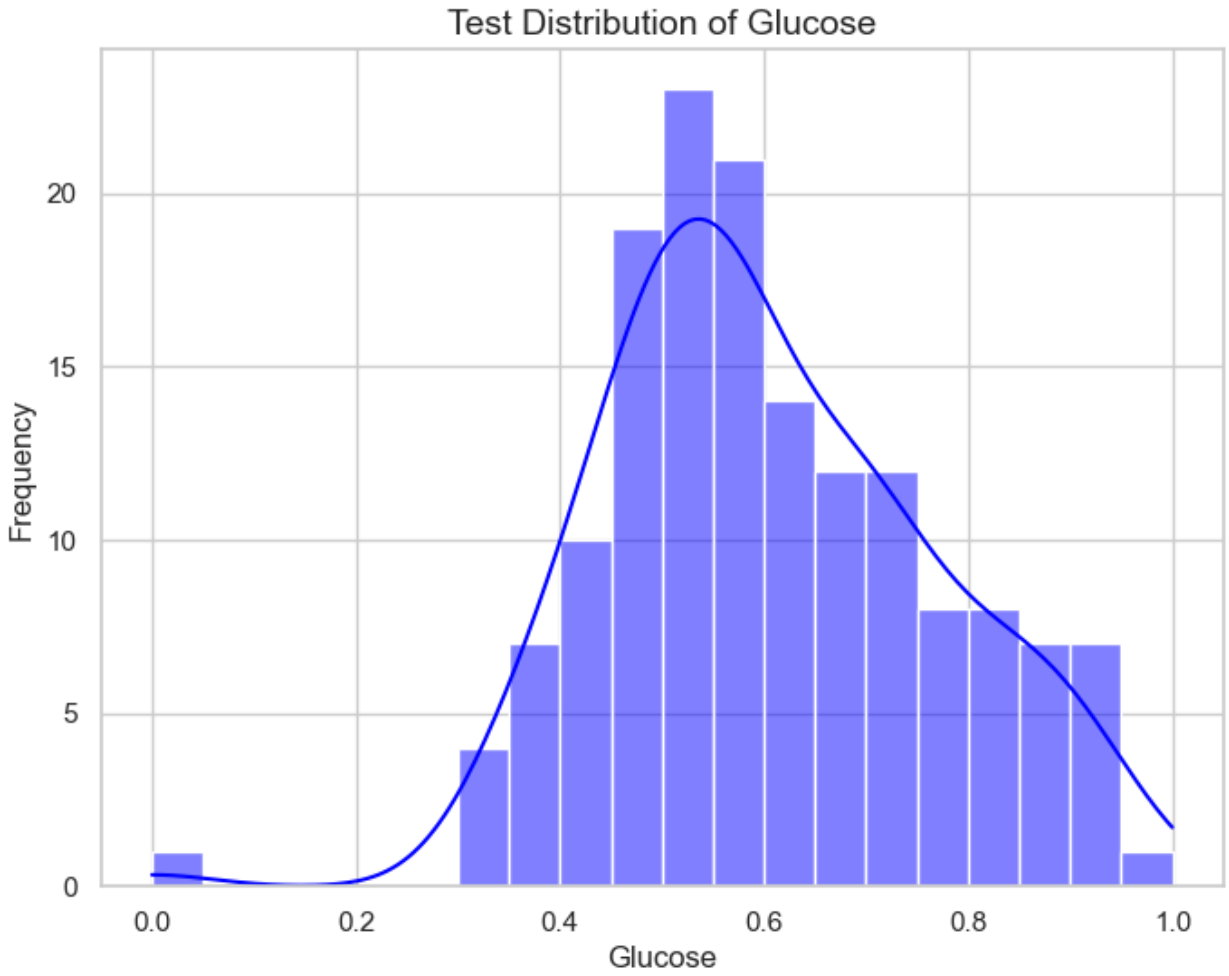

Train Distribution of Glucose
Frequency
0
20
40
60
80
0.0
0.2
0.4
0.6
0.8
1.0
Glucose

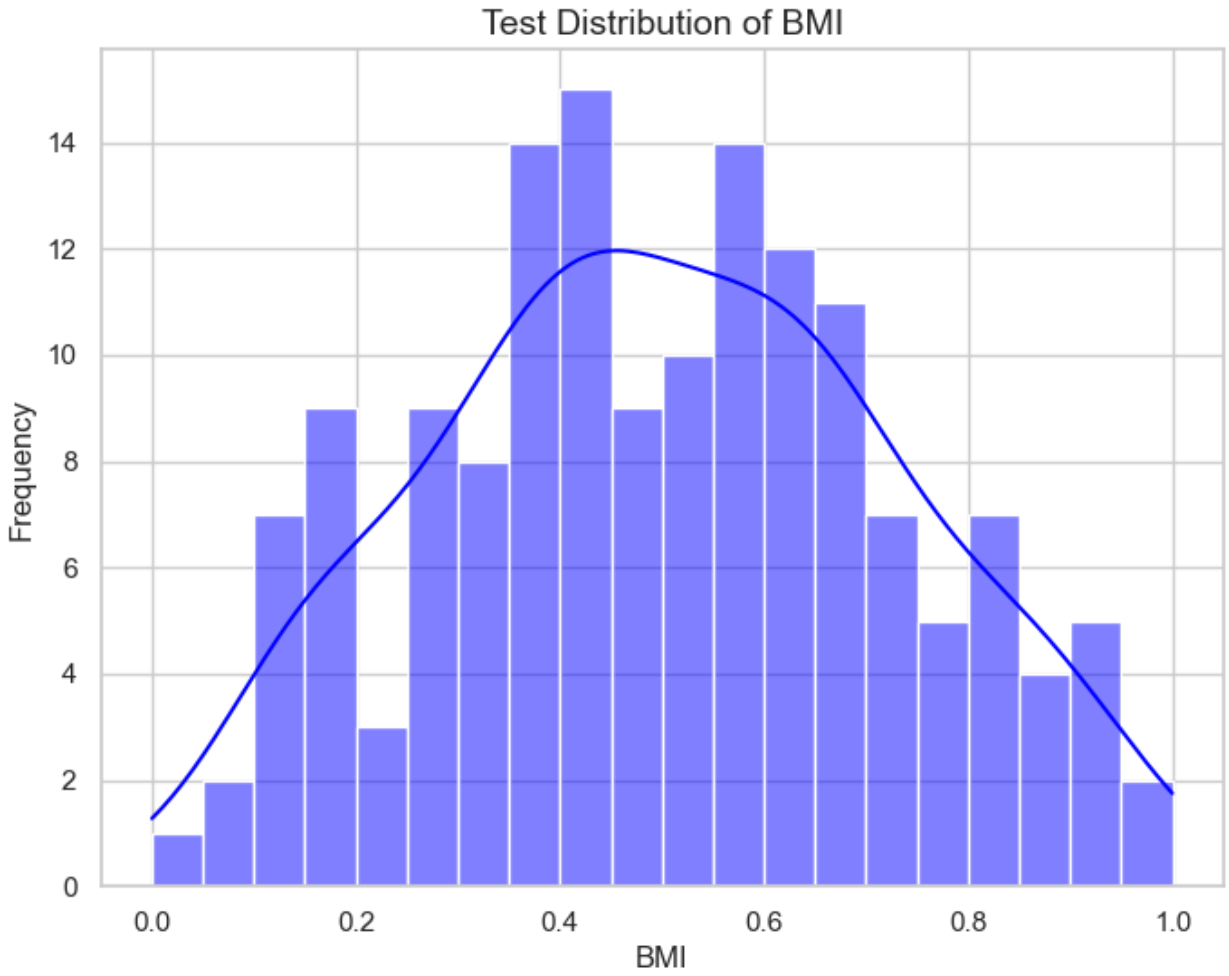

Train Distribution of BMI
Frequency
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
BMI

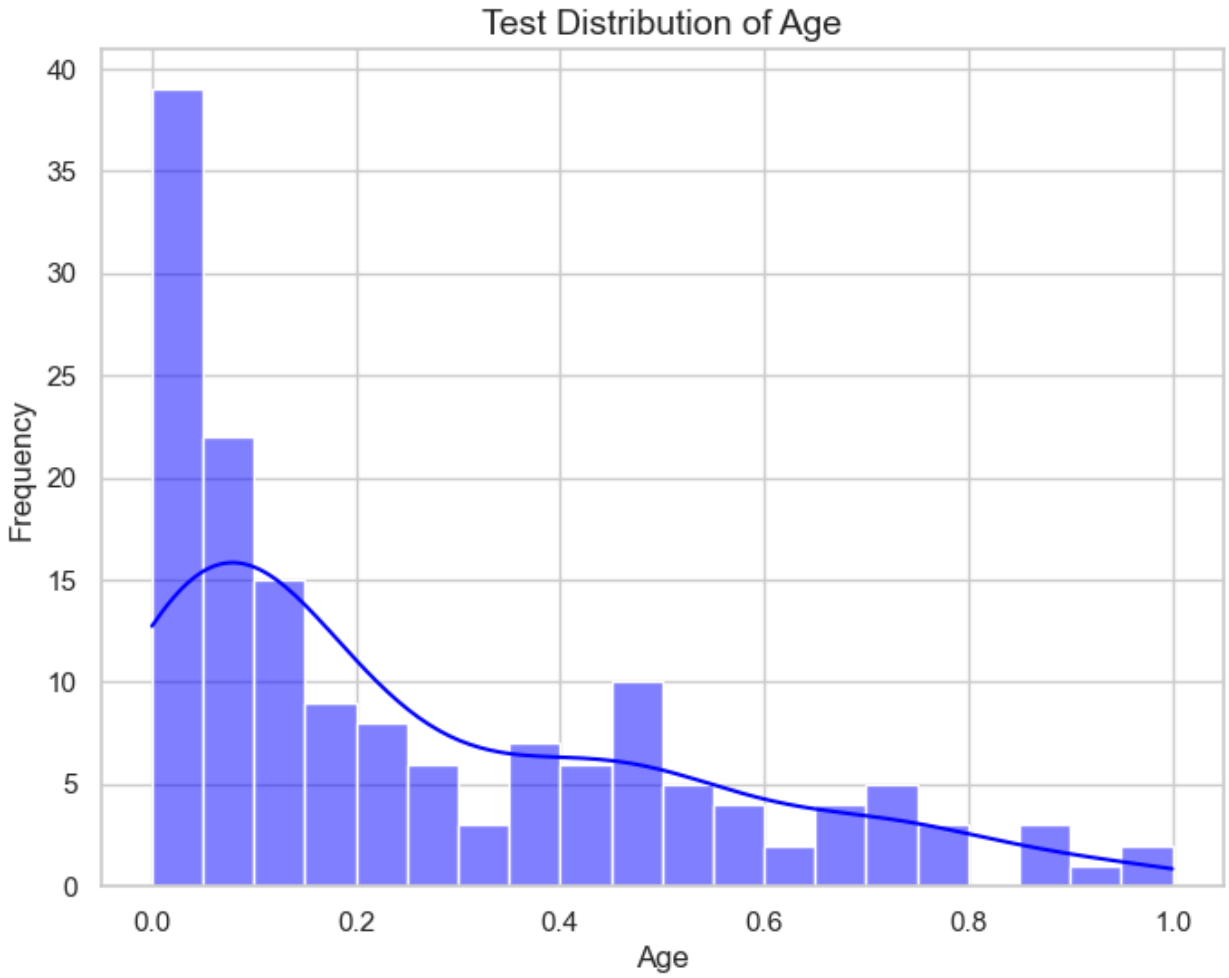



```
sns.set(style ='whitegrid')
for column in x_test_scalled.columns:
    plt.figure(figsize = (8,6))
    sns.histplot(x_test_scalled[column],kde = True,bins = 20 , color =
'blue')
    plt.title(f'Test Distribution of {column}',fontsize = 14)
    plt.xlabel(column)
    plt.ylabel('Frequency')
    plt.show()
```


Test Distribution of Pregnancies
Frequency
25
20
15
10
5
0
0.0
0.2
0.4
0.6
0.8
1.0
Pregnancies


Test Distribution of Glucose
Frequency
0
5
10
15
20
0.0
0.2
0.4
0.6
0.8
1.0
Glucose


Test Distribution of BMI
Frequency
0
2
4
6
8
10
12
14
0.0
0.2
0.4
0.6
0.8
1.0
BMI



DecisionTree Train

```
tree_classifier = DecisionTreeClassifier()
tree_classifier.fit(x_train_scalled,y_train)
DecisionTreeClassifier()
y_pred = tree_classifier.predict(x_test_scalled)
text_representation = export_text(tree_classifier)
print(text_representation)
```

```
|--- feature_1 <= 0.64
|   |--- feature_3 <= 0.13
|   |   |--- feature_2 <= 0.68
|   |   |   |--- feature_2 <= 0.46
|   |   |   |   |--- feature_0 <= 0.15
|   |   |   |   |   |--- class: 0
|   |   |   |   |--- feature_0 >  0.15
|   |   |   |   |   |--- feature_2 <= 0.34
|   |   |   |   |   |   |--- feature_2 <= 0.33
```

```
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_2 >  0.33
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_2 >  0.34
|   |   |   |   |   |   |--- class: 0
|   |   |   |--- feature_2 >  0.46
|   |   |   |   |--- feature_2 <= 0.46
|   |   |   |   |   |--- class: 1
|   |   |   |   |--- feature_2 >  0.46
|   |   |   |   |   |--- feature_2 <= 0.57
|   |   |   |   |   |   |--- feature_2 <= 0.56
|   |   |   |   |   |   |   |--- feature_1 <= 0.50
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.56
|   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.09
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_3 >  0.09
|   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.41
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_1 >  0.41
|   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_2 >  0.56
|   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.03
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_0 >  0.03
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_1 >  0.50
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.50
