AdaBoost Classifier From Scratch in Python

Import Libraries

In [1]:
```
# Basic Libraries
import numpy as np
import pandas as pd

# Load Data
from sklearn.datasets import load_breast_cancer

# Split Data
from sklearn.model_selection import train_test_split

# Data Visualization
import matplotlib.pyplot as plt
import seaborn as sns
```

Build AdaBoost From Scratch

Decision Stump Function

In [2]:
```
# A simple implementation of a weak classifier - decision stump
def decision_stump(X, y, weights):
    # Get the number of features in the dataset
    num_features = X.shape[1]

    # Initialize the best stump and the minimum error
    best_stump = {}
    min_error = float('inf')

    # Loop over each feature in the dataset
    for feature in range(num_features):
        # Get the unique values of the current feature
        feature_values = np.unique(X[:, feature])

        # Loop over each unique value as a potential threshold
        for threshold in feature_values:
            # Loop over the two possible inequalities
            for inequality in ["lt", "gt"]:
                # Initialize the predictions to 0
                predictions = np.zeros(len(y))

                # If the inequality is "lt", set the predictions to 1 where
                if inequality == "lt":
                    predictions[X[:, feature] <= threshold] = 1
                # If the inequality is "gt", set the predictions to 1 where
```

```
                else:
                    predictions[X[:, feature] > threshold] = 1

                # Calculate the misclassified examples
                misclassified = predictions != y
                # Calculate the weighted error by taking the dot product of
                weighted_error = np.dot(weights, misclassified)

                # If the weighted error is less than the current minimum err
                if weighted_error < min_error:
                    min_error = weighted_error
                    best_stump['feature'] = feature
                    best_stump['threshold'] = threshold
                    best_stump['inequality'] = inequality
                    best_stump['predictions'] = predictions

    # Return the best stump and the minimum error
    return best_stump, min_error
```

Main AdaBoost Model

In [3]:

```
# AdaBoost implementation
class AdaBoost:
    """
    This class implements the AdaBoost algorithm, a boosting algorithm that
    to create a strong classifier. The weak classifiers are trained in a sec
    is trained to correct the mistakes of the previous classifiers. The fina
    the predictions of the weak classifiers.

    Attributes:
        T (int): The number of weak classifiers.
        weak_classifiers (list): A list to store the weak classifiers.

    Methods:
        fit(X, y): Trains the AdaBoost model on the given data.
        predict(X): Makes predictions on the given data using the trained mo
    """
    def __init__(self, T=50):
        self.T = T  # Number of weak classifiers
        self.weak_classifiers = []  # List to store the weak classifiers

    def fit(self, X, y):
        # Initialize weights uniformly
        weights = np.full(len(y), (1 / len(y)))

        # Train T weak classifiers
        for _ in range(self.T):
            # Get the best decision stump and its error for the current weig
            stump, error = decision_stump(X, y, weights)

            # Handle zero error case to avoid division by zero
            if error == 0:
                error = 1e-10

            # Compute alpha (amount of say)
```

```
            alpha = 0.5 * np.log((1 - error) / error)
            # Store alpha in the stump
            stump['alpha'] = alpha
            # Add the stump to the list of weak classifiers
            self.weak_classifiers.append(stump)

            # Update the weights
            predictions = stump['predictions']
            # Adjust y from {0, 1} to {-1, 1} for weight update
            adjusted_y = np.where(y == 0, -1, 1)
            # Update weights based on the predictions
            weights *= np.exp(-alpha * adjusted_y * (2 * predictions - 1))
            # Normalize the weights
            weights /= np.sum(weights)

    def predict(self, X):
        # Initialize final predictions
        final_predictions = np.zeros(len(X))

        # For each weak classifier
        for stump in self.weak_classifiers:
            # Initialize predictions to 0
            predictions = np.zeros(len(X))  # default to 0
            # Get the feature, threshold, and inequality from the stump
            feature = stump['feature']
            threshold = stump['threshold']
            inequality = stump['inequality']

            # Make predictions based on the feature, threshold, and inequali
            if inequality == "lt":
                predictions[X[:, feature] <= threshold] = 1
            else:
                predictions[X[:, feature] > threshold] = 1

            # Add the weighted predictions to the final predictions
            final_predictions += stump['alpha'] * (2 * predictions - 1)  # c

        # Return the final predictions, converting {-1, 1} back to {0, 1}
        return np.where(final_predictions >= 0, 1, 0)  # return {0, 1} basec
```

