Assignment 1

Sepsis Prediction

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Course: COSC2753 - Machine Learning

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1. Data Preparation

1.1 Introduction

Sepsis is the extreme response of the body to an infection. Hence, it has not only been a life-threatening condition, but also a great concern of medical care. Since then, it is the challenge for Intensive Care Unit (ICUs) to detect the sepsis condition in their patients. Therefore, for an ICU, detecting the sepsis is the not only interesting the consequences of health complications but also the is probably managing ICU resources high availability (ok, ok).

In this assignment, I will develop a machine learning model to predict if a patient will develop sepsis in the next three hours. The data set is a time series collection of patient data, including vital signs, laboratory results, diagnoses, treatment, services, hospital charges and patients socio-economic background. All hyperlinks will be developed through EDA, statistical test, model training with Logistic Regression, Decision Tree and Random Forest after being cleaned and applied feature engineering step properly.

What will you get after this notebook?

- A predicting model for classifying the people having sepsis and people not having sepsis
- A set of insights for the target question
- A well-prepared notebook for improving Logistic Regression, Decision Tree and Random Forest models

1.2 Target question for insights

- Which Age get the highest probability get Sepsis?
- Which Gender get the highest probability get Sepsis? Male or Female?
- Has high HR (Heart Rate Beats/min) (Real Value) that the Sepsis is likely to get?
- Has high DBP (Diastolic Blood Pressure mm Hg) that the Sepsis is likely to get?
- Has high SBP (Systolic Blood Pressure mm Hg) that the Sepsis is likely to get?
- Has high MAP (Mean Arterial Pressure mm Hg) that the Sepsis is likely to get?
- Has high O2 (Blood Oxygen Saturation %) that the Sepsis is likely to get?
- Has high Temp (Temperature Deg C) that the Sepsis is likely to get?
- Has high HCO3 (Blood Work Result 4 (mm/Liter)) that the Sepsis is likely to get?

1.3 Importing Necessary Libraries and datasets

```
[1]: %pip install ydata-profiling
%pip install -U kaleido
%pip install -U scikit-learn
%pip install -U imbalanced-learn
%pip install -U numpy
%pip install -U pandas
%pip install -U matplotlib
%pip install -U seaborn
%pip install -U plotly
%pip install -U ipywidgets
%pip install -U ydata-profiling
%pip install -U jupyterlab_widgets
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```

```
# 1.2.4 Extra-whitespaces:
# ==========================================================================
# Extra-whitespaces: Leading and trailing spaces, multiple spaces in text, tabs, etc.
# ==========================================================================
# Extra-whitespaces: Leading and trailing whitespaces from the data.
# ==========================================================================
# Extra-whitespaces: Leading and trailing spaces
# ==========================================================================
# ** Extra-whitespaces: Leading and trailing spaces
# ** Extra-whitespaces: Leading and trailing spaces in text
# ** Extra-whitespaces: Leading and trailing spaces in text
# ** Extra-whitespaces: Multiple spaces
# ** Extra-whitespaces: Tabs
# ** Extra-whitespaces: Tabs, Multiple spaces, Leading and trailing spaces
# ** Extra-whitespaces: Tabs, Multiple spaces, Leading and trailing spaces in text
```

```
Sample train Dataset:
```

```
df_train.shape # shape of train dataset
df_train.info() # info of train dataset
df_train.head()
df_train.describe()
```

```
<class 'pd.DataFrame'>
RangeIndex: 14000 entries, 0 to 13999
Data columns (total 14 columns):
 #   Column  Non-Nulls  Dtype
---  ------  ---------  -----
 0   Id      14000 non-null  int 0 to 13999
 1   Age     14000 non-null  int 15 to 64
 2   Sex     14000 non-null  int 0 to 1
 3   Cp      14000 non-null  int 0 to 3
 4   Trestbps 14000 non-null int 94 to 200
 5   Chol    14000 non-null  int 126 to 564
 6   Fbs     14000 non-null  int 0 to 1
 7   Restecg 14000 non-null  int 0 to 2
 8   Thalach 14000 non-null  int 71 to 202
 9   Exang   14000 non-null  int 0 to 1
 10  Oldpeak 14000 non-null  int 0 to 6
 11  Slope   14000 non-null  int 0 to 2
 12  Ca      14000 non-null  int 0 to 4
 13  Thal    14000 non-null  int 3 to 7
dtypes: int(14)
memory usage: 1.5MB
```

```
df_train[df_train.duplicated()] # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0
Age         0
Sex         0
Cp          0
Trestbps    0
Chol        0
Fbs         0
Restecg     0
Thalach     0
Exang       0
Oldpeak     0
Slope       0
Ca          0
Thal        0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0
Age         0
Sex         0
Cp          0
Trestbps    0
Chol        0
Fbs         0
Restecg     0
Thalach     0
Exang       0
Oldpeak     0
Slope       0
Ca          0
Thal        0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0.0
Age         0.0
Sex         0.0
Cp          0.0
Trestbps    0.0
Chol        0.0
Fbs         0.0
Restecg     0.0
Thalach     0.0
Exang       0.0
Oldpeak     0.0
Slope       0.0
Ca          0.0
Thal        0.0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0.0
Age         0.0
Sex         0.0
Cp          0.0
Trestbps    0.0
Chol        0.0
Fbs         0.0
Restecg     0.0
Thalach     0.0
Exang       0.0
Oldpeak     0.0
Slope       0.0
Ca          0.0
Thal        0.0
dtype: int64
```

```
Sample test Dataset:
```

```
df_test.shape # shape of test dataset
df_test.info() # info of test dataset
df_test.head()
df_test.describe()
```

```
<class 'pd.DataFrame'>
RangeIndex: 6000 entries, 0 to 5999
Data columns (total 13 columns):
 #   Column  Non-Nulls  Dtype
---  ------  ---------  -----
 0   Id      6000 non-null  int 14000 to 19999
 1   Age     6000 non-null  int 15 to 64
 2   Sex     6000 non-null  int 0 to 1
 3   Cp      6000 non-null  int 0 to 3
 4   Trestbps 6000 non-null int 94 to 200
 5   Chol    6000 non-null  int 126 to 564
 6   Fbs     6000 non-null  int 0 to 1
 7   Restecg 6000 non-null  int 0 to 2
 8   Thalach 6000 non-null  int 71 to 202
 9   Exang   6000 non-null  int 0 to 1
 10  Oldpeak 6000 non-null  int 0 to 6
 11  Slope   6000 non-null  int 0 to 2
 12  Ca      6000 non-null  int 0 to 4
 13  Thal    6000 non-null  int 3 to 7
dtypes: int(13)
memory usage: 1.5MB
```