|   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.09
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_0 >  0.09
|   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.52
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_1 >  0.52
|   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of
depth 3
|   |   |   |   |   |   |   |   |--- feature_2 >  0.50
|   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.15
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_0 >  0.15
|   |   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.10
|   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of
depth 2
|   |   |   |   |   |   |   |   |   |--- feature_3 >  0.10
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_2 >  0.56
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_2 >  0.57
|   |   |   |   |   |   |--- class: 0
|   |   |--- feature_2 >  0.68
```

```
|   |   |   |--- feature_3 <= 0.03
|   |   |   |   |--- class: 0
|   |   |   |--- feature_3 >  0.03
|   |   |   |   |--- class: 1
|   |--- feature_3 >  0.13
|   |   |--- feature_2 <= 0.39
|   |   |   |--- feature_2 <= 0.14
|   |   |   |   |--- class: 1
|   |   |   |--- feature_2 >  0.14
|   |   |   |   |--- class: 0
|   |   |--- feature_2 >  0.39
|   |   |   |--- feature_1 <= 0.50
|   |   |   |   |--- feature_0 <= 0.56
|   |   |   |   |   |--- feature_1 <= 0.14
|   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_1 >  0.14
|   |   |   |   |   |   |--- feature_2 <= 0.43
|   |   |   |   |   |   |   |--- feature_2 <= 0.42
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_2 >  0.42
|   |   |   |   |   |   |   |   |--- feature_1 <= 0.46
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |--- feature_1 >  0.46
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_2 >  0.43
|   |   |   |   |   |   |   |--- feature_3 <= 0.36
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_3 >  0.36
|   |   |   |   |   |   |   |   |--- feature_0 <= 0.12
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |--- feature_0 >  0.12
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |--- feature_0 >  0.56
|   |   |   |   |   |--- feature_1 <= 0.45
|   |   |   |   |   |   |--- feature_2 <= 0.45
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_2 >  0.45
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_1 >  0.45
|   |   |   |   |   |   |--- class: 1
|   |   |   |--- feature_1 >  0.50
|   |   |   |   |--- feature_3 <= 0.60
|   |   |   |   |   |--- feature_0 <= 0.38
|   |   |   |   |   |   |--- feature_1 <= 0.56
|   |   |   |   |   |   |   |--- feature_3 <= 0.23