Finetuning and Visualization Class

In [4]:
```
class AdaBoostTester:
    """
    This class is designed to test the performance of the AdaBoost algorithm
    It provides methods to train the model, test its accuracy, and plot the

    Attributes:
        X_train (numpy.ndarray): The training data.
        y_train (numpy.ndarray): The labels for the training data.
        X_test (numpy.ndarray): The testing data.
        y_test (numpy.ndarray): The labels for the testing data.
        accuracies (list): A list to store the accuracy of the model for eac
        best_accuracy (float): The best accuracy achieved by the model.
        best_model (AdaBoost): The model that achieved the best accuracy.
```

```
    Methods:
        test(T_values): Trains an AdaBoost model for each value in T_values,
                        and keeps track of the model with the best accuracy.
        plot(T_values): Plots the accuracies against the number of weak lear
        get_best_model(): Returns the model that achieved the best accuracy.
        get_best_accuracy(): Returns the best accuracy achieved by the model
    """
    def __init__(self, X_train, y_train, X_test, y_test):
        # Initialize the training and testing data, the list of accuracies,
        self.X_train = X_train
        self.y_train = y_train
        self.X_test = X_test
        self.y_test = y_test
        self.accuracies = []
        self.best_accuracy = 0
        self.best_model = None

    def test(self, T_values):
        # For each value in T_values, train an AdaBoost model and test its a
        for i, T_value in enumerate(T_values):
            # Initialize and train the AdaBoost model
            adaBoostModel = AdaBoost(T=T_value)
            adaBoostModel.fit(self.X_train, self.y_train)

            # Make predictions on the test set and calculate the accuracy
            predictions = adaBoostModel.predict(self.X_test)
            accuracy = (predictions == self.y_test).mean()

            # Add the accuracy to the list of accuracies
            self.accuracies.append(accuracy)

            # Print the progress
            print(f"T = {T_value}, Test Accuracy = {accuracy:.2%} | {(i+1)/l

            # If this model has the best accuracy so far, update the best mo
            if accuracy > self.best_accuracy:
                self.best_accuracy = accuracy
                self.best_model = adaBoostModel

    def plot(self, T_values):
        # Plot the accuracies against the T_values
        plt.figure(figsize=(10, 6))
        plt.plot(T_values, self.accuracies, marker='o')
        plt.title('Accuracy vs Number of Weak Learners')
        plt.xlabel('Number of Weak Learners (T)')
        plt.ylabel('Accuracy')
        plt.grid(True)
        plt.show()

    def get_best_model(self):
        # Return the best model
        return self.best_model

    def get_best_accuracy(self):
```

```
        # Return the best accuracy
        return self.best_accuracy
```

Load Breast Cancer Dataset

In [5]:
```
cancer = load_breast_cancer()
X, y = cancer.data, cancer.target

# Create a DataFrame
df = pd.DataFrame(X, columns=cancer.feature_names)
df['target'] = y

df.head()
```

Out[5]:

