

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.



LAB REPORT

On

MACHINE LEARNING

Submitted by

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**in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING**



B.M.S. COLLEGE OF ENGINEERING

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CERTIFICATE



This is to certify that the Lab work entitled "**MACHINE LEARNING**" carried out by **HARINI N (1BM21CS256)**, who is bonafide student of **B. M. S. College of Engineering**. It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2023-24. The Lab report has been approved as it satisfies the academic requirements in respect of Machine Learning Lab - **(22CS6PCMAL)**work prescribed for the said degree.

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Course outcomes:

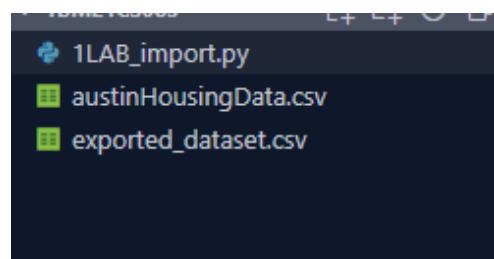
CO1	Apply machine learning techniques in computing systems
CO2	Evaluate the model using metrics
CO3	Design a model using machine learning to solve a problem
CO4	Conduct experiments to solve real-world problems using appropriate machine learning techniques

1. Write a python program to import and export data using Pandas library functions

```
import pandas as pd
df=pd.read_csv("austinHousingData.csv")
print(df.head())
df.to_csv("exported_dataset.csv")
```

Output:

```
      zpid      city streetAddress zipcode ... numOfBathrooms numOfBedrooms numOfStories homeImage
0  111373431  pflugerville    14424 Lake Victor Dr  78660 ...            3.0             4              2  111373431_ffce26843283d3365c11d81b8e6bcd6f-p_f...
1  120900430  pflugerville     1104 Strickling Dr  78660 ...            2.0             4              1  120900430_8255c127be8dcf0a1a18b7563d987088-p_f...
2  2084491383  pflugerville    1408 Fort Dessau Rd  78660 ...            2.0             3              1  2084491383_a2ad649e1a7a098111dcea084a11c855-p_f...
3  120901374  pflugerville     1025 Strickling Dr  78660 ...            2.0             3              1  120901374_b469367a619da85b1f5ceb69b675d88e-p_f...
4  60134862  pflugerville    15005 Donna Jane Loop  78660 ...            3.0             3              2  60134862_b1a48a3df3f11e005bb913873e98ce2-p_f.jpg
[5 rows x 47 columns]
```



```
import pandas as pd
url = "https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data"

col_names =
    ["sepal_length_in_cm"
     , "sepal_width_in_cm",
     "petal_length_in_cm",
     "petal_width_in_cm",
     "class"]
iris_data = pd.read_csv(url, names=col_names)

print(iris_data.head())

iris_data.to_csv("cleaned_iris_data.csv")
```

Output:

	sepal_length_in_cm	sepal_width_in_cm	petal_length_in_cm	petal_width_in_cm	class
0	5.1	3.5	1.4	0.2	Iris-setosa
1	4.9	3.0	1.4	0.2	Iris-setosa
2	4.7	3.2	1.3	0.2	Iris-setosa
3	4.6	3.1	1.5	0.2	Iris-setosa
4	5.0	3.6	1.4	0.2	Iris-setosa

2. Demonstrate various data pre-processing techniques for a given dataset

```
%matplotlib inline
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import sklearn

dataset = pd.read_csv("Data.csv")
df = pd.DataFrame(dataset)
print(df.head())

   Country    Age   Salary Purchased
0   France  44.0  72000.0      No
1   Spain   27.0  48000.0     Yes
2  Germany  30.0  54000.0      No
3   Spain   38.0  61000.0      No
4  Germany  40.0      NaN     Yes

X = df.iloc[:, :-1].values
y = df.iloc[:, -1].values

print(X)

[['France' 44.0 72000.0]
 ['Spain' 27.0 48000.0]
 ['Germany' 30.0 54000.0]
 ['Spain' 38.0 61000.0]
 ['Germany' 40.0 nan]
 ['France' 35.0 58000.0]
 ['Spain' nan 52000.0]
 ['France' 48.0 79000.0]
 ['Germany' 50.0 83000.0]
 ['France' 37.0 67000.0]]]

print(y)

['No' 'Yes' 'No' 'No' 'Yes' 'Yes' 'No' 'Yes' 'No' 'Yes']
```

```

: df2
:   Country  Age  Salary Purchased
: 0 France  44.0 72000.0      No
: 1 Spain   27.0 48000.0     Yes
: 2 Germany 30.0 54000.0      No
: 3 Spain   38.0 61000.0      No
: 4 Germany 40.0    NaN      Yes
: 5 France  35.0 58000.0     Yes
: 6 Spain   NaN  52000.0      No
: 7 France  48.0 79000.0     Yes
: 8 Germany 50.0 83000.0      No
: 9 France  37.0 67000.0     Yes

: pd.get_dummies(df2)
:   Age  Salary Country_France Country_Germany Country_Spain Purchased_No Purchased_Yes
: 0 44.0 72000.0        True        False        False       True      False
: 1 27.0 48000.0       False        False        True       False      True
: 2 30.0 54000.0       False        True        False       True      False
: 3 38.0 61000.0       False        False        True       True      False
: 4 40.0    NaN        False        True        False      False      True
: 5 35.0 58000.0       True        False        False      False      True
: 6 NaN  52000.0       False        False        True       True      False
: 7 48.0 79000.0        True        False        False      False      True
: 8 50.0 83000.0       False        True        False       True      False
: 9 37.0 67000.0       True        False        False      False      True

df.isnull().sum()

Country      0
Age         1
Salary      1
Purchased   0
dtype: int64

df1 = df.copy()

# summarize the shape of the raw data
print("Before:",df1.shape)

# drop rows with missing values
df1.dropna(inplace=True)

# summarize the shape of the data with missing rows removed
print("After:",df1.shape)

```

Before: (10, 4)
After: (8, 4)

3. Decision Tree algorithm

Code and output:

```
✓ [6] import pandas as pd
     import numpy as np
     import math
     # Reading the dataset (Tennis-dataset)
     data = pd.read_csv('PlayTennis.csv')
```

```
✓ [2] data.head()
```

	outlook	temp	humidity	windy	play
0	sunny	hot	high	False	no
1	sunny	hot	high	True	no
2	overcast	hot	high	False	yes
3	rainy	mild	high	False	yes
4	rainy	cool	normal	False	yes

Next steps: [View recommended plots](#)

```
✓ [8] def highlight(cell_value):
    ...
    Highlight yes / no values in the dataframe
    ...
    color_1 = 'background-color: pink;'
    color_2 = 'background-color: lightgreen;'

    if cell_value == 'no':
        return color_1
    elif cell_value == 'yes':
        return color_2

    data.style.applymap(highlight)\n        .set_properties(subset=data.columns, **{'width': '100px'})\n        .set_table_styles([{'selector': 'th', 'props': [(['background-color', 'lightgray'], ('border', '1px solid gray'),\n            ('font-weight', 'bold')])],\n            {'selector': 'tr:hover', 'props': [(['background-color', 'white'], ('border', '1.5px solid black'))]}])
```

	outlook	temp	humidity	windy	play
0	sunny	hot	high	False	no
1	sunny	hot	high	True	no
2	overcast	hot	high	False	yes
3	rainy	mild	high	False	yes
4	rainy	cool	normal	False	yes
5	rainy	cool	normal	True	no
6	overcast	cool	normal	True	yes
7	sunny	mild	high	False	no
8	sunny	cool	normal	False	yes
9	rainy	mild	normal	False	yes
10	sunny	mild	normal	True	yes
11	overcast	mild	high	True	yes
12	overcast	hot	normal	False	yes
13	rainy	mild	high	True	no

```

✓ [3] def find_entropy(data):
    """
    Returns the entropy of the class or features
    formula: - Σ P(X)logP(X)
    """
    entropy = 0
    for i in range(data.nunique()):
        x = data.value_counts()[i]/data.shape[0]
        entropy += (-x * math.log(x,2))
    return round(entropy,3)

def information_gain(data, data_):
    """
    Returns the information gain of the features
    """
    info = 0
    for i in range(data_.nunique()):
        df = data[data_ == data_.unique()[i]]
        w_avg = df.shape[0]/data.shape[0]
        entropy = find_entropy(df.play)
        x = w_avg * entropy
        info += x
    ig = find_entropy(data.play) - info
    return round(ig, 3)

def entropy_and_infogain(datax, feature):
    """
    Grouping features with the same class and computing their
    entropy and information gain for splitting
    """
    for i in range(data[feature].nunique()):
        df = datax[datax[feature]==data[feature].unique()[i]]
        if df.shape[0] < 1:
            continue

        display(df[[feature, 'play']].style.applymap(highlight)\.
            .set_properties(subset=[feature, 'play'], **{'width': '80px'})\.
            .set_table_styles([{'selector': 'th', 'props': [('background-color', 'lightgray'),
                ('border', '1px solid gray'),
                ('font-weight', 'bold')],},
                {'selector': 'td', 'props': [('border', '1px solid gray')],},
                {'selector': 'tr:hover', 'props': [('background-color', 'white'),
                ('border', '1.5px solid black')]}])))

    print(f'Entropy of {feature} - {data[feature].unique()[i]} = {find_entropy(df.play)}')
    print(f'Information Gain for {feature} = {information_gain(datax, datax[feature])}')

```

```
✓ [4] print(f'Entropy of the entire dataset: {find_entropy(data.play)}')  
Entropy of the entire dataset: 0.94
```

```
✓ [5] entropy_and_infogain(data, 'outlook')
```

	outlook	play
0	sunny	no
1	sunny	no
7	sunny	no
8	sunny	yes
10	sunny	yes

Entropy of outlook - sunny = 0.971

	outlook	play
2	overcast	yes
6	overcast	yes
11	overcast	yes
12	overcast	yes

Entropy of outlook - overcast = 0.0

	outlook	play
3	rainy	yes
4	rainy	yes
5	rainy	no
9	rainy	yes
13	rainy	no

Entropy of outlook - rainy = 0.971

Information Gain for outlook = 0.246

```
✓ [10] entropy_and_infogain(data, 'temp')
```

	temp	play
0	hot	no
1	hot	no
2	hot	yes
12	hot	yes

Entropy of temp - hot = 1.0

	temp	play
3	mild	yes
7	mild	no
9	mild	yes
10	mild	yes
11	mild	yes
13	mild	no

Entropy of temp - mild = 0.918

	temp	play
4	cool	yes
5	cool	no
6	cool	yes
8	cool	yes

Entropy of temp - cool = 0.811

Information Gain for temp = 0.029

```
▶ entropy_and_infogain(data, 'humidity')
```

	humidity	play
0	high	no
1	high	no
2	high	yes
3	high	yes
7	high	no
11	high	yes
13	high	no

Entropy of humidity - high = 0.985

	humidity	play
4	normal	yes
5	normal	no
6	normal	yes
8	normal	yes
9	normal	yes
10	normal	yes
12	normal	yes

Entropy of humidity - normal = 0.592

Information Gain for humidity = 0.151

```
✓ [12] entropy_and_infogain(data, 'windy')
```

	windy	play
0	False	no
2	False	yes
3	False	yes
4	False	yes
7	False	no
8	False	yes
9	False	yes
12	False	yes

Entropy of windy - False = 0.811

	windy	play
1	True	no
5	True	no
6	True	yes
10	True	yes
11	True	yes
13	True	no

Entropy of windy - True = 1.0

Information Gain for windy = 0.048

```

✓ 0s [13] sunny = data[data['outlook'] == 'sunny']
sunny.style.applymap(highlight)\n    .set_properties(subset=data.columns, **{'width': '100px'})\n    .set_table_styles([{('selector': 'th', 'props': [('background-color', 'lightgray'), ('border', '1px solid gray'),\n        ('font-weight', 'bold')]),\n        ('selector': 'tr:hover', 'props': [('background-color', 'white'), ('border', '1.5px solid black')]}])

```

	outlook	temp	humidity	windy	play
0	sunny	hot	high	False	no
1	sunny	hot	high	True	no
7	sunny	mild	high	False	no
8	sunny	cool	normal	False	yes
10	sunny	mild	normal	True	yes

```
✓ 0s [14] print(f'Entropy of the Sunny dataset: {find_entropy(sunny.play)}')
```