|   |   |   |   |   |   |   |   |--- feature_1 <= 0.53
|   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.15
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_3 >  0.15
```

```
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_1 >  0.53
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_3 >  0.23
|   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.54
|   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.52
|   |   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.51
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |   |   |--- feature_1 >  0.51
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_1 >  0.52
|   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_1 >  0.54
|   |   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.46
|   |   |   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.49
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |   |--- feature_2 >  0.49
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_3 >  0.46
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_1 >  0.56
|   |   |   |   |   |   |   |   |--- feature_3 <= 0.39
|   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.63
|   |   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.41
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_2 >  0.41
|   |   |   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.66
|   |   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of
depth 10
|   |   |   |   |   |   |   |   |   |   |   |--- feature_2 >  0.66
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_1 >  0.63
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_3 >  0.39
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_0 >  0.38
|   |   |   |   |   |   |   |--- feature_3 <= 0.30
|   |   |   |   |   |   |   |   |--- feature_1 <= 0.62
|   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.15
|   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.56
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_1 >  0.56
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_3 >  0.15
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_1 >  0.62
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_3 >  0.30
|   |   |   |   |   |   |   |--- feature_2 <= 0.58
```

```
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.55
|   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.50
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_0 >  0.50
|   |   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.41
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_2 >  0.41