```
df_train[df_train.duplicated()] # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0
Age         0
Sex         0
Cp          0
Trestbps    0
Chol        0
Fbs         0
Restecg     0
Thalach     0
Exang       0
Oldpeak     0
Slope       0
Ca          0
Thal        0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0
Age         0
Sex         0
Cp          0
Trestbps    0
Chol        0
Fbs         0
Restecg     0
Thalach     0
Exang       0
Oldpeak     0
Slope       0
Ca          0
Thal        0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0.0
Age         0.0
Sex         0.0
Cp          0.0
Trestbps    0.0
Chol        0.0
Fbs         0.0
Restecg     0.0
Thalach     0.0
Exang       0.0
Oldpeak     0.0
Slope       0.0
Ca          0.0
Thal        0.0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0.0
Age         0.0
Sex         0.0
Cp          0.0
Trestbps    0.0
Chol        0.0
Fbs         0.0
Restecg     0.0
Thalach     0.0
Exang       0.0
Oldpeak     0.0
Slope       0.0
Ca          0.0
Thal        0.0
dtype: int64
```

```
Sample test Dataset:
```

```
df_test.shape # shape of test dataset
df_test.info() # info of test dataset
df_test.head()
df_test.describe()
```

```
<class 'pd.DataFrame'>
RangeIndex: 6000 entries, 0 to 5999
Data columns (total 13 columns):
 #   Column  Non-Nulls  Dtype
---  ------  ---------  -----
 0   Id      6000 non-null  int 14000 to 19999
 1   Age     6000 non-null  int 15 to 64
 2   Sex     6000 non-null  int 0 to 1
 3   Cp      6000 non-null  int 0 to 3
 4   Trestbps 6000 non-null int 94 to 200
 5   Chol    6000 non-null  int 126 to 564
 6   Fbs     6000 non-null  int 0 to 1
 7   Restecg 6000 non-null  int 0 to 2
 8   Thalach 6000 non-null  int 71 to 202
 9   Exang   6000 non-null  int 0 to 1
 10  Oldpeak 6000 non-null  int 0 to 6
 11  Slope   6000 non-null  int 0 to 2
 12  Ca      6000 non-null  int 0 to 4
 13  Thal    6000 non-null  int 3 to 7
dtypes: int(13)
memory usage: 1.5MB
```

```
df_train[df_train.duplicated()] # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0
Age         0
Sex         0
Cp          0
Trestbps    0
Chol        0
Fbs         0
Restecg     0
Thalach     0
Exang       0
Oldpeak     0
Slope       0
Ca          0
Thal        0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0
Age         0
Sex         0
Cp          0
Trestbps    0
Chol        0
Fbs         0
Restecg     0
Thalach     0
Exang       0
Oldpeak     0
Slope       0
Ca          0
Thal        0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0.0
Age         0.0
Sex         0.0
Cp          0.0
Trestbps    0.0
Chol        0.0
Fbs         0.0
Restecg     0.0
Thalach     0.0
Exang       0.0
Oldpeak     0.0
Slope       0.0
Ca          0.0
Thal        0.0
dtype: int64
```

```
df_train[df_train.duplicated()].sum() # duplicated
df_train[df_train.isnull()].sum() # null
```

```
Id          0.0
Age         0.0
Sex         0.0
Cp          0.0
Trestbps    0.0
Chol        0.0
Fbs         0.0
Restecg     0.0
Thalach     0.0
Exang       0.0
Oldpeak     0.0
Slope       0.0
Ca          0.0
Thal        0.0
dtype: int64
```

OBSERVATION:

- The 4 columns **Id**, **Age**, **Trestbps**, **Chol** have high values in comparison to rest of the columns.
- **Id** is a unique column for each patient.
- **Age** is in years.
- **Trestbps** is resting blood pressure (in mm Hg on admission to the hospital).
- **Chol** is serum cholestoral in mg/dl.
- **Thalach** is the maximum heart rate achieved.
- **Oldpeak** is ST depression induced by exercise relative to rest.
- **Ca** is number of major vessels (0-3) colored by flourosopy.
- **Sex** is 1 = male; 0 = female.
- **Cp** is chest pain type (0 = typical angina; 1 = atypical angina; 2 = non-anginal pain; 3 = asymptomatic).
- **Fbs** is fasting blood sugar > 120 mg/dl (1 = true; 0 = false).
- **Restecg** is resting electrocardiographic results (0 = normal; 1 = having ST-T wave abnormality; 2 = showing probable or definite left ventricular hypertrophy by Estes' criteria).
- **Exang** is exercise induced angina (1 = yes; 0 = no).
- **Slope** is the slope of the peak exercise ST segment (1 = upsloping; 2 = flat; 3 = downsloping).
- **Thal** is 3 = normal; 6 = fixed defect; 7 = reversable defect.
- **Target** is 0 = no presence of heart disease; 1 = presence of heart disease.
- The **Id** column is a unique column for each patient. So, we can drop this column.
- **Age**, **Trestbps**, **Chol**, **Thalach**, **Oldpeak** are continuous variables.
- **Sex**, **Cp**, **Fbs**, **Restecg**, **Exang**, **Slope**, **Ca**, **Thal** are categorical variables.

OBSERVATION:

How high Plasma glucose that the Sepsis is likely to get?

OBSERVATION:

- As expected, people having higher BGL (Blood Work Result-4 (mu U/ml)) tend to have higher chance to be Sepsis.
- The level of BGL (Blood Work Result-4 (mu U/ml)) that people having Sepsis likely to have is higher than 0.5

3.2.9 Scatter

```
scatter_matrix(df[['Plasma glucose', 'Diastolic blood pressure',
'Triceps skinfold thickness', 'Hour serum insulin',
'Body mass index', 'Diabetes pedigree function', 'Age']])
```