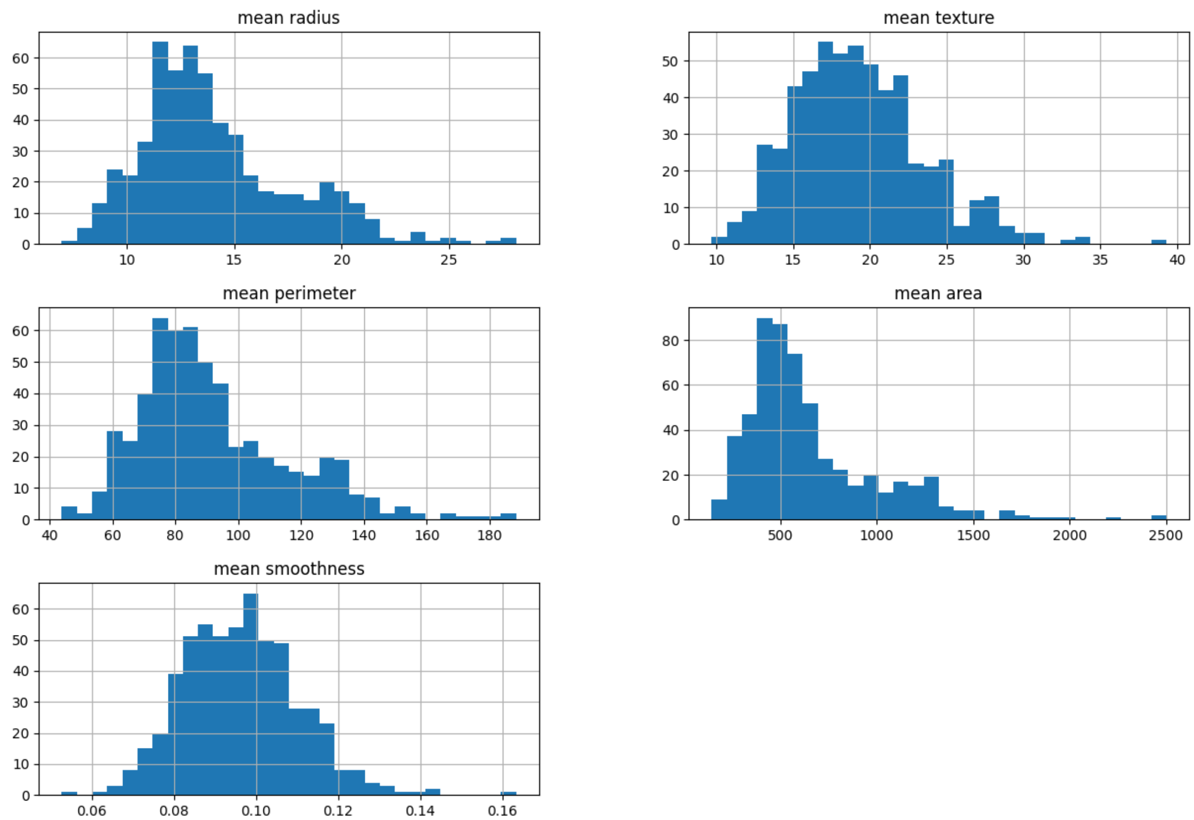
	mean radius	mean texture	mean perimeter	mean area	mean smoothness	mean compactness	mean concavity	mean concave points	symm
0	17.99	10.38	122.80	1001.0	0.11840	0.27760	0.3001	0.14710	0
1	20.57	17.77	132.90	1326.0	0.08474	0.07864	0.0869	0.07017	0
2	19.69	21.25	130.00	1203.0	0.10960	0.15990	0.1974	0.12790	0.
3	11.42	20.38	77.58	386.1	0.14250	0.28390	0.2414	0.10520	0.
4	20.29	14.34	135.10	1297.0	0.10030	0.13280	0.1980	0.10430	0.