|   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of
depth 5
|   |   |   |   |   |   |   |   |--- feature_2 >  0.55
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_2 >  0.58
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.67
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |--- feature_2 >  0.67
|   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.54
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_1 >  0.54
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_3 >  0.60
|   |   |   |   |   |   |--- feature_0 <= 0.15
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_0 >  0.15
|   |   |   |   |   |   |   |--- class: 0
|--- feature_1 >  0.64
|   |--- feature_2 <= 0.45
|   |   |--- feature_1 <= 0.73
|   |   |   |--- feature_2 <= 0.42
|   |   |   |   |--- feature_1 <= 0.67
|   |   |   |   |   |--- class: 0
|   |   |   |   |--- feature_1 >  0.67
|   |   |   |   |   |--- feature_1 <= 0.68
|   |   |   |   |   |   |--- feature_0 <= 0.38
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_0 >  0.38
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_1 >  0.68
|   |   |   |   |   |   |--- feature_3 <= 0.03
|   |   |   |   |   |   |   |--- feature_0 <= 0.15
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_0 >  0.15
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_3 >  0.03
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |--- feature_2 >  0.42
|   |   |   |   |--- feature_2 <= 0.43
|   |   |   |   |   |--- class: 1
|   |   |   |   |--- feature_2 >  0.43
|   |   |   |   |   |--- class: 0
```

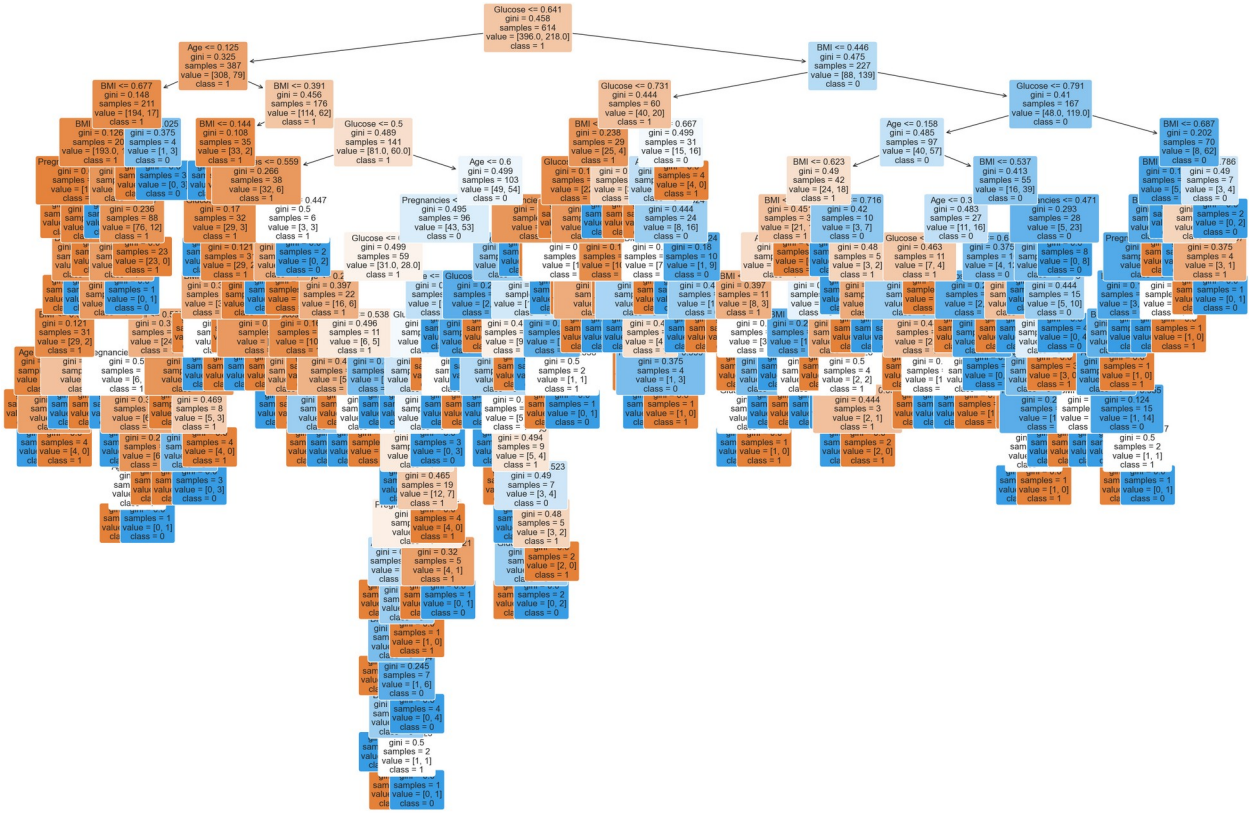
```
|   |   |--- feature_1 >  0.73
|   |   |   |--- feature_3 <= 0.67
|   |   |   |   |--- feature_3 <= 0.08
|   |   |   |   |   |--- class: 0
|   |   |   |   |--- feature_3 >  0.08
|   |   |   |   |   |--- feature_1 <= 0.82
|   |   |   |   |   |   |--- feature_2 <= 0.44
|   |   |   |   |   |   |   |--- feature_0 <= 0.15
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_0 >  0.15
|   |   |   |   |   |   |   |   |--- feature_3 <= 0.40
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_3 >  0.40
|   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.56
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_0 >  0.56
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_2 >  0.44
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_1 >  0.82
|   |   |   |   |   |   |--- feature_2 <= 0.42
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_2 >  0.42
|   |   |   |   |   |   |   |--- feature_1 <= 0.91
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_1 >  0.91