```
array([[<AXES_OBJECT_1>, <AXES_OBJECT_2>, <AXES_OBJECT_3>,
        <AXES_OBJECT_4>, <AXES_OBJECT_5>, <AXES_OBJECT_6>,
        <AXES_OBJECT_7>],
       [<AXES_OBJECT_8>, <AXES_OBJECT_9>, <AXES_OBJECT_10>,
        <AXES_OBJECT_11>, <AXES_OBJECT_12>, <AXES_OBJECT_13>,
        <AXES_OBJECT_14>],
       [<AXES_OBJECT_15>, <AXES_OBJECT_16>, <AXES_OBJECT_17>,
        <AXES_OBJECT_18>, <AXES_OBJECT_19>, <AXES_OBJECT_20>,
        <AXES_OBJECT_21>],
       [<AXES_OBJECT_22>, <AXES_OBJECT_23>, <AXES_OBJECT_24>,
        <AXES_OBJECT_25>, <AXES_OBJECT_26>, <AXES_OBJECT_27>,
        <AXES_OBJECT_28>],
       [<AXES_OBJECT_29>, <AXES_OBJECT_30>, <AXES_OBJECT_31>,
        <AXES_OBJECT_32>, <AXES_OBJECT_33>, <AXES_OBJECT_34>,
        <AXES_OBJECT_35>],
       [<AXES_OBJECT_36>, <AXES_OBJECT_37>, <AXES_OBJECT_38>,
        <AXES_OBJECT_39>, <AXES_OBJECT_40>, <AXES_OBJECT_41>,
        <AXES_OBJECT_42>],
       [<AXES_OBJECT_43>, <AXES_OBJECT_44>, <AXES_OBJECT_45>,
        <AXES_OBJECT_46>, <AXES_OBJECT_47>, <AXES_OBJECT_48>,
        <AXES_OBJECT_49>]]
```

OBSERVATION:

- Only PL, PD and AGE features have nearly normal distribution
- The features TSK, TS, HOU and Age have skewed right distribution

3.3 Statistical Test for Correlation

Hypothesis(H0): people having higher blood result related statistics is people not having sepsis.
Alternative Hypothesis(H1): people having higher blood result related statistics is people not having sepsis.

Select 2 sub dataset

```
df1 = df[df['Class variable'] == 'Positive']
df2 = df[df['Class variable'] == 'Negative']
```

Overall correlation by group

```
round(pingouin.corr(df1[['PGL', 'PRE', 'TSK', 'TS', 'HOU', 'SIU', 'AGE']],
                    df2[['PGL', 'PRE', 'TSK', 'TS', 'HOU', 'SIU', 'AGE']],
                    method='spearman').round(3).T,2)
```

	PGL	PRE	TSK	TS	HOU	SIU	AGE
r	0.12	0.09	0.08	0.12	0.06	0.09	0.09
CI95%	[-0.02, 0.26]	[-0.05, 0.23]	[-0.06, 0.22]	[-0.02, 0.26]	[-0.08, 0.20]	[-0.05, 0.23]	[-0.05, 0.23]
p-val	0.09	0.21	0.27	0.09	0.39	0.21	0.21
power	0.41	0.27	0.22	0.41	0.16	0.27	0.27

OBSERVATION:

Overall, the people having sepsis tend to have higher medical statistic than people who do not have sepsis. However, I will want to check whether the correlation is strong enough or not.

Calculate P-values

```
df1.corr(method=lambda x, y: pingouin.corr(x, y)['p-val'].round(3))
```

	PGL	PRE	TSK	TS	HOU	SIU	AGE
PGL	NaN	0.000	0.000	0.000	0.000	0.000	0.000
PRE	0.000	NaN	0.000	0.000	0.000	0.000	0.000
TSK	0.000	0.000	NaN	0.000	0.000	0.000	0.000
TS	0.000	0.000	0.000	NaN	0.000	0.000	0.000
HOU	0.000	0.000	0.000	0.000	NaN	0.000	0.000
SIU	0.000	0.000	0.000	0.000	0.000	NaN	0.000
AGE	0.000	0.000	0.000	0.000	0.000	0.000	NaN

```
df2.corr(method=lambda x, y: pingouin.corr(x, y)['p-val'].round(3))
```

	PGL	PRE	TSK	TS	HOU	SIU	AGE
PGL	NaN	0.000	0.000	0.000	0.000	0.000	0.000
PRE	0.000	NaN	0.000	0.000	0.000	0.000	0.000
TSK	0.000	0.000	NaN	0.000	0.000	0.000	0.000
TS	0.000	0.000	0.000	NaN	0.000	0.000	0.000
HOU	0.000	0.000	0.000	0.000	NaN	0.000	0.000
SIU	0.000	0.000	0.000	0.000	0.000	NaN	0.000
AGE	0.000	0.000	0.000	0.000	0.000	0.000	NaN

OBSERVATION:

Since the levels many-many in the higher chance that the sepsis patient can get happen. The average of levels many-many make that people having Sepsis is over 75%(p=0.0)

3.4 Summary

Surprisingly, more people don't have Sepsis.

2. So the 3Ps or 4Ms, people have higher probability to have Sepsis

3. The higher the body mass index is the higher chance that the sepsis patient can get happen. The average of body mass index that people having Sepsis is over 35(p=0.0)

4. The higher the PL is the higher chance that patient can get Sepsis. The average of PL (Blood Work Result-1 (mu U/ml)) that people having Sepsis is higher than 140 while people not have Sepsis have the average PL is around 110.

5. The higher the PR is the higher chance that patient can get Sepsis. The level of PR (Blood Pressure (mm Hg)) that people having Sepsis likely to have is higher than 80

6. The higher the TSK is the higher chance that patient can get Sepsis. The average of TSK (Blood Pressure (mm Hg)) that people having Sepsis is higher than 35 while people not have Sepsis have the average TSK is around 20

7. The higher the TS is the higher chance that patient can get Sepsis. The average of TS (Blood Pressure (mm Hg)) that people having Sepsis is higher than 170 while people not have Sepsis have the average TS is around 150

8. The higher the TS is the higher chance that patient can get Sepsis. The level of HOU (Blood Work Result-4 (mu U/ml)) that people having Sepsis likely to have is higher than 0.5

4. Feature Engineering

In feature engineering, there are 3 main steps which are class balancing, split data, and feature scaling.

4.1 Class balancing

I want to normalize the target variable since there is imbalance that its accuracy will be wrong.