Entropy of the Sunny dataset: 0.971

```
✓ 0s [15] entropy_and_infogain(sunny, 'temp')
```

	temp	play
0	hot	no
1	hot	no

Entropy of temp - hot = 0.0

	temp	play
7	mild	no
10	mild	yes

Entropy of temp - mild = 1.0

	temp	play
8	cool	yes

Entropy of temp - cool = 0.0

Information Gain for temp = 0.571

```
✓ 0s [16] entropy_and_infogain(sunny, 'humidity')
```

	humidity	play
0	high	no
1	high	no
7	high	no

Entropy of humidity - high = 0.0

	humidity	play
8	normal	yes
10	normal	yes

Entropy of humidity - normal = 0.0

Information Gain for humidity = 0.971

```
✓ 0s [17] entropy_and_infogain(sunny, 'windy')
```

	windy	play
0	False	no
7	False	no
8	False	yes

Entropy of windy - False = 0.918

	windy	play
1	True	no
10	True	yes

Entropy of windy - True = 1.0

Information Gain for windy = 0.02

```

✓ [13] rainy = data[data['outlook'] == 'rainy']
rainy.style.applymap(highlight)\n    .set_properties(subset=data.columns, **{'width': '100px'})\n    .set_table_styles([{'selector': 'th', 'props': [(['background-color', 'lightgray'], ('border', '1px solid gray'),\n        ('font-weight', 'bold')])],\n        {'selector': 'tr:hover', 'props': [(['background-color', 'white'], ('border', '1.5px solid black'))]}])

```

	outlook	temp	humidity	windy	play
3	rainy	mild	high	False	yes
4	rainy	cool	normal	False	yes
5	rainy	cool	normal	True	no
9	rainy	mild	normal	False	yes
13	rainy	mild	high	True	no

```

✓ [19] print(f'Entropy of the Rainy dataset: {find_entropy(rainy.play)}')

```

Entropy of the Rainy dataset: 0.971

```

✓ [20] entropy_and_infogain(rainy, 'temp')

```

	temp	play
3	mild	yes
9	mild	yes
13	mild	no

Entropy of temp - mild = 0.918

	temp	play
4	cool	yes
5	cool	no

Entropy of temp - cool = 1.0

Information Gain for temp = 0.02

```

✓ [21] entropy_and_infogain(rainy, 'humidity')

```

	humidity	play
3	high	yes
13	high	no

Entropy of humidity - high = 1.0

	humidity	play
4	normal	yes
5	normal	no
9	normal	yes

Entropy of humidity - normal = 0.918

Information Gain for humidity = 0.02

```

✓ [22] entropy_and_infogain(rainy, 'windy')

```

	windy	play
3	False	yes
4	False	yes
9	False	yes

Entropy of windy - False = 0.0

	windy	play
5	True	no
13	True	no

Entropy of windy - True = 0.0

Information Gain for windy = 0.971

4. Build KNN Classification model for a given dataset.:

Code and output:

```
✓ 3s [1] import numpy as np
    import pandas as pd
    import matplotlib.pyplot as plt
    import plotly.express as px
    import seaborn as sns

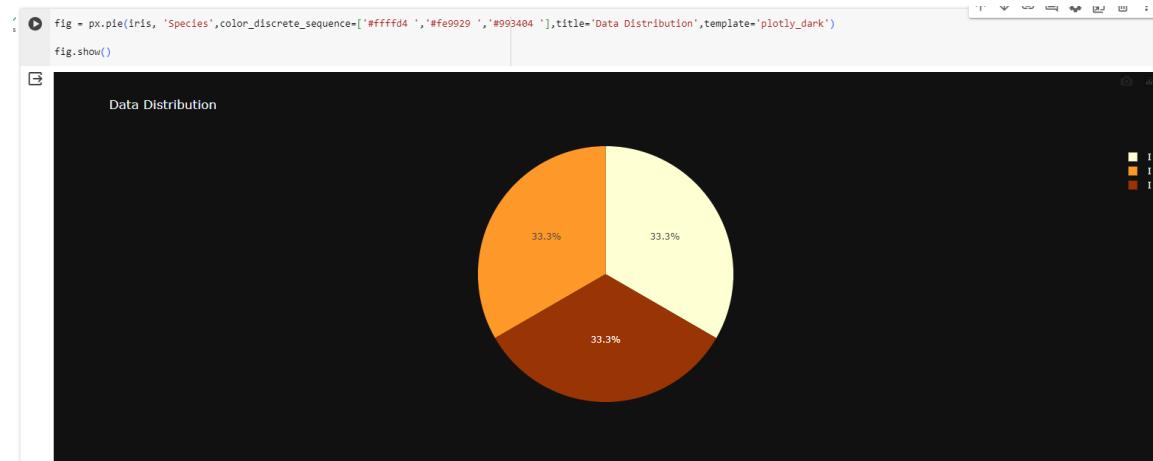
✓ 0s [3] iris = pd.read_csv("Iris.csv") #Load Data
    iris.drop('Id',inplace=True,axis=1) #Drop Id column

✓ 0s [4] iris.head()
```

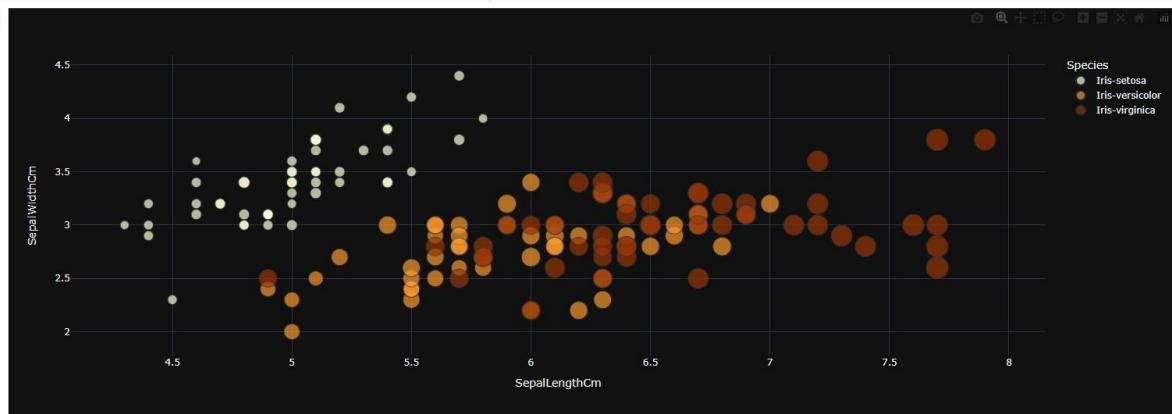
	SepalLengthCm	SepalWidthCm	PetalLengthCm	PetalWidthCm	Species
0	5.1	3.5	1.4	0.2	Iris-setosa
1	4.9	3.0	1.4	0.2	Iris-setosa
2	4.7	3.2	1.3	0.2	Iris-setosa
3	4.6	3.1	1.5	0.2	Iris-setosa
4	5.0	3.6	1.4	0.2	Iris-setosa

Next steps: [View recommended plots](#)

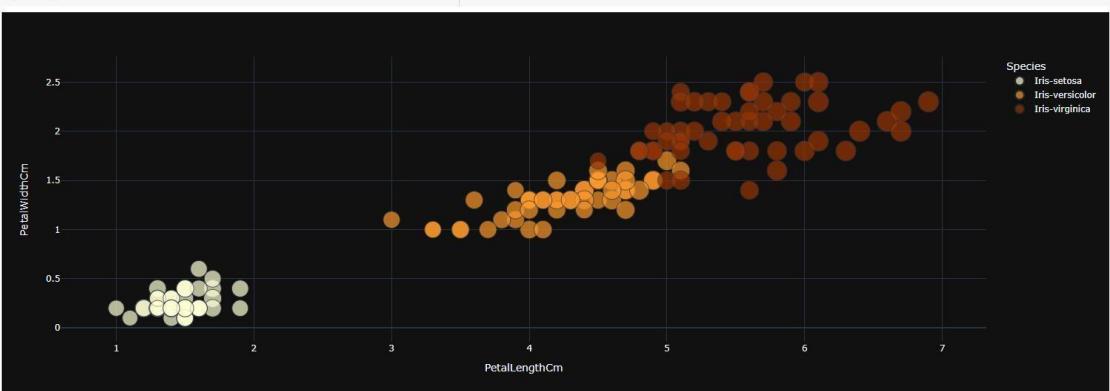
```
✓ 0s [5] X = iris.iloc[:, :-1] #Set our training data
    y = iris.iloc[:, -1] #Set training labels
```



```
fig = px.scatter(data_frame=iris, x='SepalLengthCm',y='SepalWidthCm',  
                  color='Species',size='PetalLengthCm', color_discrete_sequence=['#ffffd4 ','#fe9929 ','#993404 '], template='plotly_dark',)  
fig.show()
```



```
fig = px.scatter(data_frame=iris, x='PetalLengthCm',y='PetalWidthCm',  
                  color='Species',size='SepalLengthCm', color_discrete_sequence=['#ffffd4 ','#fe9929 ','#993404 '], template='plotly_dark',)  
fig.show()
```



```
ls [9] class KNN:
    """
    K-Nearest Neighbors (KNN) classification algorithm

    Parameters:
    -----
    n_neighbors : int, optional (default=5)
        Number of neighbors to use in the majority vote.

    Methods:
    -----
    fit(X_train, y_train):
        Stores the values of X_train and y_train.

    predict(X):
        Predicts the class labels for each example in X.

    """
    def __init__(self, n_neighbors=5):
        self.n_neighbors = n_neighbors

    def euclidean_distance(self, x1, x2):
        """
        Calculate the Euclidean distance between two data points.

        Parameters:
        -----
        x1 : numpy.ndarray, shape (n_features,)
            A data point in the dataset.

        x2 : numpy.ndarray, shape (n_features,)
            A data point in the dataset.

        Returns:
        -----
        distance : float
            The Euclidean distance between x1 and x2.
        """
        return np.linalg.norm(x1 - x2)
```

```

def fit(self, X_train, y_train):
    """
    Stores the values of X_train and y_train.

    Parameters:
    -----
    X_train : numpy.ndarray, shape (n_samples, n_features)
        The training dataset.

    y_train : numpy.ndarray, shape (n_samples,)
        The target labels.
    """
    self.X_train = X_train
    self.y_train = y_train

def predict(self, X):
    """
    Predicts the class labels for each example in X.

    Parameters:
    -----
    X : numpy.ndarray, shape (n_samples, n_features)
        The test dataset.

    Returns:
    -----
    predictions : numpy.ndarray, shape (n_samples,)
        The predicted class labels for each example in X.
    """
    # Create empty array to store the predictions
    predictions = []
    # Loop over X examples
    for x in X:
        # Get prediction using the prediction helper function
        prediction = self._predict(x)
        # Append the prediction to the predictions list
        predictions.append(prediction)
    return np.array(predictions)

```

```

def _predict(self, x):
    """
    Predicts the class label for a single example.

    Parameters:
    -----
    x : numpy.ndarray, shape (n_features,)
        A data point in the test dataset.

    Returns:
    -----
    most_occuring_value : int
        The predicted class label for x.
    """
    # Create empty array to store distances
    distances = []
    # Loop over all training examples and compute the distance between x and all the training examples
    for x_train in self.X_train:
        distance = self.euclidean_distance(x, x_train)
        distances.append(distance)
    distances = np.array(distances)

    # Sort by ascendingly distance and return indices of the given n neighbours
    n_neighbors_idxs = np.argsort(distances)[: self.n_neighbors]

    # Get labels of n-neighbour indexes
    labels = self.y_train[n_neighbors_idxs]
    labels = list(labels)
    # Get the most frequent class in the array
    most_occuring_value = max(labels, key=labels.count)
    return most_occuring_value

```

```

[11] def train_test_split(X, y, random_state=42, test_size=0.2):
    """
    Splits the data into training and testing sets.

    Parameters:
    -----
    X (numpy.ndarray): Features array of shape (n_samples, n_features).
    y (numpy.ndarray): Target array of shape (n_samples,).
    random_state (int): Seed for the random number generator. Default is 42.
    test_size (float): Proportion of samples to include in the test set. Default is 0.2.

    Returns:
    -----
    Tuple[numpy.ndarray]: A tuple containing X_train, X_test, y_train, y_test.
    """
    # Get number of samples
    n_samples = X.shape[0]

    # Set the seed for the random number generator
    np.random.seed(random_state)

    # Shuffle the indices
    shuffled_indices = np.random.permutation(np.arange(n_samples))

    # Determine the size of the test set
    test_size = int(n_samples * test_size)

    # Split the indices into test and train
    test_indices = shuffled_indices[:test_size]
    train_indices = shuffled_indices[test_size:]

    # Split the features and target arrays into test and train
    X_train, X_test = X[train_indices], X[test_indices]
    y_train, y_test = y[train_indices], y[test_indices]

    return X_train, X_test, y_train, y_test