5 rows × 31 columns

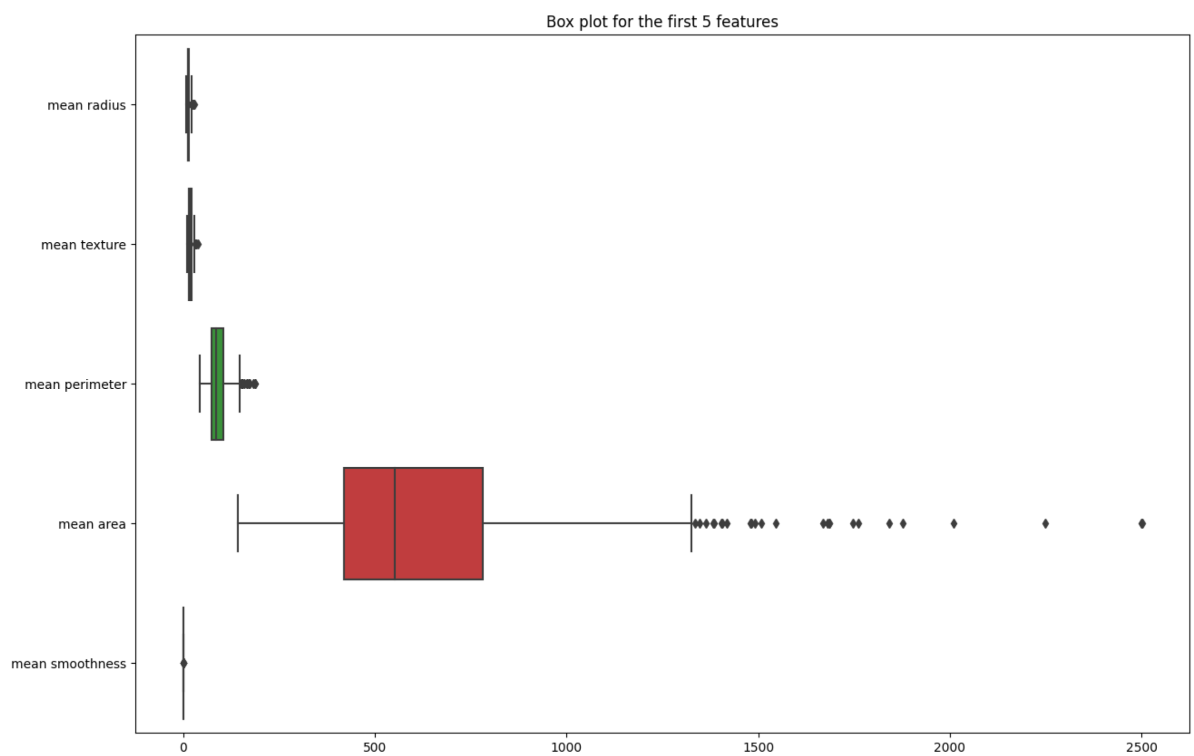
EDA

In [6]:
```
# Plot the distribution of the features
plt.figure(figsize=(20, 10))
df.iloc[:, :5].hist(bins=30, figsize=(15, 10))
plt.show()
```

```
<Figure size 2000x1000 with 0 Axes>
```

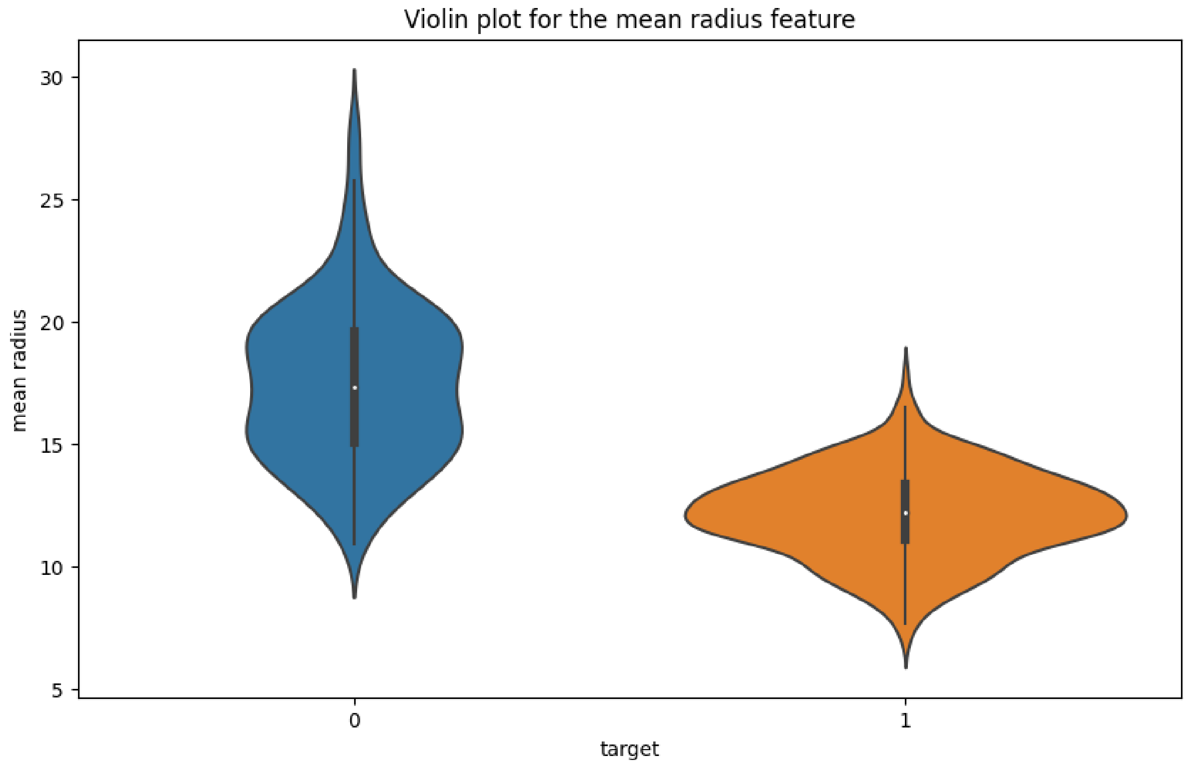


In [7]:
```
plt.figure(figsize=(15, 10))
sns.boxplot(data=df.iloc[:, :5], orient="h")
plt.title('Box plot for the first 5 features')
plt.show()
```