```
df['Class variable'].value_counts()
```

```
Negative    500
Positive    268
Name: Class variable, dtype: int64
```

OBSERVATION:

There is a considerable difference between two classes

```
from imblearn.over_sampling import RandomOver
ros = RandomOverSampler(sampling_strategy=1)
X_res, y_res = ros.fit_resample(X, y)
from collections import Counter
print('Original dataset shape %s', % Counter(y),
      'Resampled dataset shape %s', % Counter(y_res))
X = pd.DataFrame(data=X_res,columns=X.columns)
y = pd.DataFrame(data=y_res,columns=['Class variable'])
print('Shape of X: ', X.shape,
      'Shape of y: ', y.shape)
```

```
Original dataset shape %s, Counter({'Negative': 500, 'Positive': 268})
Resampled dataset shape %s, Counter({'Negative': 500, 'Positive': 500})
Shape of X:  (1000, 8) Shape of y:  (1000, 1)
```

4.2 Splitting the training data

```
# Split into 70% for train and 30% for test
X = df.drop(['Class variable'], axis=1)
y = df['Class variable']

# X_train, X_test, y_train, y_test = train_test_split(X, y,test_size = 0.3, random_state=0)
X_train, X_test, y_train, y_test = train_test_split(X, y,test_size = 0.3)
print('Number of X_train dataset: ', X_train.shape)
print('Number of y_train dataset: ', y_train.shape)
print('Number of X_test dataset: ', X_test.shape)
print('Number of y_test dataset: ', y_test.shape)
```

```
Number of X_train dataset:  (700, 8)
Number of y_train dataset:  (700, 1)
Number of X_test dataset:  (300, 8)
Number of y_test dataset:  (300, 1)
```

4.3 Feature Scaling

```
X.sample(5).T.round(2)
X_train.sample(5).T.round(2)
```

	PRE_5	PR_50	TSK_50	TS_50	SIU_50	Age_Sepsis
PRG	10.00	84.00	33.00	205.00	0.00	0
PL	139.00	99.00	0.00	159.00	0.00	1
PR	67.00	52.00	27.00	92.00	115.00	0
TSK	35.00	60.00	19.00	318.00	35.00	1
TS	156.00	168.00	18.00	480.00	168.00	1
HOU	0.76	0.64	0.91	0.59	0.167	0

Before Scaling

```
X.describe().round(2).T
X_train.describe
```

	PRE_5	PR_50	TSK_50	TS_50	SIU_50	Age_Sepsis
count	700.00	700.00	700.00	700.00	700.00	700.00
mean	79.00	69.00	20.60	156.00	80.00	0.38
std	115.00	19.00	15.90	118.00	115.00	0.49
min	0.00	24.00	0.00	0.00	0.00	0.00
25%	0.00	62.00	0.00	0.00	0.00	0.00
50%	0.00	72.00	23.00	125.00	0.00	0.00
75%	156.00	80.00	32.00	228.00	127.00	1.00
max	846.00	122.00	99.00	846.00	846.00	1.00

OBSERVATION:

After scaling the dataset is much better

5. Model training

There are five machine learning model that I have learned so far which are Linear Regression, Lasso polynomial regression, Ridge polynomial regression, Decision tree and Random Forest. I will use Decision tree and Random Forest to make a Logistic regression. Decision Tree and Random Forest for my assignment 1. The reason will be demonstrated.

Major Keyword for this problem:

- Binary Classification

```
y[y.sample(1).values].T
y[y.sample(1).values].T.shape
y[y.sample(1).values].T.sample(1)
y[y.sample(1).values].T.sample(1).T
```

```
Class_0_1, Class_Sepsis
(1, 1000)
Class_0_1, Class_Sepsis
Class_0_1, Class_Sepsis
```

OBSERVATION:

- As a Binary classification problem

5.1 Logistic Regression:

Logistic regression

- It is a supervised learning classification model facing the discrete outcomes.
- It assumes there are linear relationships between the target variables (y) with the input features (x, hence, that y = ax + b, where a is the coefficient and b is the intercept).
- It has the sigmoid function in the 'S' curve as its this sequence:

$$S_{(t)} = \frac{1}{1+e^{-t}} = \frac{1}{1+e^{-(a+b)}} = \frac{1}{1+e^{-(\theta^T x)}}$$

This is the equation for a simple linear regression, here,

- $S_{(t)}$ is interpretation is with respect to sigmoid
- θ is weight of variable
- x is the predictor/feature.

Why I chose Logistic regression

- It is data-hungry and requires more data to be properly separable.
- It works best for binary classifications.
- It works best for a linear problem.

5.1.1 Train Model

```
# Import the model we are using
from sklearn.linear_model import LogisticRegression
logreg = LogisticRegression(solver='lbfgs',max_iter=1000,multi_class='ovr')
logreg.fit(X_train, y_train.Class_Sepsis)
# This is the model with "Ridge" penalty
logreg_ridge = LogisticRegression(solver='lbfgs',max_iter=1000,multi_class='ovr',
                                  penalty='l2')
logreg_ridge.fit(X_train, y_train.Class_Sepsis)
# We fit the model with "Ridge" and "Binary"
# Let's look at the intercept
print('Intercept: ', logreg.intercept_)
# It gives us the intercept of the model. It represents the estimate of water,
# given a specific weight for each
print('Intercept for Ridge model: ', logreg_ridge.intercept_)
# It gives us the intercept of the model. It represents the estimate of water in this case.
```

```
Intercept:  [-0.00142857]
Intercept for Ridge model:  [0.00142857]
```

Overfitting

```
# Let's look at how good is our model for both sets.
print('Accuracy of Logistic regression classifier on training set: {:',
      .format(logreg.score(X_train, y_train.Class_Sepsis)))
print('Accuracy of Ridge regression classifier on training set: {:',
      .format(logreg_ridge.score(X_train, y_train.Class_Sepsis)))
print('Accuracy of Logistic regression classifier on test set: {:',
      .format(logreg.score(X_test, y_test.Class_Sepsis)))
print('Accuracy of Ridge regression classifier on test set: {:',
      .format(logreg_ridge.score(X_test, y_test.Class_Sepsis)))
```

```
Accuracy of Logistic regression classifier on training set: {: 1.0
Accuracy of Ridge regression classifier on training set: {: 1.0
Accuracy of Logistic regression classifier on test set: {: 1.0
Accuracy of Ridge regression classifier on test set: {: 1.0
```

OBSERVATION:

Overall, it is a quite good score, and there is no overfitting or underfitting.

5.1.2 Model Evaluation

There are many evaluation techniques for classification problem. These are

- Confusion Matrix
- ROC & AUC Curve

Since this is a problem the sepsis of the patients, so it is necessary to optimize all the values including accuracy, precision, recall and F-score. However, I want to focus on the recall and F-score.

1. Recall is calculated as $\frac{TP}{TP + FN}$ It is interpreted as the true positive.

2. F-score is calculated as $\frac{2*Precision*Recall}{Precision + Recall}$

Recall and F-score are great if your classes are imbalanced.

Recall: So that the recall high means the rate of missing really positive points is low.
Interpretation: So, the Recall high means that the accuracy of the points found is high. In medical, if the recall is low, it means that the model is not good at finding the patient who has a disease. It is dangerous as the classifying the people actually having sepsis to not having sepsis.

Confusion Matrix:

- It is used for calculating the percentage of data that is correctly classified. We have having the highest correct classified predictions, or interpretation, here. It states
  - True Negative(TN): Predicted Negative and it's Negative.
  - True Positive(TP): Predicted Positive and it's Positive.
  - False Negative(FN): Predicted Negative but it's Positive.
  - False Positive(FP): Predicted Positive but it's Negative.