```

```
[12] X_train, X_test, y_train, y_test = train_test_split(X.values, y.values, test_size = 0.2, random_state=42) #
```

```

[13] model = KNN(7)
      model.fit(X_train, y_train)

[14] def compute_accuracy(y_true, y_pred):
      """
      Computes the accuracy of a classification model.

      Parameters:
      y_true (numpy array): A numpy array of true labels for each data point.
      y_pred (numpy array): A numpy array of predicted labels for each data point.

      Returns:
      float: The accuracy of the model, expressed as a percentage.
      """
      y_true = y_true.flatten()
      total_samples = len(y_true)
      correct_predictions = np.sum(y_true == y_pred)
      return (correct_predictions / total_samples)

[15] predictions = model.predict(X_test)
      accuracy = compute_accuracy(y_test, predictions)
      print(f" our model got accuracy score of : {accuracy}")

      our model got accuracy score of : 0.9666666666666667

[16] from sklearn.neighbors import KNeighborsClassifier
      skmodel = KNeighborsClassifier(n_neighbors=7)
      skmodel.fit(X_train, y_train)

      *      KNeighborsClassifier
      KNeighborsClassifier(n_neighbors=7)

[17] sk_predictions = skmodel.predict(X_test)
      sk_accuracy = compute_accuracy(y_test, sk_predictions)
      print(f" sklearn-model got accuracy score of : {sk_accuracy}")

      sklearn-model got accuracy score of : 0.9666666666666667

```

5. Linear Regression:

Code and output:

```
import math
import numpy as np
import pandas as pd
import plotly.express as px
import pickle

[2] # Load the training and test datasets
train_data = pd.read_csv('train.csv')
test_data = pd.read_csv('test.csv')

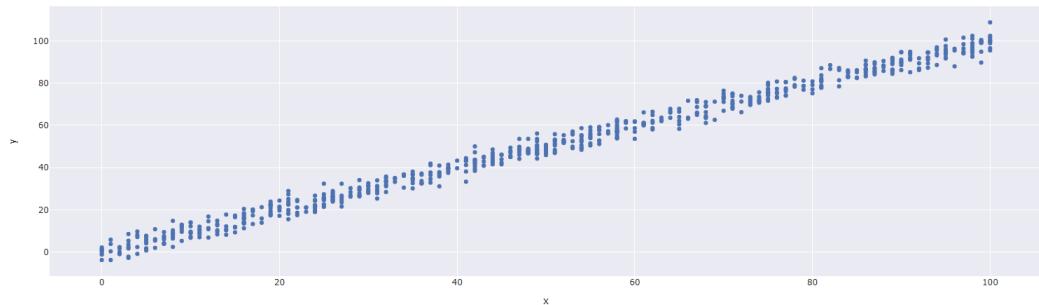
# Remove rows with missing values
train_data = train_data.dropna()
test_data = test_data.dropna()
```

```
[3] train_data.head()
```

	x	y
0	24.0	21.549452
1	50.0	47.464463
2	15.0	17.218656
3	38.0	36.586398
4	87.0	87.288984

Next steps: [View recommended plots](#)

```
[4] px.scatter(x=train_data['x'], y=train_data['y'], template='seaborn')
```



```
[5] # Set training data and target
X_train = train_data['x'].values
y_train = train_data['y'].values

# Set testing data and target
X_test = test_data['x'].values
y_test = test_data['y'].values
```

```

[6] """
Standardizes the input data using mean and standard deviation.

Parameters:
    X_train (numpy.ndarray): Training data.
    X_test (numpy.ndarray): Testing data.

Returns:
    Tuple of standardized training and testing data.
"""

# Calculate the mean and standard deviation using the training data
mean = np.mean(X_train, axis=0)
std = np.std(X_train, axis=0)

# Standardize the data
X_train = (X_train - mean) / std
X_test = (X_test - mean) / std

return X_train, X_test

X_train, X_test = standardize_data(X_train, X_test)

[7] X_train = np.expand_dims(X_train, axis=-1)
X_test = np.expand_dims(X_test, axis=-1)

[8] class LinearRegression:
"""
Linear Regression Model with Gradient Descent

Linear regression is a supervised machine learning algorithm used for modeling the relationship
between a dependent variable (target) and one or more independent variables (features) by fitting
a linear equation to the observed data.

This class implements a linear regression model using gradient descent optimization for training.
It provides methods for model initialization, training, prediction, and model persistence.

Parameters:
    learning_rate (float): The learning rate used in gradient descent.
    convergence_tol (float, optional): The tolerance for convergence (stopping criterion). Defaults to 1e-6.

Attributes:

[8]     W (numpy.ndarray): Coefficients (weights) for the linear regression model.
        b (float): Intercept (bias) for the linear regression model.

Methods:
    initialize_parameters(n_features): Initialize model parameters.
    forward(X): Compute the forward pass of the linear regression model.
    compute_cost(predictions): Compute the mean squared error cost.
    backward(predictions): Compute gradients for model parameters.
    fit(X, y, iterations, plot_cost=True): Fit the linear regression model to training data.
    predict(X): Predict target values for new input data.
    save_model(filename=None): Save the trained model to a file using pickle.
    load_model(filename): Load a trained model from a file using pickle.

Examples:
    >>> from linear_regression import LinearRegression
    >>> model = LinearRegression(learning_rate=0.01)
    >>> model.fit(X_train, y_train, iterations=1000)
    >>> predictions = model.predict(X_test)
    """

    def __init__(self, learning_rate, convergence_tol=1e-6):
        self.learning_rate = learning_rate
        self.convergence_tol = convergence_tol
        self.W = None
        self.b = None

    def initialize_parameters(self, n_features):
        """
        Initialize model parameters.

        Parameters:
            n_features (int): The number of features in the input data.
        """
        self.W = np.random.randn(n_features) * 0.01
        self.b = 0

    def forward(self, X):
        """
        Compute the forward pass of the linear regression model.

        Parameters:
            X (numpy.ndarray): Input data of shape (m, n_features).
        """

```

```
[8]     Returns:
...         numpy.ndarray: Predictions of shape (m,).
...
...     return np.dot(X, self.W) + self.b

def compute_cost(self, predictions):
"""
Compute the mean squared error cost.

Parameters:
predictions (numpy.ndarray): Predictions of shape (m,).

Returns:
float: Mean squared error cost.
"""

m = len(predictions)
cost = np.sum(np.square(predictions - self.y)) / (2 * m)
return cost

def backward(self, predictions):
"""
Compute gradients for model parameters.

Parameters:
predictions (numpy.ndarray): Predictions of shape (m,).

Updates:
numpy.ndarray: Gradient of W.
float: Gradient of b.
"""

m = len(predictions)
self.dW = np.dot(predictions - self.y, self.X) / m
self.db = np.sum(predictions - self.y) / m
def fit(self, X, y, iterations, plot_cost=True):
"""
Fit the linear regression model to the training data.

Parameters:
X (numpy.ndarray): Training input data of shape (m, n_features).
y (numpy.ndarray): Training labels of shape (m,).
iterations (int): The number of iterations for gradient descent.
plot_cost (bool, optional): Whether to plot the cost during training. Defaults to True.

```

```
[8]
Raises:
AssertionError: If input data and labels are not NumPy arrays or have mismatched shapes.

Plots:
Plotly line chart showing cost vs. iteration (if plot_cost is True).
"""

assert isinstance(X, np.ndarray), "X must be a NumPy array"
assert isinstance(y, np.ndarray), "y must be a NumPy array"
assert X.shape[0] == y.shape[0], "X and y must have the same number of samples"
assert iterations > 0, "Iterations must be greater than 0"

self.X = X
self.y = y
self.initialize_parameters(X.shape[1])
costs = []

for i in range(iterations):
    predictions = self.forward(X)
    cost = self.compute_cost(predictions)
    self.backward(predictions)
    self.W -= self.learning_rate * self.dW
    self.b -= self.learning_rate * self.db
    costs.append(cost)

    if i % 100 == 0:
        print(f'Iteration: {i}, Cost: {cost}')

    if i > 0 and abs(costs[-1] - costs[-2]) < self.convergence_tol:
        print(f'Converged after {i} iterations.')
        break

if plot_cost:
    fig = px.line(y=costs, title="Cost vs Iteration", template="plotly_dark")
    fig.update_layout(
        title_font_color="#41BEE9",
        xaxis=dict(color="#41BEE9", title="Iterations"),
        yaxis=dict(color="#41BEE9", title="Cost")
    )
    fig.show()
```

```

        fig.show()
    def predict(self, X):
        """
        Predict target values for new input data.

        Parameters:
            X (numpy.ndarray): Input data of shape (m, n_features).

        Returns:
            numpy.ndarray: Predicted target values of shape (m,).
        """
        return self.forward(X)

    def save_model(self, filename=None):
        """
        Save the trained model to a file using pickle.

        Parameters:
            filename (str): The name of the file to save the model to.
        """
        model_data = {
            'learning_rate': self.learning_rate,
            'convergence_tol': self.convergence_tol,
            'W': self.W,
            'b': self.b
        }

        with open(filename, 'wb') as file:
            pickle.dump(model_data, file)

    @classmethod
    def load_model(cls, filename):
        """
        Load a trained model from a file using pickle.

        Parameters:
            filename (str): The name of the file to load the model from.
        """

```

```

8]     with open(filename, 'wb') as file:
            pickle.dump(model_data, file)

    @classmethod
    def load_model(cls, filename):
        """
        Load a trained model from a file using pickle.

        Parameters:
            filename (str): The name of the file to load the model from.

        Returns:
            LinearRegression: An instance of the LinearRegression class with loaded parameters.
        """
        with open(filename, 'rb') as file:
            model_data = pickle.load(file)

        # Create a new instance of the class and initialize it with the loaded parameters
        loaded_model = cls(model_data['learning_rate'], model_data['convergence_tol'])
        loaded_model.W = model_data['W']
        loaded_model.b = model_data['b']

        return loaded_model

```

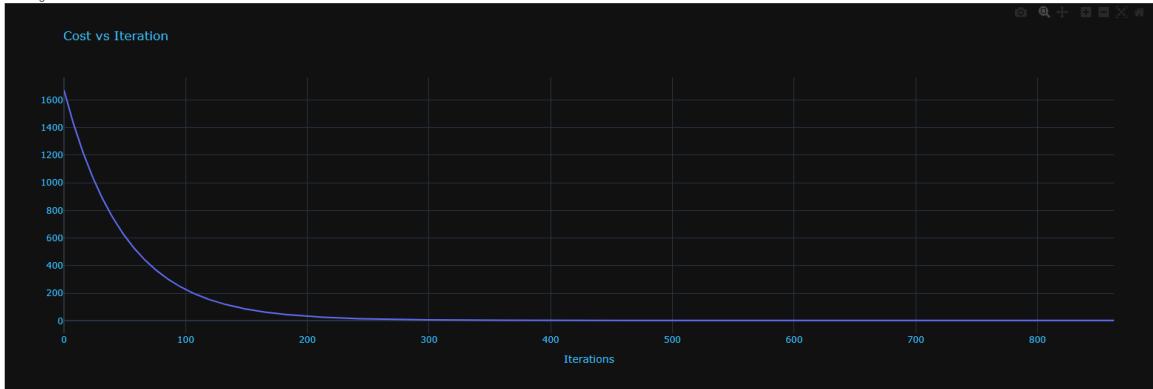
```

9] lr = LinearRegression(0.01)
lr.fit(X_train, y_train, 10000)

Iteration: 0, Cost: 1670.0184887161677
Iteration: 100, Cost: 227.15535101517312
Iteration: 200, Cost: 33.84101696145528
Iteration: 300, Cost: 7.9408253395546575
Iteration: 400, Cost: 4.4707260872934835
Iteration: 500, Cost: 4.005803317758673
Iteration: 600, Cost: 3.943513116253261
Iteration: 700, Cost: 3.9351674953098015
Iteration: 800, Cost: 3.9340493517293096
Converged after 863 iterations.