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |--- feature_3 >  0.67
|   |   |   |   |--- class: 0
|   |--- feature_2 >  0.45
|   |   |--- feature_1 <= 0.79
|   |   |   |--- feature_3 <= 0.16
|   |   |   |   |--- feature_2 <= 0.62
|   |   |   |   |   |--- feature_2 <= 0.58
|   |   |   |   |   |   |--- feature_3 <= 0.06
|   |   |   |   |   |   |   |--- feature_2 <= 0.49
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_2 >  0.49
|   |   |   |   |   |   |   |   |--- feature_1 <= 0.65
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_1 >  0.65
|   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.50
|   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.68
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_1 >  0.68
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_2 >  0.50
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_3 >  0.06
```

```
|   |   |   |   |   |   |   |--- feature_3 <= 0.11
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.49
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |--- feature_2 >  0.49
|   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.54
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_2 >  0.54
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_3 >  0.11
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.52
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_2 >  0.52
|   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.53
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_2 >  0.53
|   |   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.06
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_0 >  0.06
|   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_2 >  0.58
|   |   |   |   |   |   |--- class: 0
|   |   |   |   |--- feature_2 >  0.62
|   |   |   |   |   |--- feature_1 <= 0.72
|   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_1 >  0.72
|   |   |   |   |   |   |--- feature_3 <= 0.01
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_3 >  0.01
|   |   |   |   |   |   |   |--- feature_2 <= 0.71
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_2 >  0.71
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |--- feature_3 >  0.16
|   |   |   |   |--- feature_2 <= 0.54
|   |   |   |   |   |--- feature_3 <= 0.36
|   |   |   |   |   |   |--- feature_1 <= 0.69
|   |   |   |   |   |   |   |--- feature_0 <= 0.35
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_0 >  0.35
|   |   |   |   |   |   |   |   |--- feature_1 <= 0.66
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_1 >  0.66
|   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.28