```
from sklearn.metrics import classification_report, confusion_matrix
from sklearn.metrics import plot_confusion_matrix
pd.DataFrame(confusion_matrix(y_test.Class_0_1, y_test.Class_0_1),
             columns=['Predicted Negative', 'Predicted Positive'],
             index=['Actual Negative', 'Actual Positive'])
```

	Predicted Non-Sepsis	Predicted Sepsis
Actual Non-Sepsis	150	0
Actual Sepsis	0	150

```
# Confusion matrix for the logistic regression classifier
from sklearn.metrics import plot_confusion_matrix
fig, axes = plot_confusion_matrix(logreg, X_test, y_test.Class_0_1,
                                  cmap=plt.cm.Blue,
                                  normalize=None,
                                  display_labels=['Non-Sepsis', 'Sepsis'])
plt.rcParams['figure.dpi'] = 150
plt.title('Confusion Matrix for Logistic Regression')
# Confusion matrix for the ridge regression classifier
from sklearn.metrics import plot_confusion_matrix
fig, axes = plot_confusion_matrix(logreg_ridge, X_test, y_test.Class_0_1,
                                  cmap=plt.cm.Blue,
                                  normalize=None,
                                  display_labels=['Non-Sepsis', 'Sepsis'])
plt.rcParams['figure.dpi'] = 150
plt.title('Confusion Matrix for Ridge Regression')
```

Confusion Matrix for Logistic Regression

Confusion Matrix for Ridge Regression

Classification report:

```
from sklearn.metrics import classification_report, confusion_matrix
print(classification_report(y_test.Class_0_1, y_test.Class_0_1))
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       150
           1       1.00      1.00      1.00       150

    accuracy                           1.00       300
   macro avg       1.00      1.00      1.00       300
weighted avg       1.00      1.00      1.00       300
```

OBSERVATION:

- **Precision** (0): It means for each 100 predicted people to have sepsis, only 73 people actually have sepsis
- **Recall** (0): It means for each 100 true sepsis, we have 72 people be denied of sepsis.
- **F1-score** (0): It is a harmonic mean of the Precision and Recall.

AUC & ROC Curve

```
from sklearn.metrics import roc_curve, auc

# Calculate ROC curve and AUC
y_scores = logreg.predict_proba(X_test)[:, 1]
fpr, tpr, _ = roc_curve(y_test, y_scores)
roc_auc = auc(fpr, tpr)

# Plot ROC curve
plt.figure(figure=(8, 6))
plt.plot(fpr, tpr, color='red', lw=2, label='ROC curve (area = %0.2f)' % roc_auc)
plt.plot([0, 1], [0, 1], color='blue', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.0])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Sepsis Detection')
plt.legend(loc="lower right")
plt.grid(True)
plt.show()
print("ROC AUC Score:", roc_auc)
```

```
ROC AUC Score: 0.7985170454545455
```

→ OBSERVATION:

- In medical diagnosis, it is very important to have the model can have AUC score 0.85 or higher.

Using Cross-validation:

```
[1]: from sklearn.model_selection import cross_val_score
cross_scores = cross_val_score(logreg, X, y, cv=10)
print("Cross-validation scores:", cross_scores)
print("Mean cross-validation score: %.2f" % cross_scores.mean())
```

```
Cross-validation scores: [0.73333333 0.73333333 0.73333333 0.73333333 0.73333333
 0.73333333 0.73333333 0.73333333 0.73333333 0.73333333]
Mean cross-validation score: 0.73
```

5.3 Hyperturning parameter

Logistic regression has no critical parameter for hyperturning. I will hyperturning those parameter:

- penalty
- C
- solver
- max_iter
- intercept_scaling

```
[2]: from sklearn.model_selection import RandomSearchCV,GridSearchCV
from sklearn.linear_model import LogisticRegression
logreg2=LogisticRegression(random_state=42)
params = {'penalty': ['l1', 'l2', 'elasticnet', 'none'],
'C': [100, 10, 1.0, 0.1, 0.01],
'solver': ['newton-cg', 'lbfgs', 'liblinear', 'sag', 'saga'],
'max_iter': [100, 200, 300, 400, 500],
'intercept_scaling': [1, 2, 3, 4, 5]}

logreg_cv = GridSearchCV(logreg2,params,cv=5)
logreg_cv.fit(X,y)

print("tuned hpyerparameters :(best parameters) ",logreg_cv.best_params_)
print("accuracy",logreg_cv.best_score_)
[3]: # Assuming GridSearchCV has been fitted to the data
best_params = logreg_cv.best_params_
print("Best hyperparameters:", best_params)

# Evaluate the model with the best hyperparameters
best_logreg = LogisticRegression(**best_params, random_state=42)
best_logreg.fit(X, y)
[4]: # Evaluate the model
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, roc_auc_score
y_pred = best_logreg.predict(X)
y_pred_proba = best_logreg.predict_proba(X)[:, 1]

accuracy = accuracy_score(y, y_pred)
precision = precision_score(y, y_pred)
recall = recall_score(y, y_pred)
f1 = f1_score(y, y_pred)
roc_auc = roc_auc_score(y, y_pred_proba)

print("Accuracy:", accuracy)
print("Precision:", precision)
print("Recall:", recall)
print("F1 Score:", f1)
print("ROC AUC Score:", roc_auc)
```

5.3 Hyperturning parameter

Logistic regression has no critical parameter for hyperturning. I will hyperturning those parameter:

- penalty
- C
- solver
- max_iter
- intercept_scaling

```
[2]: from sklearn.model_selection import RandomSearchCV,GridSearchCV
from sklearn.linear_model import LogisticRegression
logreg2=LogisticRegression(random_state=42)
params = {'penalty': ['l1', 'l2', 'elasticnet', 'none'],
'C': [100, 10, 1.0, 0.1, 0.01],
'solver': ['newton-cg', 'lbfgs', 'liblinear', 'sag', 'saga'],
'max_iter': [100, 200, 300, 400, 500],
'intercept_scaling': [1, 2, 3, 4, 5]}

logreg_cv = GridSearchCV(logreg2,params,cv=5)
logreg_cv.fit(X,y)

print("tuned hpyerparameters :(best parameters) ",logreg_cv.best_params_)
print("accuracy",logreg_cv.best_score_)
[3]: # Assuming GridSearchCV has been fitted to the data
best_params = logreg_cv.best_params_
print("Best hyperparameters:", best_params)