```

```
Iteration: 700, Cost: 3.9340493517293096
Iteration: 800, Cost: 3.9340493517293096
Converged after 803 iterations.
```



```
[10] lr.save_model('model.pkl')
```

```
[11] model = LinearRegression.load_model("model.pkl")
```

```
[12] class RegressionMetrics:
    @staticmethod
    def mean_squared_error(y_true, y_pred):
        """
        Calculate the Mean Squared Error (MSE).

        Args:
            y_true (numpy.ndarray): The true target values.
            y_pred (numpy.ndarray): The predicted target values.

        Returns:
            float: The Mean Squared Error.
        """
        assert len(y_true) == len(y_pred), "Input arrays must have the same length."
        mse = np.mean((y_true - y_pred) ** 2)
        return mse

    @staticmethod
    def root_mean_squared_error(y_true, y_pred):
        """
        Calculate the Root Mean Squared Error (RMSE).

        Args:
            y_true (numpy.ndarray): The true target values.
            y_pred (numpy.ndarray): The predicted target values.

        Returns:
            float: The Root Mean Squared Error.
        """
        assert len(y_true) == len(y_pred), "Input arrays must have the same length."
        mse = RegressionMetrics.mean_squared_error(y_true, y_pred)
        rmse = np.sqrt(mse)
        return rmse

    @staticmethod
    def r_squared(y_true, y_pred):
        """
        Calculate the R-squared (R^2) coefficient of determination.

        Args:
            y_true (numpy.ndarray): The true target values.
            y_pred (numpy.ndarray): The predicted target values.
        
```

```
[12]     @staticmethod
def r_squared(y_true, y_pred):
    """
    Calculate the R-squared (R^2) coefficient of determination.

    Args:
        y_true (numpy.ndarray): The true target values.
        y_pred (numpy.ndarray): The predicted target values.

    Returns:
        float: The R-squared (R^2) value.
    """
    assert len(y_true) == len(y_pred), "Input arrays must have the same length."
    mean_y = np.mean(y_true)
    ss_total = np.sum((y_true - mean_y) ** 2)
    ss_residual = np.sum((y_true - y_pred) ** 2)
    r2 = 1 - (ss_residual / ss_total)
    return r2
```

```
[13] y_pred = model.predict(X_test)
mse_value = RegressionMetrics.mean_squared_error(y_test, y_pred)
rmse_value = RegressionMetrics.root_mean_squared_error(y_test, y_pred)
r_squared_value = RegressionMetrics.r_squared(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse_value}")
print(f"Root Mean Squared Error (RMSE): {rmse_value}")
print(f"R-squared (Coefficient of Determination): {r_squared_value}")

Mean Squared Error (MSE): 9.44266965025894
Root Mean Squared Error (RMSE): 3.07289271701095
R-squared (Coefficient of Determination): 0.9887898724670081
```

```
▶ model.predict([[2]])
array([107.82727115])
```

6. Logistic Regression

```

✓ [4] import math
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import plotly.express as px
import pprint
import pickle

✓ [5] df = pd.read_csv('breast-cancer.csv')

✓ [5] df.head()

  id diagnosis radius_mean texture_mean perimeter_mean area_mean smoothness_mean compactness_mean concavity_mean ...
  0 842302 M 17.99 10.38 122.80 1001.0 0.11840 0.27760 0.3001 0.14710 ... 25.38 17.33 184.60
  1 842517 M 20.57 17.77 132.90 1326.0 0.08474 0.07864 0.0869 0.07017 ... 24.99 23.41 158.80
  2 84300903 M 19.69 21.25 130.00 1203.0 0.10960 0.15990 0.1974 0.12790 ... 23.57 25.53 152.50
  3 84348301 M 11.42 20.38 77.58 386.1 0.14250 0.28390 0.2414 0.10520 ... 14.91 26.50 98.87
  4 84558402 M 20.29 14.34 135.10 1297.0 0.10030 0.13280 0.1980 0.10430 ... 22.54 16.67 152.20
5 rows × 32 columns

✓ [6] df.drop('id', axis=1, inplace=True) #drop redundant columns

✓ [7] df['diagnosis'] = (df['diagnosis'] == 'M').astype(int) #encode the label into 1/0

✓ [8] corr = df.corr()

✓ [9] plt.figure(figsize=(20,20))
sns.heatmap(corr, cmap='mako_r', annot=True)
plt.show()

```

```
✓ [12] # Get the absolute value of the correlation
cor_target = abs(corr["diagnosis"])

# Select highly correlated features (threshold = 0.2)
relevant_features = cor_target[cor_target>0.2]

# Collect the names of the features
names = [index for index, value in relevant_features.items()]

# Drop the target variable from the results
names.remove('diagnosis')

# Display the results
pprint.pprint(names)

[ 'radius_mean',
  'texture_mean',
  'perimeter_mean',
  'area_mean',
  'smoothness_mean',
  'compactness_mean',
  'concavity_mean',
  'concave points_mean',
  'symmetry_mean',
  'radius_se',
  'perimeter_se',
  'area_se',
  'compactness_se',
  'concavity_se',
  'concave points_se',
  'radius_worst',
  'texture_worst',
  'perimeter_worst',
  'area_worst',
  'smoothness_worst',
  'compactness_worst',
  'concavity_worst',
  'concave points_worst',
  'symmetry_worst',
  'fractal_dimension_worst']
```

```
[13] X = df[names].values
y = df['diagnosis'].values

[14] def train_test_split(X, y, random_state=42, test_size=0.2):
    """
    Splits the data into training and testing sets.

    Parameters:
        X (numpy.ndarray): Features array of shape (n_samples, n_features).
        y (numpy.ndarray): Target array of shape (n_samples,).
        random_state (int): Seed for the random number generator. Default is 42.
        test_size (float): Proportion of samples to include in the test set. Default is 0.2.

    Returns:
        Tuple[numpy.ndarray]: A tuple containing X_train, X_test, y_train, y_test.
    """
    # Get number of samples
    n_samples = X.shape[0]

    # Set the seed for the random number generator
    np.random.seed(random_state)

    # Shuffle the indices
    shuffled_indices = np.random.permutation(np.arange(n_samples))

    # Determine the size of the test set
    test_size = int(n_samples * test_size)

    # Split the indices into test and train
    test_indices = shuffled_indices[:test_size]
    train_indices = shuffled_indices[test_size:]

    # Split the features and target arrays into test and train
    X_train, X_test = X[train_indices], X[test_indices]
    y_train, y_test = y[train_indices], y[test_indices]

    return X_train, X_test, y_train, y_test
```

```

/x [15] x_train, x_test, y_train, y_test = train_test_split(X,y)

/x [16] def standardize_data(X_train, X_test):
    """
        Standardizes the input data using mean and standard deviation.

    Parameters:
        X_train (numpy.ndarray): Training data.
        X_test (numpy.ndarray): Testing data.

    Returns:
        Tuple of standardized training and testing data.
    """
    # Calculate the mean and standard deviation using the training data
    mean = np.mean(X_train, axis=0)
    std = np.std(X_train, axis=0)

    # Standardize the data
    X_train = (X_train - mean) / std
    X_test = (X_test - mean) / std

    return X_train, X_test

x_train, x_test = standardize_data(X_train, X_test)

/x [17] def sigmoid(z):
    """
        Compute the sigmoid function for a given input.

        The sigmoid function is a mathematical function used in logistic regression and neural networks
        to map any real-valued number to a value between 0 and 1.

    Parameters:
        z (float or numpy.ndarray): The input value(s) for which to compute the sigmoid.

    Returns:
        float or numpy.ndarray: The sigmoid of the input value(s).

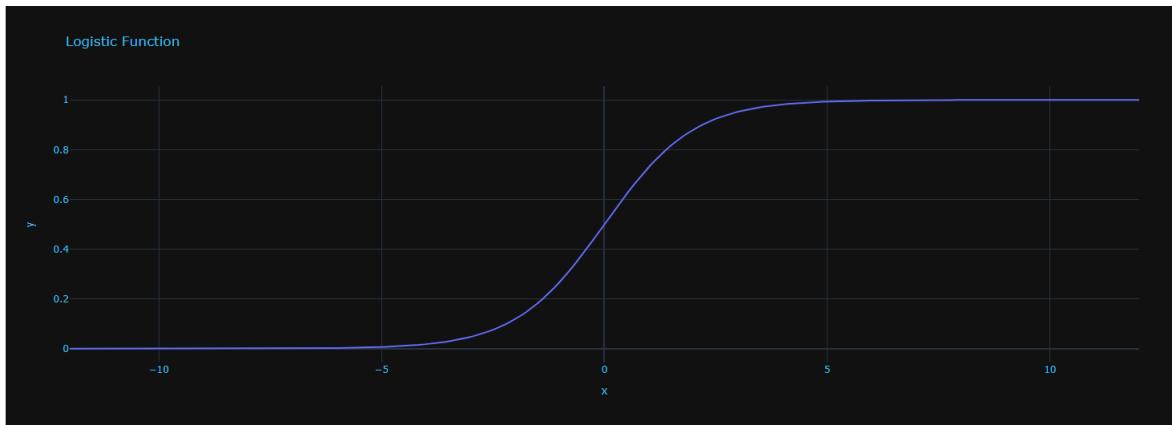
    Example:
        >>> sigmoid(0)
        0.5
    """
    # Compute the sigmoid function using the formula: 1 / (1 + e^(-z)).
    sigmoid_result = 1 / (1 + np.exp(-z))

    # Return the computed sigmoid value.
    return sigmoid_result

/z z = np.linspace(-12, 12, 200)

fig = px.line(x=z, y=sigmoid(z), title='Logistic Function', template="plotly_dark")
fig.update_layout(
    title_font_color="#41BEE9",
    xaxis=dict(color="#41BEE9"),
    yaxis=dict(color="#41BEE9"))
)
fig.show()

```



```
[19] class LogisticRegression:
    """
    Logistic Regression model.

    Parameters:
        learning_rate (float): Learning rate for the model.

    Methods:
        initialize_parameter(): Initializes the parameters of the model.
        sigmoid(): Computes the sigmoid activation function for given input z.
        forward(X): Computes forward propagation for given input X.
    """

    def __init__(self, learning_rate=0.0001):
        np.random.seed(1)
        self.learning_rate = learning_rate

    def initialize_parameter(self):
        """
        Initializes the parameters of the model.
        """
        self.W = np.zeros(self.X.shape[1])
        self.b = 0.0

    def forward(self, X):
        """
        Computes forward propagation for given input X.

        Parameters:
            X (numpy.ndarray): Input array.

        Returns:
            numpy.ndarray: Output array.
        """
        Z = np.matmul(X, self.W) + self.b
        A = sigmoid(Z)
        return A
```

```
    def compute_cost(self, predictions):
        """
        Computes the cost function for given predictions.

        Parameters:
            predictions (numpy.ndarray): Predictions of the model.

        Returns:
            float: Cost of the model.
        """
        m = self.X.shape[0] # number of training examples
        # compute the cost
        cost = np.sum((-np.log(predictions + 1e-8) * self.y) + (-np.log(1 - predictions + 1e-8)) * (
            1 - self.y)) # we are adding small value epsilon to avoid log of 0
```

```
[19]     """
    Compute cost of the model.
    m = self.X.shape[0] # number of training examples
    # compute the cost
    cost = np.sum((-np.log(predictions + 1e-8) * self.y) + (-np.log(1 - predictions + 1e-8)) * (
        1 - self.y)) # we are adding small value epsilon to avoid log of 0
    cost = cost / m
    return cost
def compute_gradient(self, predictions):
    """
    Computes the gradients for the model using given predictions.

    Parameters:
        predictions (numpy.ndarray): Predictions of the model.
    """
    # get training shape
    m = self.X.shape[0]

    # compute gradients
    self.dW = np.matmul(self.X.T, (predictions - self.y))
    self.dW = np.array([np.mean(grad) for grad in self.dW])

    self.db = np.sum(np.subtract(predictions, self.y))

    # scale gradients
    self.dW = self.dW * 1 / m
    self.db = self.db * 1 / m

def fit(self, X, y, iterations, plot_cost=True):
    """
    Trains the model on given input X and labels y for specified iterations.

    Parameters:
        X (numpy.ndarray): Input features array of shape (n_samples, n )
        y (numpy.ndarray): Labels array of shape (n_samples, 1)
        iterations (int): Number of iterations for training.
        plot_cost (bool): Whether to plot cost over iterations or not.

    Returns:
        None.
    """
    self.X = X
```

```

19]         self.X = X
        self.y = y

        self.initialize_parameter()

        costs = []
        for i in range(iterations):
            # forward propagation
            predictions = self.forward(self.X)

            # compute cost
            cost = self.compute_cost(predictions)
            costs.append(cost)

            # compute gradients
            self.compute_gradient(predictions)

            # update parameters
            self.W = self.W - self.learning_rate * self.dW
            self.b = self.b - self.learning_rate * self.db

            # print cost every 100 iterations
            if i % 10000 == 0:
                print("Cost after iteration {}: {}".format(i, cost))

        if plot_cost:
            fig = px.line(y=costs,title="Cost vs Iteration",template="plotly_dark")
            fig.update_layout(
                title_font_color="#41BEE9",
                xaxis=dict(color="#41BEE9",title="Iterations"),
                yaxis=dict(color="#41BEE9",title="cost")
            )
            fig.show()
    def predict(self, X):
        """
        Predicts the labels for given input X.

        Parameters:
        X (numpy.ndarray): Input features array.

        Returns:
        numpy.ndarray: Predicted labels.
        """