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_3 >  0.28
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_1 >  0.69
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_3 >  0.36
```

```
|   |   |   |   |   |   |   |--- feature_3 <= 0.68
|   |   |   |   |   |   |   |   |--- feature_1 <= 0.65
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_1 >  0.65
|   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.46
|   |   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.46
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_2 >  0.46
|   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |--- feature_2 >  0.46
|   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_3 >  0.68
|   |   |   |   |   |   |   |   |--- feature_3 <= 0.78
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_3 >  0.78
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_2 >  0.54
|   |   |   |   |   |   |--- feature_0 <= 0.47
|   |   |   |   |   |   |   |--- feature_3 <= 0.21
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_3 >  0.21
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.68
|   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.59
|   |   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.24
|   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |   |--- feature_3 >  0.24
|   |   |   |   |   |   |   |   |   |   |   |--- feature_0 <= 0.18
|   |   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of
depth 2
|   |   |   |   |   |   |   |   |   |   |   |--- feature_0 >  0.18
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |--- feature_2 >  0.59
|   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_2 >  0.68
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_0 >  0.47
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |--- feature_1 >  0.79
|   |   |   |   |--- feature_2 <= 0.69
|   |   |   |   |   |--- feature_2 <= 0.55
|   |   |   |   |   |   |--- feature_2 <= 0.55
|   |   |   |   |   |   |   |--- feature_0 <= 0.56
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.50
|   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.50
|   |   |   |   |   |   |   |   |   |   |--- feature_3 <= 0.08
|   |   |   |   |   |   |   |   |   |   |   |--- feature_2 <= 0.47
|   |   |   |   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |   |   |--- feature_2 >  0.47
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
```

```
|   |   |   |   |   |   |   |   |   |--- feature_3 >  0.08
|   |   |   |   |   |   |   |   |   |   |--- feature_1 <= 0.95