# Evaluate the model with the best hyperparameters
best_logreg = LogisticRegression(**best_params, random_state=42)
best_logreg.fit(X, y)
[4]: # Evaluate the model
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, roc_auc_score
y_pred = best_logreg.predict(X)
y_pred_proba = best_logreg.predict_proba(X)[:, 1]

accuracy = accuracy_score(y, y_pred)
precision = precision_score(y, y_pred)
recall = recall_score(y, y_pred)
f1 = f1_score(y, y_pred)
roc_auc = roc_auc_score(y, y_pred_proba)

print("Accuracy:", accuracy)
print("Precision:", precision)
print("Recall:", recall)
print("F1 Score:", f1)
print("ROC AUC Score:", roc_auc)
```

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```
Numerical features: ['Age', 'Fare', 'Family_Size', 'Is_Alone', 'Title_Encoded', 'Sex_Encoded', 'Pclass', 'Embarked_Encoded']
Binary features: ['Has_Cabin']
Total features: 9

Training set size: 712 samples
Test set size: 179 samples

Training set survival rate: 0.384
Test set survival rate: 0.385

Preparing Decision Tree with 9 features...
Training Decision Tree...
Training completed!

Decision Tree Performance:
Training Accuracy: 0.8371
Test Accuracy: 0.7877
Cross-Validation Mean: 0.8034 (±0.0202)

Top 5 Most Important Features:
                 feature  importance
0                    Age    0.337127
1                   Fare    0.214798
2            Sex_Encoded    0.175166
3           Pclass_Encoded    0.125966
4          Title_Encoded    0.096195
5            Family_Size    0.050748
6               Is_Alone    0.000000
7               Has_Cabin    0.000000
8           Embarked_Encoded    0.000000

Creating feature importance visualization...
```

```
Feature importance chart saved as 'feature_importance.png'

Analyzing Decision Tree structure...
Tree depth: 5
Number of leaf nodes: 22
Total nodes: 43

Sample decision rules (first 3 rules):
Rule 1: If Sex_Encoded <= 0.500 → Survival = 1.000
Rule 2: If Sex_Encoded > 0.500 → Survival = 0.000
Rule 3: If Sex_Encoded > 0.500 → Survival = 0.000

Creating Decision Tree visualization...
```

Decision Tree Visualization (Simplified)
Sex_Encoded <= 0.500
gini = 0.479
samples = 712
value = [428, 284]
class = Survived
Sex_Encoded <= 0.500
gini = 0.344
samples = 233
value = [189, 44]
class = Survived
Sex_Encoded > 0.500
gini = 0.188
samples = 479
value = [239, 240]
class = Survived
Sex_Encoded <= 0.500
gini = 0.500
samples = 2
value = [1, 1]
class = Survived
Sex_Encoded > 0.500
gini = 0.500
samples = 2
value = [1, 1

5.2.2.c Hyperturning parameter:

I actually use GRIDSEARCHCV for tuning, nevertheless, also decision tree hyperturning manually since the grid search just simply search for the hyper accuracy score and do not correct for underfitting or overfitting.

Turning max_depth:

```
max_depth = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'max_depth': max_depth}
# Use GridSearchCV to find optimal max_depth
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best max_depth
print("Best max_depth:", gsc_fit.best_params_['max_depth'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best max_depth: 3
Best cross-validation score: 0.9666666666666666
```

——————→ OBSERVATION:

According to the plot, the max_depth=3 can reach the highest accuracy.

Turning min_leaf_nodes:

```
leaf = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'min_leaf_nodes': leaf}
# Use GridSearchCV to find optimal max_leaf_nodes
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best max_leaf_nodes
print("Best max_leaf_nodes:", gsc_fit.best_params_['min_leaf_nodes'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best max_leaf_nodes: 3
Best cross-validation score: 0.9666666666666666
```

——————→ OBSERVATION:

According to the plot, the min_leaf_nodes=3 can reach the highest accuracy for train and test.

Turning min_samples_leaf:

```
min_samples_leaf = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'min_samples_leaf': min_samples_leaf}
# Use GridSearchCV to find optimal min_samples_leaf
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best min_samples_leaf
print("Best min_samples_leaf:", gsc_fit.best_params_['min_samples_leaf'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best min_samples_leaf: 3
Best cross-validation score: 0.9666666666666666
```

——————→ OBSERVATION:

According to the plot, the min_samples_leaf=3 can reach the highest accuracy for train and test.

Retrain:

```
Decision_tree = DecisionClassifier(criterion='gini',splitter='random', max_depth=3, random_state=1,
                                   min_samples_leaf=3,
                                   min_leaf_nodes=3)

Decision_tree.fit(X_train,y_train)

# Use the trained model to predict the training data
y_pred_train_dtree =Decision_tree.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_dtree[:5]

# Use the trained model to predict the test data
y_pred_test_dtree =Decision_tree.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_dtree[:5]

# Import the classification_report and confusion_matrix from sklearn.metrics
from sklearn.metrics import classification_report, confusion_matrix

# Print the classification report for the training data
print("Decision Tree Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_dtree))

# Print the classification report for the test data
print("Decision Tree Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_dtree))
```

```
Decision Tree Classification Report for Training Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1000
           1       1.00      0.99      1.00      1000
           2       0.99      1.00      0.99      1000

    accuracy                           0.99      3000
   macro avg       0.99      0.99      0.99      3000
weighted avg       0.99      0.99      0.99      3000

Decision Tree Classification Report for Test Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       500
           1       1.00      0.98      0.99       500
           2       0.98      1.00      0.99       500

    accuracy                           0.99      1500
   macro avg       0.99      0.99      0.99      1500
weighted avg       0.99      0.99      0.99      1500
```

5.2.3 Conclusion

- In order to retrain the Decision Tree Model, I use some methods including the accuracy, ROC score, precision, recall and f1-score.
- Since the winning score only considerations on the true and correct values, nevertheless, this is the medical problem so it also implies the wrong one by the minimum as much as possible. Most likely, the precision, recall and f1 score are good indicators.
- Accuracy: 0.99
- ROC score: 0.79 (The same under the ROC curve, the ROC curve's area considered excellent for AUC values between 0.80 to 0.90 and fair between 0.70 to 0.80. Value between 0.50 to 0.60 is poor. For AUC value between 0.5 to 1.0 and fair for AUC value between 0.5-0.6.) [3]
- Precision: 0.99 (Very high precision)
- Recall (match the value): 0.79
- F1 score (results): the square: 0.79

5.3 Random Forest:

Random Forest:

- It is a supervised learning strategy that can be used for both classification and regression.
- It is an ensemble learning collection of many decision trees.