In [8]:
```
plt.figure(figsize=(10, 6))
sns.violinplot(x='target', y='mean radius', data=df)
```

```
plt.title('Violin plot for the mean radius feature')
plt.show()
```

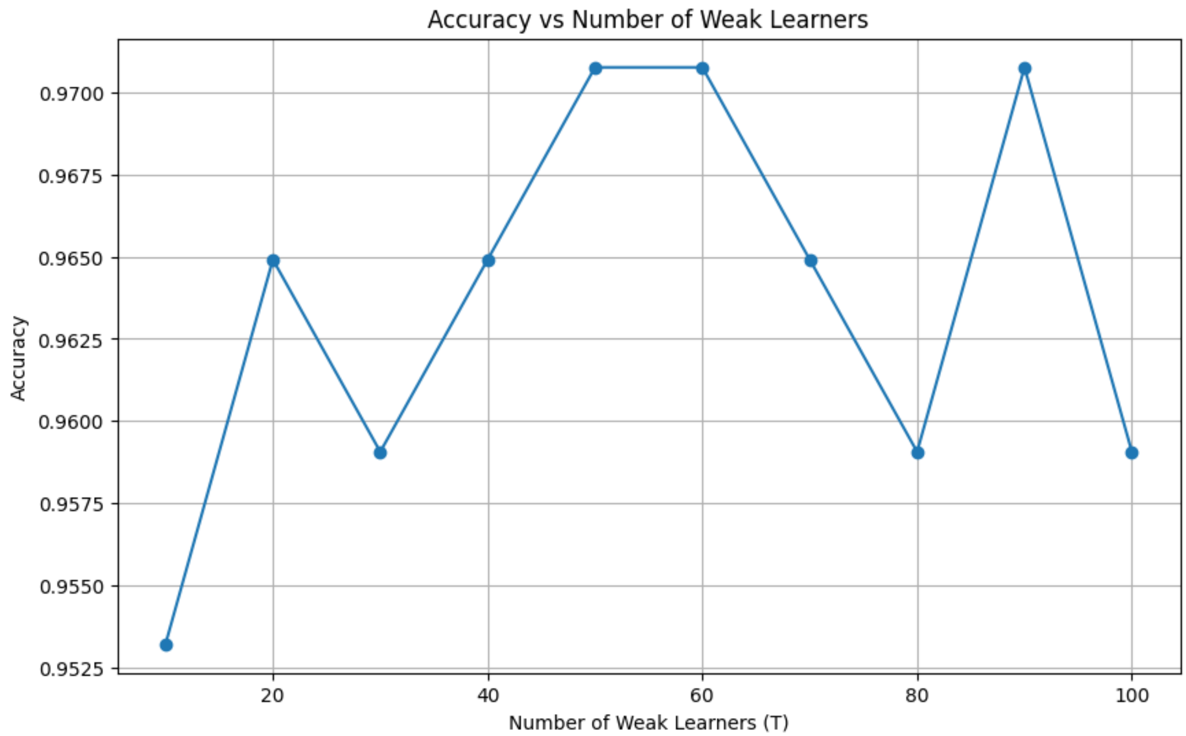


Predict Data

In [9]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)

T_values = list(range(10, 101, 10))
tester = AdaBoostTester(X_train, y_train, X_test, y_test)
tester.test(T_values)
print(f"Best Accuracy = {tester.get_best_accuracy():.2%}")
tester.plot(T_values)
```

```
T = 10, Test Accuracy = 95.32% | 10.00% complete
T = 20, Test Accuracy = 96.49% | 20.00% complete
T = 30, Test Accuracy = 95.91% | 30.00% complete
T = 40, Test Accuracy = 96.49% | 40.00% complete
T = 50, Test Accuracy = 97.08% | 50.00% complete
T = 60, Test Accuracy = 97.08% | 60.00% complete
T = 70, Test Accuracy = 96.49% | 70.00% complete
T = 80, Test Accuracy = 95.91% | 80.00% complete
T = 90, Test Accuracy = 97.08% | 90.00% complete
T = 100, Test Accuracy = 95.91% | 100.00% complete
Best Accuracy = 97.08%
```



Accuracy vs Number of Weak Learners
Accuracy
0.9700
0.9675
0.9650
0.9625
0.9600
0.9575
0.9550
0.9525
20
40
60
80
100
Number of Weak Learners (T)