|   |   |   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |   |   |--- feature_1 >  0.95
|   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of
depth 2
|   |   |   |   |   |   |   |   |--- feature_2 >  0.50
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |   |--- feature_2 >  0.50
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |--- feature_0 >  0.56
|   |   |   |   |   |   |   |   |--- feature_2 <= 0.51
|   |   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |   |   |--- feature_2 >  0.51
|   |   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_2 >  0.55
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_2 >  0.55
|   |   |   |   |   |   |--- class: 1
|   |   |   |   |--- feature_2 >  0.69
|   |   |   |   |   |--- feature_2 <= 0.79
|   |   |   |   |   |   |--- feature_1 <= 0.82
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |   |--- feature_1 >  0.82
|   |   |   |   |   |   |   |--- feature_1 <= 0.91
|   |   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |   |--- feature_1 >  0.91
|   |   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_2 >  0.79
|   |   |   |   |   |   |--- class: 1


feature_names = best_features.columns.tolist()
target_names = [str(name) for name in Y.unique().tolist()]
plt.figure(figsize=(30, 20))
plot_tree(tree_classifier,
          feature_names = feature_names,
          class_names = target_names,
          filled = True,
          rounded = True,
         fontsize = 12)
plt.savefig('tree_visualization.png')
```




```
matrix = confusion_matrix(y_pred,y_test)
matrix

array([[76, 23],
       [28, 27]], dtype=int64)

labels = np.array([["TN", "FP"], ["FN", "TP"]])
sns.heatmap(matrix, annot = labels, fmt = "" , cbar = True)
plt.xlabel("Predicted Labels")
plt.ylabel("Actual Labels")
plt.savefig('Conf_matrix.png')
```


```
accuracy_score(y_pred,y_test)
```

```
0.6688311688311688
```

```
precision_score(y_pred,y_test)
```

```
0.54
```

```
recall_score(y_pred,y_test)
```

```
0.4909090909090909
```

```
f1_score(y_pred,y_test)
```

```
0.5142857142857142
```

```
input_data = pd.DataFrame([[0.01,0.04, 0.5,0.02 ]], columns =
best_features.columns)
prediction = tree_classifier.predict(input_data)
print("Prediction:", prediction)
```

```
Prediction: [0]
```

```
pk.dump(tree_classifier , open('tree_classifier_model.pkl', 'wb'))
```

```
savedmodel = pk.load(open('tree_classifier_model.pkl','rb'))
```

```
input_data =pd.DataFrame([[0.9,0.7,0.5, 0.02]], columns =
best_features.columns)
prediction = savedmodel.predict(input_data)
print("Prediction:", prediction)
```

```
Prediction: [0]
```