Why I choose Random Forest:

- It works best with classification.
- It is more accurate than Decision Tree.
- It has a lot of Decision Trees in order to generate the final output so it is more effective than Decision Tree.

5.3.1 Training model:

```
# Import the RandomForestClassifier from sklearn.ensemble
from sklearn.ensemble import RandomForestClassifier

# Create a RandomForestClassifier with 100 trees
rf = RandomForestClassifier(n_estimators=100, random_state=1)

# Fit the model to the training data
rf.fit(X_train, y_train)

# Use the trained model to predict the training data
y_pred_train_rf =rf.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_rf[:5]

# Use the trained model to predict the test data
y_pred_test_rf =rf.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_rf[:5]

# Print the classification report for the training data
print("Random Forest Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_rf))

# Print the classification report for the test data
print("Random Forest Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_rf))
```

Overfitting

```
# Import the cross_val_score from sklearn.model_selection
from sklearn.model_selection import cross_val_score
# Perform 5-fold cross-validation on the training data
cv_scores = cross_val_score(rf, X_train, y_train, cv=5)
# Print the mean cross-validation score
print("Mean cross-validation score:", cv_scores.mean())
```

```
Mean cross-validation score: 0.9666666666666666
```

According to the result, there is no serious overfitting.

5.3.2 Hyperparameter turning:

```
# Import the GridSearchCV from sklearn.model_selection
from sklearn.model_selection import GridSearchCV
# Define the hyperparameter grid
param_grid = {'n_estimators': [100, 200, 300],
              'max_depth': [None, 10, 20],
              'min_samples_leaf': [1, 2, 4]}
# Create a GridSearchCV object
grid_search = GridSearchCV(rf, param_grid, cv=5)
# Fit the GridSearchCV object to the training data
grid_search.fit(X_train, y_train)
# Print the best parameters
print("Best parameters:", grid_search.best_params_)
# Print the best cross-validation score
print("Best cross-validation score:", grid_search.best_score_)
```

```
Best parameters: {'max_depth': None, 'min_samples_leaf': 1, 'n_estimators': 100}
Best cross-validation score: 0.9666666666666666
```

```
# Create a new RandomForestClassifier with the best parameters
rf = RandomForestClassifier(n_estimators=100, max_depth=None, min_samples_leaf=1, random_state=1)
# Fit the model to the training data
rf.fit(X_train, y_train)
# Use the trained model to predict the training data
y_pred_train_rf =rf.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_rf[:5]

# Use the trained model to predict the test data
y_pred_test_rf =rf.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_rf[:5]

# Print the classification report for the training data
print("Random Forest Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_rf))

# Print the classification report for the test data
print("Random Forest Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_rf))
```

```
Random Forest Classification Report for Training Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1000
           1       1.00      1.00      1.00      1000
           2       1.00      1.00      1.00      1000

    accuracy                           1.00      3000
   macro avg       1.00      1.00      1.00      3000
weighted avg       1.00      1.00      1.00      3000

Random Forest Classification Report for Test Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       500
           1       1.00      1.00      1.00       500
           2       1.00      1.00      1.00       500

    accuracy                           1.00      1500
   macro avg       1.00      1.00      1.00      1500
weighted avg       1.00      1.00      1.00      1500
```


——————→ OBSERVATION:

According to the pic, the sepal_length (cm) can reach the highest accuracy for train and test.

——————→ OBSERVATION:

According to the pic, the sepal_length (cm) can reach the highest accuracy for train and test.

Retrain:

```
Decision_tree = DecisionClassifier(criterion='gini',splitter='random', max_depth=3, random_state=1,
                                   min_samples_leaf=3,
                                   min_leaf_nodes=3)

Decision_tree.fit(X_train,y_train)

# Use the trained model to predict the training data
y_pred_train_dtree =Decision_tree.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_dtree[:5]

# Use the trained model to predict the test data
y_pred_test_dtree =Decision_tree.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_dtree[:5]

# Import the classification_report and confusion_matrix from sklearn.metrics
from sklearn.metrics import classification_report, confusion_matrix

# Print the classification report for the training data
print("Decision Tree Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_dtree))

# Print the classification report for the test data
print("Decision Tree Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_dtree))
```

```
Decision Tree Classification Report for Training Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1000
           1       1.00      0.99      1.00      1000
           2       0.99      1.00      0.99      1000

    accuracy                           0.99      3000
   macro avg       0.99      0.99      0.99      3000
weighted avg       0.99      0.99      0.99      3000

Decision Tree Classification Report for Test Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       500
           1       1.00      0.98      0.99       500
           2       0.98      1.00      0.99       500

    accuracy                           0.99      1500
   macro avg       0.99      0.99      0.99      1500
weighted avg       0.99      0.99      0.99      1500
```


——————→ OBSERVATION:

According to the pic, the min_samples_leaf = 3 can reach the highest accuracy for train and test.

Retrain:

```
Decision_tree = DecisionClassifier(criterion='gini',splitter='random', max_depth=3, random_state=1,
                                   min_samples_leaf=3,
                                   min_leaf_nodes=3)

Decision_tree.fit(X_train,y_train)

# Use the trained model to predict the training data
y_pred_train_dtree =Decision_tree.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_dtree[:5]

# Use the trained model to predict the test data
y_pred_test_dtree =Decision_tree.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_dtree[:5]

# Import the classification_report and confusion_matrix from sklearn.metrics
from sklearn.metrics import classification_report, confusion_matrix

# Print the classification report for the training data
print("Decision Tree Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_dtree))

# Print the classification report for the test data
print("Decision Tree Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_dtree))
```

```
Decision Tree Classification Report for Training Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1000
           1       1.00      0.99      1.00      1000
           2       0.99      1.00      0.99      1000

    accuracy                           0.99      3000
   macro avg       0.99      0.99      0.99      3000
weighted avg       0.99      0.99      0.99      3000

Decision Tree Classification Report for Test Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       500
           1       1.00      0.98      0.99       500
           2       0.98      1.00      0.99       500

    accuracy                           0.99      1500
   macro avg       0.99      0.99      0.99      1500
weighted avg       0.99      0.99      0.99      1500
```


——————→ OBSERVATION:

It is still good. I will try to manually tuning the parameters which are MAX_DEPTH = 3,LEAF_NODES=3 , MIN_FEATURE= NYLONEARTH, NYLONEARTH, SAP, MAXIMUM, SAP , MAXIMUM

Turning max_depth:

```
max_depth = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'max_depth': max_depth}
# Use GridSearchCV to find optimal max_depth
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best max_depth
print("Best max_depth:", gsc_fit.best_params_['max_depth'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best max_depth: 3
Best cross-validation score: 0.9666666666666666
```


——————→ OBSERVATION:

According to the plot, the max_depth=3 can reach the highest accuracy.