```

```
[19]     predictions = self.forward(X)
             return np.round(predictions)

    def save_model(self, filename=None):
        """
        Save the trained model to a file using pickle.

        Parameters:
            filename (str): The name of the file to save the model to.
        """
        model_data = {
            'learning_rate': self.learning_rate,
            'W': self.W,
            'b': self.b
        }

        with open(filename, 'wb') as file:
            pickle.dump(model_data, file)

    @classmethod
    def load_model(cls, filename):
        """
        Load a trained model from a file using pickle.

        Parameters:
            filename (str): The name of the file to load the model from.

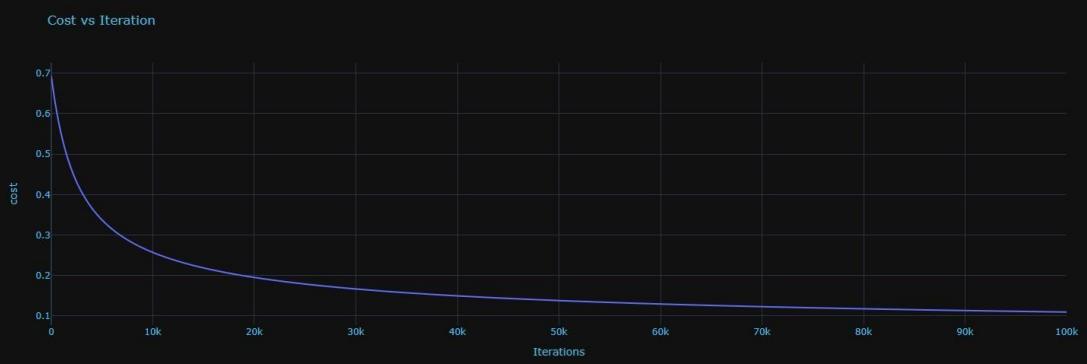
        Returns:
            LogisticRegression: An instance of the LogisticRegression class with loaded parameters.
        """
        with open(filename, 'rb') as file:
            model_data = pickle.load(file)

        # Create a new instance of the class and initialize it with the loaded parameters
        loaded_model = cls(model_data['learning_rate'])
        loaded_model.W = model_data['W']
        loaded_model.b = model_data['b']

        return loaded_model
```

```
[20] lg = LogisticRegression()
      lg.fit(X_train, y_train, 100000)
```

```
Cost after iteration 0: 0.6931471605599454
Cost after iteration 10000: 0.257077837858246
Cost after iteration 20000: 0.19529178673689726
Cost after iteration 30000: 0.166853626756163852
Cost after iteration 40000: 0.14978939548676498
Cost after iteration 50000: 0.13887613401554
Cost after iteration 60000: 0.126691234813
Cost after iteration 70000: 0.123114403988139
Cost after iteration 80000: 0.11785163708790082
Cost after iteration 90000: 0.113515771386802
```



```

[22] lg.save_model("model.pkl")

[23] class ClassificationMetrics:
    @staticmethod
    def accuracy(y_true, y_pred):
        """
        Computes the accuracy of a classification model.

        Parameters:
        y_true (numpy array): A numpy array of true labels for each data point.
        y_pred (numpy array): A numpy array of predicted labels for each data point.

        Returns:
        float: The accuracy of the model, expressed as a percentage.
        """
        y_true = y_true.flatten()
        total_samples = len(y_true)
        correct_predictions = np.sum(y_true == y_pred)
        return (correct_predictions / total_samples)

    @staticmethod
    def precision(y_true, y_pred):
        """
        Computes the precision of a classification model.

        Parameters:
        y_true (numpy array): A numpy array of true labels for each data point.
        y_pred (numpy array): A numpy array of predicted labels for each data point.

        Returns:
        float: The precision of the model, which measures the proportion of true positive predictions
        out of all positive predictions made by the model.
        """
        true_positives = np.sum((y_true == 1) & (y_pred == 1))
        false_positives = np.sum((y_true == 0) & (y_pred == 1))
        return true_positives / (true_positives + false_positives)

```

```

[23] @staticmethod
def recall(y_true, y_pred):
    """
    Computes the recall (sensitivity) of a classification model.

    Parameters:
    y_true (numpy array): A numpy array of true labels for each data point.
    y_pred (numpy array): A numpy array of predicted labels for each data point.

    Returns:
    float: The recall of the model, which measures the proportion of true positive predictions
    out of all actual positive instances in the dataset.
    """
    true_positives = np.sum((y_true == 1) & (y_pred == 1))
    false_negatives = np.sum((y_true == 1) & (y_pred == 0))
    return true_positives / (true_positives + false_negatives)

    @staticmethod
    def f1_score(y_true, y_pred):
        """
        Computes the F1-score of a classification model.

        Parameters:
        y_true (numpy array): A numpy array of true labels for each data point.
        y_pred (numpy array): A numpy array of predicted labels for each data point.

        Returns:
        float: The F1-score of the model, which is the harmonic mean of precision and recall.
        """
        precision_value = ClassificationMetrics.precision(y_true, y_pred)
        recall_value = ClassificationMetrics.recall(y_true, y_pred)
        return 2 * (precision_value * recall_value) / (precision_value + recall_value)

```

```
[24] model = LogisticRegression.load_model("model.pkl")
```

```
✓ [24] model = LogisticRegression.load_model("model.pkl")
0s

✓ [25] y_pred = model.predict(X_test)
        accuracy = ClassificationMetrics.accuracy(y_test, y_pred)
        precision = ClassificationMetrics.precision(y_test, y_pred)
        recall = ClassificationMetrics.recall(y_test, y_pred)
        f1_score = ClassificationMetrics.f1_score(y_test, y_pred)

        print(f"Accuracy: {accuracy:.2%}")
        print(f"Precision: {precision:.2%}")
        print(f"Recall: {recall:.2%}")
        print(f"F1-Score: {f1_score:.2%}")

Accuracy: 98.23%
Precision: 100.00%
Recall: 95.24%
F1-Score: 97.56%
```

7. Build Support vector machine model for a given dataset

```
✓ 1a  from google.colab import drive
drive.mount('/content/drive')

Mounted at /content/drive

✓ [2] import seaborn as sns
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import plotly.express as px

✓ [3] df = pd.read_csv('/content/drive/MyDrive/breast-cancer.csv')
df.head()

id diagnosis radius_mean texture_mean perimeter_mean area_mean smoothness_mean compactness_mean concavity_mean concave
points_mean ... rad
0 842302 M 17.99 10.38 122.80 1001.0 0.11840 0.27760 0.3001 0.14710 ...
1 842517 M 20.57 17.77 132.90 1326.0 0.08474 0.07864 0.0869 0.07017 ...
2 84300903 M 19.69 21.25 130.00 1203.0 0.10960 0.15990 0.1974 0.12790 ...
3 84348301 M 11.42 20.38 77.58 386.1 0.14250 0.28390 0.2414 0.10520 ...
4 84358402 M 20.29 14.34 135.10 1297.0 0.10030 0.13280 0.1980 0.10430 ...

5 rows × 32 columns

[4] df.drop('id', axis=1, inplace=True) #drop redundant columns

[5] df.describe().T

radius_mean texture_mean perimeter_mean area_mean smoothness_mean compactness_mean concavity_mean concave
points_mean ... rad
count 569.0 14.127292 3.524049 6.981000 11.700000 13.370000 15.780000 28.11000
mean 569.0 19.289649 4.301036 9.710000 16.170000 18.840000 21.800000 39.28000
std 569.0 91.969033 24.298981 43.790000 75.170000 86.240000 104.100000 188.50000
min 569.0 654.889104 351.914129 143.500000 420.300000 551.100000 782.700000 2501.00000
25% 569.0 0.096360 0.014064 0.052630 0.086370 0.095870 0.105300 0.16340
50% 569.0 0.104341 0.052813 0.019380 0.064920 0.092630 0.130400 0.34540
75% 569.0 0.088799 0.079720 0.000000 0.029560 0.061540 0.130700 0.42680
max 569.0 0.048919 0.038803 0.000000 0.020310 0.033500 0.074000 0.20120
symmetry_mean 569.0 0.181162 0.027414 0.106000 0.161900 0.179200 0.195700 0.30400
fractal_dimension_mean 569.0 0.062798 0.007060 0.049960 0.057700 0.061540 0.066120 0.09744
radius_se 569.0 0.405172 0.277313 0.111500 0.232400 0.324200 0.478900 2.87300
texture_se 569.0 1.216853 0.551648 0.360200 0.833900 1.108000 1.474000 4.88500
perimeter_se 569.0 2.866059 2.021855 0.757000 1.606000 2.287000 3.357000 21.98000
area_se 569.0 40.337079 45.491006 6.802000 17.850000 24.530000 45.190000 542.20000
smoothness_se 569.0 0.007041 0.003003 0.001713 0.005169 0.006380 0.008146 0.03113
compactness_se 569.0 0.025478 0.017000 0.002252 0.012000 0.020450 0.022450 0.12540
```

```

✓ [7] df['diagnosis'] = (df['diagnosis'] == 'M').astype(int) #encode the label into 1/0
✓ [8] corr = df.corr()

✓ [10] # Get the absolute value of the correlation
        cor_target = abs(corr["diagnosis"])

# Select highly correlated features (threshold = 0.2)
relevant_features = cor_target[cor_target>0.2]

# Collect the names of the features
names = [index for index, value in relevant_features.items()]

# Drop the target variable from the results
names.remove('diagnosis')

# Display the results
print(names)

['radius_mean', 'texture_mean', 'perimeter_mean', 'area_mean', 'smoothness_mean', 'compactness_mean', 'concavity_mean', 'concave points_mean', 'symmetry_mean']

[11] X = df[names].values
y = df['diagnosis']

[12] def scale(X):
    """
    Standardizes the data in the array X.

    Parameters:
    X (numpy.ndarray): Features array of shape (n_samples, n_features).

    Returns:
    numpy.ndarray: The standardized features array.
    """
    # Calculate the mean and standard deviation of each feature
    mean = np.mean(X, axis=0)
    std = np.std(X, axis=0)

    # Standardize the data
    X = (X - mean) / std
    return X

[13] X = scale(X)

✓ [14] def train_test_split(X, y, random_state=42, test_size=0.2):
    """
    Splits the data into training and testing sets.

    Parameters:
    X (numpy.ndarray): Features array of shape (n_samples, n_features).
    y (numpy.ndarray): Target array of shape (n_samples,).
    random_state (int): Seed for the random number generator. Default is 42.
    test_size (float): Proportion of samples to include in the test set. Default is 0.2.

    Returns:
    Tuple[numpy.ndarray]: A tuple containing X_train, X_test, y_train, y_test.
    """
    # Get number of samples
    n_samples = X.shape[0]

    # Set the seed for the random number generator
    np.random.seed(random_state)

    # Shuffle the indices
    shuffled_indices = np.random.permutation(np.arange(n_samples))

    # Determine the size of the test set
    test_size = int(n_samples * test_size)

    # Split the indices into test and train
    test_indices = shuffled_indices[:test_size]
    train_indices = shuffled_indices[test_size:]

    # Split the features and target arrays into test and train
    X_train, X_test = X[train_indices], X[test_indices]
    y_train, y_test = y[train_indices], y[test_indices]

    return X_train, X_test, y_train, y_test

✓ [15] X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_state=42) #split the data into traing and validation

```

```

[18] class SVM:
    """
    A Support Vector Machine (SVM) implementation using gradient descent.

    Parameters:
    -----
    iterations : int, default=1000
        The number of iterations for gradient descent.
    lr : float, default=0.01
        The learning rate for gradient descent.
    lambdaa : float, default=0.01
        The regularization parameter.

    Attributes:
    -----
    lambdaa : float
        The regularization parameter.
    iterations : int
        The number of iterations for gradient descent.
    lr : float
        The learning rate for gradient descent.
    w : numpy array
        The weights.
    b : float
        The bias.

    Methods:
    -----
    initialize_parameters(X)
        Initializes the weights and bias.
    gradient_descent(X, y)
        Updates the weights and bias using gradient descent.
    ...

    update_parameters(dw, db)
        Updates the weights and bias.
    fit(X, y)
        Fits the SVM to the data.
    predict(X)
        Predicts the labels for the given data.

    """
    def __init__(self, iterations=1000, lr=0.01, lambdaa=0.01):
        """
        Initializes the SVM model.

        Parameters:
        -----
        iterations : int, default=1000
            The number of iterations for gradient descent.
        lr : float, default=0.01
            The learning rate for gradient descent.
        lambdaa : float, default=0.01
            The regularization parameter.
        """
        self.lambdaa = lambdaa
        self.iterations = iterations
        self.lr = lr
        self.w = None
        self.b = None
    def initialize_parameters(self, X):
        """
        Initializes the weights and bias.

        Parameters:
        -----
        ...