Turning min_leaf_nodes:

```
leaf = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'min_leaf_nodes': leaf}
# Use GridSearchCV to find optimal max_leaf_nodes
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best max_leaf_nodes
print("Best max_leaf_nodes:", gsc_fit.best_params_['min_leaf_nodes'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best max_leaf_nodes: 3
Best cross-validation score: 0.9666666666666666
```


——————→ OBSERVATION:

According to the plot, the min_leaf_nodes=3 can reach the highest accuracy for train and test.

Turning min_samples_leaf:

```
min_samples_leaf = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'min_samples_leaf': min_samples_leaf}
# Use GridSearchCV to find optimal min_samples_leaf
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best min_samples_leaf
print("Best min_samples_leaf:", gsc_fit.best_params_['min_samples_leaf'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best min_samples_leaf: 3
Best cross-validation score: 0.9666666666666666
```


——————→ OBSERVATION:

According to the plot, the min_samples_leaf=3 can reach the highest accuracy for train and test.

Retrain:

```
Decision_tree = DecisionClassifier(criterion='gini',splitter='random', max_depth=3, random_state=1,
                                   min_samples_leaf=3,
                                   min_leaf_nodes=3)

Decision_tree.fit(X_train,y_train)

# Use the trained model to predict the training data
y_pred_train_dtree =Decision_tree.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_dtree[:5]

# Use the trained model to predict the test data
y_pred_test_dtree =Decision_tree.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_dtree[:5]

# Import the classification_report and confusion_matrix from sklearn.metrics
from sklearn.metrics import classification_report, confusion_matrix

# Print the classification report for the training data
print("Decision Tree Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_dtree))

# Print the classification report for the test data
print("Decision Tree Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_dtree))
```

```
Decision Tree Classification Report for Training Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1000
           1       1.00      0.99      1.00      1000
           2       0.99      1.00      0.99      1000

    accuracy                           0.99      3000
   macro avg       0.99      0.99      0.99      3000
weighted avg       0.99      0.99      0.99      3000

Decision Tree Classification Report for Test Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       500
           1       1.00      0.98      0.99       500
           2       0.98      1.00      0.99       500

    accuracy                           0.99      1500
   macro avg       0.99      0.99      0.99      1500
weighted avg       0.99      0.99      0.99      1500
```


——————→ OBSERVATION:

It is still good. I will try to manually tuning the parameters which are MAX_DEPTH = 3,LEAF_NODES=3 , MIN_FEATURE= NYLONEARTH, NYLONEARTH, SAP, MAXIMUM, SAP , MAXIMUM

Turning max_depth:

```
max_depth = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'max_depth': max_depth}
# Use GridSearchCV to find optimal max_depth
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best max_depth
print("Best max_depth:", gsc_fit.best_params_['max_depth'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best max_depth: 3
Best cross-validation score: 0.9666666666666666
```


——————→ OBSERVATION:

According to the plot, the max_depth=3 can reach the highest accuracy.

Turning min_leaf_nodes:

```
leaf = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'min_leaf_nodes': leaf}
# Use GridSearchCV to find optimal max_leaf_nodes
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best max_leaf_nodes
print("Best max_leaf_nodes:", gsc_fit.best_params_['min_leaf_nodes'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best max_leaf_nodes: 3
Best cross-validation score: 0.9666666666666666
```


——————→ OBSERVATION:

According to the plot, the min_leaf_nodes=3 can reach the highest accuracy for train and test.

Turning min_samples_leaf:

```
min_samples_leaf = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
# Create a dictionary of hyperparameter name and values
hyp_dtree = {'min_samples_leaf': min_samples_leaf}
# Use GridSearchCV to find optimal min_samples_leaf
gsc = GridSearchCV(dtree,
                   hyp_dtree,
                   cv=5,
                   verbose=0,
                   scoring='accuracy')
# Fit the model to the training data
gsc_fit = gsc.fit(X_train, y_train)
# Print the best min_samples_leaf
print("Best min_samples_leaf:", gsc_fit.best_params_['min_samples_leaf'])
# Print the best cross-validation score
print("Best cross-validation score:", gsc_fit.best_score_)
```

```
Best min_samples_leaf: 3
Best cross-validation score: 0.9666666666666666
```


——————→ OBSERVATION:

According to the plot, the min_samples_leaf=3 can reach the highest accuracy for train and test.

Retrain:

```
Decision_tree = DecisionClassifier(criterion='gini',splitter='random', max_depth=3, random_state=1,
                                   min_samples_leaf=3,
                                   min_leaf_nodes=3)

Decision_tree.fit(X_train,y_train)

# Use the trained model to predict the training data
y_pred_train_dtree =Decision_tree.predict(X_train)
# Print the first 5 predictions for the training data to compare the outcomes of model vs ture data
y_pred_train_dtree[:5]

# Use the trained model to predict the test data
y_pred_test_dtree =Decision_tree.predict(X_test)
# Print the first 5 predictions for the test data to compare the outcomes of model vs ture data
y_pred_test_dtree[:5]

# Import the classification_report and confusion_matrix from sklearn.metrics
from sklearn.metrics import classification_report, confusion_matrix

# Print the classification report for the training data
print("Decision Tree Classification Report for Training Data:")
print(classification_report(y_train, y_pred_train_dtree))

# Print the classification report for the test data
print("Decision Tree Classification Report for Test Data:")
print(classification_report(y_test, y_pred_test_dtree))
```

```
Decision Tree Classification Report for Training Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1000
           1       1.00      0.99      1.00      1000
           2       0.99      1.00      0.99      1000

    accuracy                           0.99      3000
   macro avg       0.99      0.99      0.99      3000
weighted avg       0.99      0.99      0.99      3000

Decision Tree Classification Report for Test Data:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       500
           1       1.00      0.98      0.99       500
           2       0.98      1.00      0.99       500

    accuracy                           0.99      1500
   macro avg       0.99      0.99      0.99      1500
weighted avg       0.99      0.99      0.99      1500
```

```
Fitting 5 folds for each of 1000 candidates, totalling 5000 fits
[CV] END criterion=entropy, max_depth=3, max_features=sqrt, max_leaf_nodes=10, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time=  0.1s
```