```

```

✓ [18]      X : numpy array
             The input data.
"""
m, n = X.shape
self.w = np.zeros(n)
self.b = 0

def gradient_descent(self, X, y):
"""
Updates the weights and bias using gradient descent.

Parameters:
-----
X : numpy array
    The input data.
y : numpy array
    The target values.
"""
y_ = np.where(y <= 0, -1, 1)
for i, x in enumerate(X):
    if y_[i] * (np.dot(x, self.w) - self.b) >= 1:
        dw = 2 * self.lambdab * self.w
        db = 0
    else:
        dw = 2 * self.lambdab * self.w - np.dot(x, y_[i])
        db = y_[i]
    self.update_parameters(dw, db)

def update_parameters(self, dw, db):
"""
Updates the weights and bias.

Parameters:

```

```

✓ [18]      dw : numpy array
             The change in weights.
db : float
             The change in bias.
"""
self.w = self.w - self.lr * dw
self.b = self.b - self.lr * db
def fit(self, X, y):
"""
Fits the SVM to the data.

Parameters:
-----
X : numpy array
    The input data.
y : numpy array
    The target values.
"""
self.initialize_parameters(X)
for i in range(self.iterations):
    self.gradient_descent(X, y)

def predict(self, X):
"""
Predicts the class labels for the test data.

Parameters
-----
X : array-like, shape (n_samples, n_features)
    The input data.

Returns

```

```
[18]     Returns
-----
y_pred : array-like, shape (n_samples,)
    The predicted class labels.

"""
# get the outputs
output = np.dot(X, self.w) - self.b
# get the signs of the labels depending on if it's greater/less than zero
label_signs = np.sign(output)
#set predictions to 0 if they are less than or equal to -1 else set them to 1
predictions = np.where(label_signs <= -1, 0, 1)
return predictions
```

```
[19] def accuracy(y_true, y_pred):
"""
Computes the accuracy of a classification model.

Parameters:
-----
y_true (numpy array): A numpy array of true labels for each data point.
y_pred (numpy array): A numpy array of predicted labels for each data point.

Returns:
-----
float: The accuracy of the model
"""
total_samples = len(y_true)
correct_predictions = np.sum(y_true == y_pred)
return (correct_predictions / total_samples)
```

```
[20] model = SVM()
model.fit(X_train,y_train)
predictions = model.predict(X_test)

accuracy(y_test, predictions)
```

```
→ 0.9823008849557522
```

```
[28] model.predict([-0.47069438, -0.16048584, -0.44810956, -0.49199876,  0.23411429,
  0.02765051, -0.10984741, -0.27623152,  0.41394897, -0.03274296,
 -0.18269561, -0.22105292, -0.35591235, -0.16192949, -0.23133322,
 -0.26903951, -0.16890536, -0.33393537, -0.35629925,  0.4485028 ,
 -0.10474068, -0.02441212, -0.19956318,  0.18320441,  0.19695794])
```

```
→ array(0)
```

8. Build k-Means algorithm to cluster a set of data stored in a .CSV file.

```
✓ [1] from google.colab import drive
drive.mount('/content/drive')

↳ Mounted at /content/drive

✓ [2] import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import plotly.express as px
import seaborn as sns
import plotly.graph_objects as go

✓ [3] iris = pd.read_csv("/content/drive/MyDrive/Iris.csv") #Load Data
iris.drop('Id',inplace=True,axis=1) #Drop Id column

✓ [4] X = iris.iloc[:, :-1] #Set our training data
y = iris.iloc[:, -1] #We'll use this just for visualization as clustering doesn't require labels

✓ [5] class Kmeans:
    """
    K-Means clustering algorithm implementation.

    Parameters:
    K (int): Number of clusters

    Attributes:
    K (int): Number of clusters
    centroids (numpy.ndarray): Array containing the centroids of each cluster

    Methods:
    __init__(self, K): Initializes the Kmeans instance with the specified number of clusters.
    initialize_centroids(self, X): Initializes the centroids for each cluster by selecting K random points from the dataset.
    assign_points_centroids(self, X): Assigns each point in the dataset to the nearest centroid.
    compute_mean(self, X, points): Computes the mean of the points assigned to each centroid.
    fit(self, X, iterations=10): Clusters the dataset using the K-Means algorithm.
    """

    def __init__(self, K):
        assert K > 0, "K should be a positive integer."
        self.K = K

    def initialize_centroids(self, X):
        assert X.shape[0] >= self.K, "Number of data points should be greater than or equal to K."

        randomized_X = np.random.permutation(X.shape[0])
        centroid_idx = randomized_X[:self.K] # get the indices for the centroids
        self.centroids = X[centroid_idx] # assign the centroids to the selected points

    def assign_points_centroids(self, X):
        """
        Assign each point in the dataset to the nearest centroid.

        Parameters:
        X (numpy.ndarray): dataset to cluster

        Returns:
        numpy.ndarray: array containing the index of the centroid for each point
        """
        X = np.expand_dims(X, axis=1) # expand dimensions to match shape of centroids
        distance = np.linalg.norm((X - self.centroids), axis=1) # calculate Euclidean distance between each point and each centroid
        points = np.argmin(distance, axis=1) # assign each point to the closest centroid
        assert len(points) == X.shape[0], "Number of assigned points should equal the number of data points."
```

```

✓ [5]     points = np.argmax(distance, axis=1) # assign each point to the closest centroid
          assert len(points) == X.shape[0], "Number of assigned points should equal the number of data points."
          return points

def compute_mean(self, X, points):
    """
    Compute the mean of the points assigned to each centroid.

    Parameters:
    X (numpy.ndarray): dataset to cluster
    points (numpy.ndarray): array containing the index of the centroid for each point

    Returns:
    numpy.ndarray: array containing the new centroids for each cluster
    """
    centroids = np.zeros((self.K, X.shape[1])) # initialize array to store centroids
    for i in range(self.K):
        centroid_mean = X[points == i].mean(axis=0) # calculate mean of the points assigned to the current centroid
        centroids[i] = centroid_mean # assign the new centroid to the mean of its points
    return centroids

def fit(self, X, iterations=10):
    """
    Cluster the dataset using the K-Means algorithm.

    Parameters:
    X (numpy.ndarray): dataset to cluster
    iterations (int): number of iterations to perform (default=10)

    Returns:
    numpy.ndarray: array containing the final centroids for each cluster
    numpy.ndarray: array containing the index of the centroid for each point
    """
    self.initialize_centroids(X) # initialize the centroids

```

```

✓ [5]     """
    self.initialize_centroids(X) # initialize the centroids
    for i in range(iterations):
        points = self.assign_points_centroids(X) # assign each point to the nearest centroid
        self.centroids = self.compute_mean(X, points) # compute the new centroids based on the mean of their points

        # Assertions for debugging and validation
        assert len(self.centroids) == self.K, "Number of centroids should equal K."
        assert X.shape[1] == self.centroids.shape[1], "Dimensionality of centroids should match input data."
        assert max(points) < self.K, "Cluster index should be less than K."
        assert min(points) >= 0, "Cluster index should be non-negative."

    return self.centroids, points

```

```

✓ [6] X = X.values

✓ [7] kmeans = Kmeans(3)
      centroids, points = kmeans.fit(X, 1000)

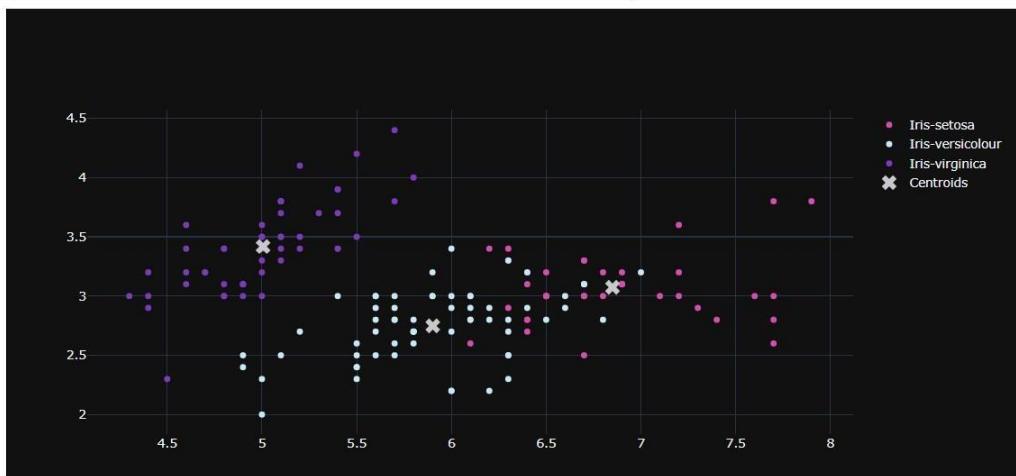
✓ [8] fig = go.Figure()
      fig.add_trace(go.Scatter(
          x=X[points == 0, 0], y=X[points == 0, 1],
          mode='markers', marker_color='#DB4CB2', name='Iris-setosa'
      ))
      fig.add_trace(go.Scatter(
          x=X[points == 1, 0], y=X[points == 1, 1],
          mode='markers', marker_color='#c9e9f6', name='Iris-versicolour'
      ))

```

```

' [8] ))
fig.add_trace(go.Scatter(
    x=X[points == 2, 0], y=X[points == 2, 1],
    mode='markers',marker_color='#7D3AC1',name='Iris-virginica'
))

fig.add_trace(go.Scatter(
    x=centroids[:, 0], y=centroids[:, 1],
    mode='markers',marker_color='#CAC9CD',marker_symbol=4,marker_size=13,name='Centroids'
))
fig.update_layout(template='plotly_dark',width=1000, height=500,)
```



9. Implement Dimensionality reduction using Principle Component Analysis

```
+ Code + Text ✓ RAM Disk
```

```
✓ [1] from google.colab import drive
drive.mount('/content/drive')

↳ Mounted at /content/drive

✓ [2] import seaborn as sns
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import plotly.express as px
import plotly.graph_objects as go
from plotly.subplots import make_subplots

✓ [3] df = pd.read_csv('/content/drive/MyDrive/breast-cancer.csv')
df.head()

→ id diagnosis radius_mean texture_mean perimeter_mean area_mean smoothness_mean compactness_mean concavity_mean concave points_mean ... radius_worst
0 842302 M 17.99 10.38 122.80 1001.0 0.11840 0.27760 0.3001 0.14710 ... 25.38
1 842517 M 20.57 17.77 132.90 1326.0 0.08474 0.07864 0.0869 0.07017 ... 24.99
2 84300903 M 19.69 21.25 130.00 1203.0 0.10960 0.15990 0.1974 0.12790 ... 23.57
3 84348301 M 11.42 20.38 77.58 386.1 0.14250 0.28390 0.2414 0.10520 ... 14.91
4 84358402 M 20.29 14.34 135.10 1297.0 0.10030 0.13280 0.1980 0.10430 ... 22.54
5 rows × 32 columns
```

```
→
```

```
✓ [4] df.drop('id', axis=1, inplace=True) #drop redundant columns

✓ [5] df['diagnosis'] = (df['diagnosis'] == 'M').astype(int) #encode the label into 1/0

✓ [6] corr = df.corr()

✓ [7] # Get the absolute value of the correlation
cor_target = abs(corr["diagnosis"])

# Select highly correlated features (threshold = 0.2)
relevant_features = cor_target[cor_target>0.2]

# Collect the names of the features
names = [index for index, value in relevant_features.items()]

# Drop the target variable from the results
names.remove('diagnosis')

# Display the results
print(names)

→ ['radius_mean', 'texture_mean', 'perimeter_mean', 'area_mean', 'smoothness_mean', 'compactness_mean', 'concavity_mean', 'concave p
↳
```

```
✓ [8] # Get the absolute value of the correlation
cor_target = abs(corr["diagnosis"])

# Select highly correlated features (threshold = 0.2)
relevant_features = cor_target[cor_target>0.2]

# Collect the names of the features
names = [index for index, value in relevant_features.items()]

# Drop the target variable from the results
names.remove('diagnosis')

# Display the results
print(names)

→ ['radius_mean', 'texture_mean', 'perimeter_mean', 'area_mean', 'smoothness_mean', 'compactness_mean', 'concavity_mean', 'concave p
↳
```

```
✓ [9] X = df[names].values
```

```

[9] X = df[names].values

[11] class PCA:
    """
    Principal Component Analysis (PCA) class for dimensionality reduction.
    """

    def __init__(self, n_components):
        """
        Constructor method that initializes the PCA object with the number of components to retain.

        Args:
        - n_components (int): Number of principal components to retain.
        """
        self.n_components = n_components

    def fit(self, X):
        """
        Fits the PCA model to the input data and computes the principal components.

        Args:
        - X (numpy.ndarray): Input data matrix with shape (n_samples, n_features).
        """
        # Compute the mean of the input data along each feature dimension.
        mean = np.mean(X, axis=0)

        # Subtract the mean from the input data to center it around zero.
        X = X - mean

        # Compute the covariance matrix of the centered input data.
        cov = np.cov(X.T)

```

```

[11]     # Compute the covariance matrix of the centered input data.
cov = np.cov(X.T)

        # Compute the eigenvectors and eigenvalues of the covariance matrix.
eigenvalues, eigenvectors = np.linalg.eigh(cov)
        # Reverse the order of the eigenvalues and eigenvectors.
eigenvalues = eigenvalues[::-1]
eigenvectors = eigenvectors[:, ::-1]

        # Keep only the first n_components eigenvectors as the principal components.
self.components = eigenvectors[:, :self.n_components]

        # Compute the explained variance ratio for each principal component.
        # Compute the total variance of the input data
total_variance = np.sum(np.var(X, axis=0))

        # Compute the variance explained by each principal component
self.explained_variances = eigenvalues[:self.n_components]

        # Compute the explained variance ratio for each principal component
self.explained_variance_ratio_ = self.explained_variances / total_variance

    def transform(self, X):
        """
        Transforms the input data by projecting it onto the principal components.

        Args:
        - X (numpy.ndarray): Input data matrix with shape (n_samples, n_features).

        Returns:
        - transformed_data (numpy.ndarray): Transformed data matrix with shape (n_samples, n_components).
        """
        # Center the input data around zero using the mean computed during the fit step.
X = X - np.mean(X, axis=0)

```

```

✓ 0s [11] def transform(self, X):
    """Project the centered input data onto the principal components.

    Ctrl+M B     transformed_data = np.dot(X, self.components)

    return transformed_data

    def fit_transform(self, X):
        """
        Fits the PCA model to the input data and computes the principal components then
        transforms the input data by projecting it onto the principal components.

        Args:
        - X (numpy.ndarray): Input data matrix with shape (n_samples, n_features).
        """
        self.fit(X)
        transformed_data = self.transform(X)
        return transformed_data

```

```

✓ 0s [12] pca = PCA(2)

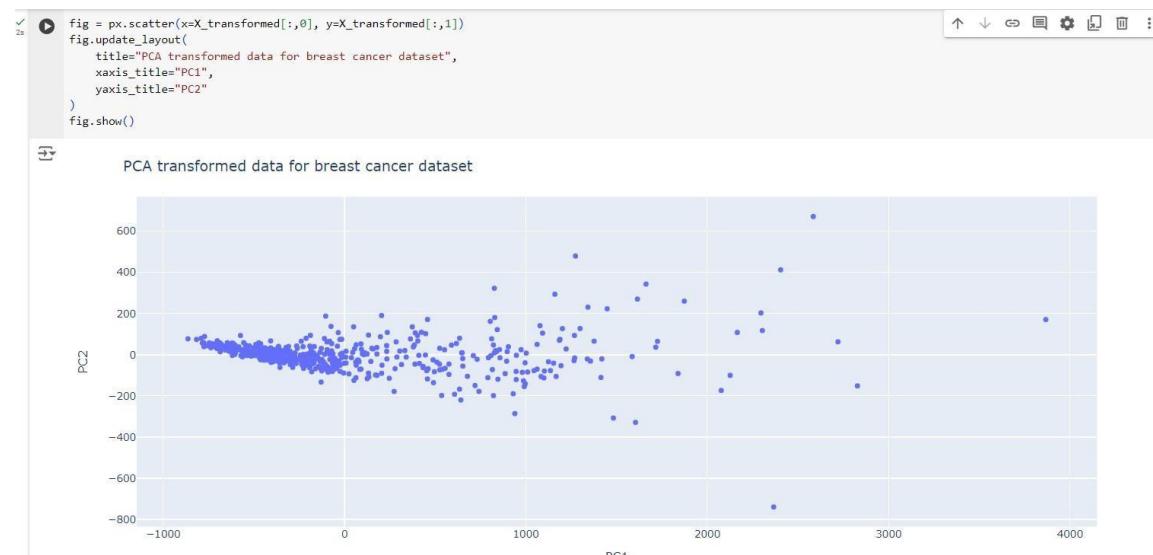
✓ 0s [13] pca.fit(X)

✓ 0s [14] pca.explained_variance_ratio_
    ↴ array([0.98377428, 0.01620498])

✓ 0s [15] X_transformed = pca.transform(X)

✓ 0s [16] X_transformed[:,1].shape
    ↴ (569,)

```



10. Build Artificial Neural Network model with back propagation on a given dataset

```
✓ 0s  [1] import numpy as np
      from sklearn.model_selection import train_test_split

      db = np.loadtxt("/content/duke-breast-cancer.txt")
      print("Database raw shape (%s,%s)" % np.shape(db))

      ↵ Database raw shape (86,7130)

✓ 0s  [2] np.random.shuffle(db)
      y = db[:, 0]
      x = np.delete(db, [0], axis=1)
      x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.1)
      print(np.shape(x_train),np.shape(x_test))

      ↵ (77, 7129) (9, 7129)

✓ 0s  [3] hidden_layer = np.zeros(72)
      weights = np.random.random((len(x[0]), 72))
      output_layer = np.zeros(2)
      hidden_weights = np.random.random((72, 2))

✓ 0s  [4] def sum_function(weights, index_locked_col, x):
      result = 0
      for i in range(0, len(x)):
          result += x[i] * weights[i][index_locked_col]
      return result

✓ 0s  [5] def activate_layer(layer, weights, x):
      for i in range(0, len(layer)):
          layer[i] = 1.7159 * np.tanh(2.0 * sum_function(weights, i, x) / 3.0)

✓ 0s  [6] def soft_max(layer):
      soft_max_output_layer = np.zeros(len(layer))
      for i in range(0, len(layer)):
          denominator = 0
          for j in range(0, len(layer)):
              denominator += np.exp(layer[j] - np.max(layer))
          soft_max_output_layer[i] = np.exp(layer[i] - np.max(layer)) / denominator
      return soft_max_output_layer

✓ 0s  [7] def recalculate_weights(learning_rate, weights, gradient, activation):
      for i in range(0, len(weights)):
          for j in range(0, len(weights[i])):
              weights[i][j] = (learning_rate * gradient[j] * activation[i]) + weights[i][j]

✓ 0s  [8] def back_propagation(hidden_layer, output_layer, one_hot_encoding, learning_rate, x):
      output_derivative = np.zeros(2)
      output_gradient = np.zeros(2)
      for i in range(0, len(output_layer)):
          output_derivative[i] = (1.0 - output_layer[i]) * output_layer[i]
      for i in range(0, len(output_layer)):
          output_gradient[i] = output_derivative[i] * (one_hot_encoding[i] - output_layer[i])
      hidden_derivative = np.zeros(72)
      hidden_gradient = np.zeros(72)
      for i in range(0, len(hidden_layer)):
          hidden_derivative[i] = (1.0 - hidden_layer[i]) * (1.0 + hidden_layer[i])
      for i in range(0, len(hidden_layer)):
          sum_ = 0
          for j in range(0, len(output_gradient)):
              sum_ += output_gradient[j] * hidden_weights[i][j]
          hidden_gradient[i] = sum_ * hidden_derivative[i]
      recalculate_weights(learning_rate, hidden_weights, output_gradient, hidden_layer)
      recalculate_weights(learning_rate, weights, hidden_gradient, x)
```

```

✓ [10] one_hot_encoding = np.zeros((2,2))
    for i in range(0, len(one_hot_encoding)):
        one_hot_encoding[i][1] = 1
    training_correct_answers = 0
    for i in range(0, len(x_train)):
        activate_layer(hidden_layer, weights, x_train[i])
        activate_layer(output_layer, hidden_weights, hidden_layer)
        output_layer = soft_max(output_layer)
        training_correct_answers += 1 if y_train[i] == np.argmax(output_layer) else 0
        back_propagation(hidden_layer, output_layer, one_hot_encoding[int(y_train[i])], -1, x_train[i])
    print("MLP Correct answers while learning: %s / %s (Accuracy = %s) on %s database." % (training_correct_answers, len(x_train),
                                                                                           training_correct_answers/len(x_train), "Duke breast cancer"))

→ MLP Correct answers while learning: 44 / 77 (Accuracy = 0.5714285714285714) on Duke breast cancer database.

```

```

✓ [11] testing_correct_answers = 0
    for i in range(0, len(x_test)):
        activate_layer(hidden_layer, weights, x_test[i])
        activate_layer(output_layer, hidden_weights, hidden_layer)
        output_layer = soft_max(output_layer)
        testing_correct_answers += 1 if y_test[i] == np.argmax(output_layer) else 0
    print("MLP Correct answers while testing: %s / %s (Accuracy = %s) on %s database" % (testing_correct_answers, len(x_test),
                                                                                      testing_correct_answers/len(x_test), "Duke breast cancer"))

→ MLP Correct answers while testing: 8 / 9 (Accuracy = 0.8888888888888888) on Duke breast cancer database

```

11a. Implement Random forest ensemble method on a given dataset.

```
✓ [17] from google.colab import drive
drive.mount('/content/drive')

↳ Mounted at /content/drive

✓ [18] import math
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import plotly.express as px

✓ [19] iris = pd.read_csv("/content/drive/MyDrive/Iris.csv") #Load Data
iris.drop('Id',inplace=True,axis=1) #Drop Id column

✓ [20] iris.head().style.background_gradient(cmap =sns.light_palette("seagreen", as_cmap=True)
)

↳ SepalLengthCm SepalWidthCm PetalLengthCm PetalWidthCm Species
0 5.100000 3.500000 1.400000 0.200000 Iris-setosa
1 4.900000 3.000000 1.400000 0.200000 Iris-setosa
2 4.700000 3.200000 1.300000 0.200000 Iris-setosa
3 4.600000 3.100000 1.500000 0.200000 Iris-setosa
4 5.000000 3.600000 1.400000 0.200000 Iris-setosa

✓ [21] X_df = iris.iloc[:, :-1] #Set our training dataframe
y_df = iris.iloc[:, -1] # Set our training labels dataframe

↳ fig = px.pie(iris, 'Species',color_discrete_sequence=['#3dec84','#009688','#2e8857'],title='Data Distribution',template='plotly')
fig.show()

Data Distribution
Iris-setosa
Iris-versicolor
Iris-virginica

✓ [22] iris['Species'] = iris['Species'].astype("category")
codes = iris['Species'].cat.codes
```

```

✓ [23] iris['Species'] = iris['Species'].astype("category")
       codes = iris['Species'].cat.codes

✓ [24] def train_test_split(X, y, random_state=42, test_size=0.2):
    """
    Splits the data into training and testing sets.

    Parameters:
        X (numpy.ndarray): Features array of shape (n_samples, n_features).
        y (numpy.ndarray): Target array of shape (n_samples,).
        random_state (int): Seed for the random number generator. Default is 42.
        test_size (float): Proportion of samples to include in the test set. Default is 0.2.

    Returns:
        Tuple[numpy.ndarray]: A tuple containing X_train, X_test, y_train, y_test.
    """
    # Get number of samples
    n_samples = X.shape[0]

    # Set the seed for the random number generator
    np.random.seed(random_state)

    # Shuffle the indices
    shuffled_indices = np.random.permutation(np.arange(n_samples))

    # Determine the size of the test set
    test_size = int(n_samples * test_size)

    # Split the indices into test and train
    test_indices = shuffled_indices[:test_size]
    train_indices = shuffled_indices[test_size:]

    # Split the features and target arrays into test and train
    X_train, X_test = X[train_indices], X[test_indices]
    y_train, y_test = y[train_indices], y[test_indices]

    return X_train, X_test, y_train, y_test

✓ [25] X = iris.iloc[:, :-1].values
       y = iris.iloc[:, -1].values.reshape(-1,1)
       X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=.2, random_state=41)

✓ [26] from sklearn.tree import DecisionTreeClassifier
       m = DecisionTreeClassifier()

✓ [27] class RandomForest:
    """
    A random forest classifier.

    Parameters
    -----
    n_trees : int, default=7
        The number of trees in the random forest.
    max_depth : int, default=7
        The maximum depth of each decision tree in the random forest.
    min_samples : int, default=2
        The minimum number of samples required to split an internal node
        of each decision tree in the random forest.

    Attributes
    -----
    n_trees : int
        The number of trees in the random forest.
    max_depth : int
        The maximum depth of each decision tree in the random forest.
    min_samples : int
        The minimum number of samples required to split an internal node
        of each decision tree in the random forest.
    trees : list of DecisionTreeClassifier
        The decision trees in the random forest.
    """
    def __init__(self, n_trees=7, max_depth=7, min_samples=2):
        """
        Initialize the random forest classifier.
        """

```

```

[27]      The decision trees in the random forest.

def __init__(self, n_trees=7, max_depth=7, min_samples=2):
    """
    Initialize the random forest classifier.

    Parameters
    -----
    n_trees : int, default=7
        The number of trees in the random forest.
    max_depth : int, default=7
        The maximum depth of each decision tree in the random forest.
    min_samples : int, default=2
        The minimum number of samples required to split an internal node
        of each decision tree in the random forest.
    """

    self.n_trees = n_trees
    self.max_depth = max_depth
    self.min_samples = min_samples
    self.trees = []

def fit(self, X, y):
    """
    Build a random forest classifier from the training set (X, y).

    Parameters
    -----
    X : array-like of shape (n_samples, n_features)
        The training input samples.
    y : array-like of shape (n_samples,)
        The target values.

    Returns
    -----
    self : object
        Returns self.
    """

    # Create an empty list to store the trees.
    self.trees = []
    # Concatenate X and y into a single dataset.
    dataset = np.concatenate((X, y.reshape(-1, 1)), axis=1)
    # Loop over the number of trees.
    """

    # Create an empty list to store the trees.
    self.trees = []
    # Concatenate X and y into a single dataset.
    dataset = np.concatenate((X, y.reshape(-1, 1)), axis=1)
    # Loop over the number of trees.
    for _ in range(self.n_trees):
        # Create a decision tree instance.
        tree = DecisionTreeClassifier(max_depth=self.max_depth, min_samples_split=self.min_samples)
        # Sample from the dataset with replacement (bootstrapping).
        dataset_sample = self.bootstrap_samples(dataset)
        # Get the X and y samples from the dataset sample.
        X_sample, y_sample = dataset_sample[:, :-1], dataset_sample[:, -1]
        # Fit the tree to the X and y samples.
        tree.fit(X_sample, y_sample)
        # Store the tree in the list of trees.
        self.trees.append(tree)
    return self

def bootstrap_samples(self, dataset):
    """
    Bootstrap the dataset by sampling from it with replacement.

    Parameters
    -----
    dataset : array-like of shape (n_samples, n_features + 1)
        The dataset to bootstrap.

    Returns
    -----
    dataset_sample : array-like of shape (n_samples, n_features + 1)
        The bootstrapped dataset sample.
    """

    # Get the number of samples in the dataset.
    n_samples = dataset.shape[0]
    # Generate random indices to index into the dataset with replacement.
    np.random.seed(1)
    indices = np.random.choice(n_samples, n_samples, replace=True)
    # Return the bootstrapped dataset sample using the generated indices.
    dataset_sample = dataset[indices]
    return dataset_sample

def most_common_label(self, v):

```

```

[27] def most_common_label(self, y):
    """
    Return the most common label in an array of labels.

    Parameters
    -----
    y : array-like of shape (n_samples,)
        The array of labels.

    Returns
    -----
    most_occuring_value : int or float
        The most common label in the array.
    """
    y = list(y)
    # get the highest present class in the array
    most_occuring_value = max(y, key=y.count)
    return most_occuring_value

def predict(self, X):
    """
    Predict class for X.

    Parameters
    -----
    X : array-like of shape (n_samples, n_features)
        The input samples.

    Returns
    -----
    majority_predictions : array-like of shape (n_samples,)
        The predicted classes.
    """
    #get prediction from each tree in the tree list on the test data
    predictions = np.array([tree.predict(X) for tree in self.trees])
    # get prediction for the same sample from all trees for each sample in the test data
    preds = np.swapaxes(predictions, 0, 1)
    #get the most voted value by the trees and store it in the final predictions array
    majority_predictions = np.array([self.most_common_label(pred) for pred in preds])
    return majority_predictions

[28] def accuracy(y_true, y_pred):
    """
    Computes the accuracy of a classification model.

    Parameters:
    y_true (numpy array): A numpy array of true labels for each data point.
    y_pred (numpy array): A numpy array of predicted labels for each data point.

    Returns:
    float: The accuracy of the model, expressed as a percentage.
    """
    y_true = y_true.flatten()
    total_samples = len(y_true)
    correct_predictions = np.sum(y_true == y_pred)
    return (correct_predictions / total_samples)

[35] from sklearn.preprocessing import LabelEncoder
label_encoder = LabelEncoder()
y_train_encoded = label_encoder.fit_transform(y_train)
y_test_encoded = label_encoder.transform(y_test)

/usr/local/lib/python3.10/dist-packages/sklearn/preprocessing/_label.py:116: DataConversionWarning:
A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().
/usr/local/lib/python3.10/dist-packages/sklearn/preprocessing/_label.py:134: DataConversionWarning:
A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().

```

```
[39] from sklearn.preprocessing import LabelEncoder  
  
label_encoder = LabelEncoder()  
y_train_encoded = label_encoder.fit_transform(y_train.ravel())  
y_test_encoded = label_encoder.transform(y_test.ravel())  
model = RandomForest(10, 10, 2)  
model.fit(X_train, y_train_encoded)  
  
predictions = model.predict(X_test)  
accuracy(y_test_encoded, predictions)
```

→ 0.9333333333333333

```
▶ from sklearn.tree import DecisionTreeClassifier  
  
# Create and train the decision tree model  
dt = DecisionTreeClassifier()  
dt.fit(X_train, y_train_encoded)  
  
# Make predictions on the test data  
predictions = dt.predict(X_test)  
  
# Calculate accuracy  
accuracy(y_test_encoded, predictions)
```

→ 0.9

11b. Implement Boosting ensemble method on a given dataset.

```
[15] # Compute error rate, alpha and w
def compute_error(y, y_pred, w_i):
    ...
    Calculate the error rate of a weak classifier m. Arguments:
    y: actual target value
    y_pred: predicted value by weak classifier
    w_i: individual weights for each observation

    Note that all arrays should be the same length
    ...
    return (sum(w_i * (np.not_equal(y, y_pred)).astype(int)))/sum(w_i)

def compute_alpha(error):
    ...
    Calculate the weight of a weak classifier m in the majority vote of the final classifier. This is called
    alpha in chapter 10.1 of The Elements of Statistical Learning. Arguments:
    error: error rate from weak classifier m
    ...
    return np.log((1 - error) / error)

def update_weights(w_i, alpha, y, y_pred):
    ...
    Update individual weights w_i after a boosting iteration. Arguments:
    w_i: individual weights for each observation
    y: actual target value
    y_pred: predicted value by weak classifier
    alpha: weight of weak classifier used to estimate y_pred
    ...
    return w_i * np.exp(alpha * (np.not_equal(y, y_pred)).astype(int))
```

```

[16] # Define AdaBoost class
class AdaBoost:

    def __init__(self):
        self.alphas = []
        self.G_M = []
        self.M = None
        self.training_errors = []
        self.prediction_errors = []

    def fit(self, X, y, M = 100):
        ...
        Fit model. Arguments:
        X: independent variables - array-like matrix
        y: target variable - array-like vector
        M: number of boosting rounds. Default is 100 - integer
        ...

        # Clear before calling
        self.alphas = []
        self.training_errors = []
        self.M = M

        # Iterate over M weak classifiers
        for m in range(0, M):

            # Set weights for current boosting iteration
            if m == 0:
                w_i = np.ones(len(y)) * 1 / len(y) # At m = 0, weights are all the same and equal to 1 / N
            else:
                # (d) Update w_i
                w_i = update_weights(w_i, alpha_m, y, y_pred)

            # (a) Fit weak classifier and predict labels
            G_m = DecisionTreeClassifier(max_depth = 1)      # Stump: Two terminal-node classification tree
            G_m.fit(X, y, sample_weight = w_i)
            y_pred = G_m.predict(X)

            self.G_M.append(G_m) # Save to list of weak classifiers

            # (b) Compute error
            error_m = compute_error(y, y_pred, w_i)
            w_i = update_weights(w_i, alpha_m, y, y_pred)

            # (a) Fit weak classifier and predict labels
            G_m = DecisionTreeClassifier(max_depth = 1)      # Stump: Two terminal-node classification tree
            G_m.fit(X, y, sample_weight = w_i)
            y_pred = G_m.predict(X)

            self.G_M.append(G_m) # Save to list of weak classifiers

            # (b) Compute error
            error_m = compute_error(y, y_pred, w_i)
            self.training_errors.append(error_m)

            # (c) Compute alpha
            alpha_m = compute_alpha(error_m)
            self.alphas.append(alpha_m)

        assert len(self.G_M) == len(self.alphas)

    def predict(self, X):
        ...
        Predict using fitted model. Arguments:
        X: independent variables - array-like
        ...

        # Initialise data frame with weak predictions for each observation
        weak_preds = pd.DataFrame(index = range(len(X)), columns = range(self.M))

        # Predict class label for each weak classifier, weighted by alpha_m
        for m in range(self.M):
            y_pred_m = self.G_M[m].predict(X) * self.alphas[m]
            weak_preds.iloc[:,m] = y_pred_m

        # Calculate final predictions
        y_pred = (1 * np.sign(weak_preds.T.sum())).astype(int)

        return y_pred

```

```
[17] import pandas as pd
     import numpy as np
     from sklearn.model_selection import train_test_split
     from sklearn.tree import DecisionTreeClassifier

     # Dataset
     df = pd.read_csv('/content/spambase.data', header = None)

     # Column names
     names = pd.read_csv('/content/spambase.names', sep = ':', skiprows=range(0, 33), header = None)
     col_names = list(names[0])
     col_names.append('Spam')

     # Rename df columns
     df.columns = col_names

     # Convert classes in target variable to {-1, 1}
     df['Spam'] = df['Spam'] * 2 - 1

     # Train - test split
     X_train, X_test, y_train, y_test = train_test_split(df.drop(columns = 'Spam').values,
                                                       df['Spam'].values,
                                                       train_size = 3065,
                                                       random_state = 2)
```



```
# Fit model
ab = AdaBoost()
ab.fit(X_train, y_train, M = 400)

# Predict on test set
y_pred = ab.predict(X_test)

from sklearn.metrics import accuracy_score

# Calculate accuracy
accuracy = accuracy_score(y_test, y_pred)
print("Accuracy:", accuracy)
```



Accuracy: 0.9440104166666666