1.Linear SVC

**Results:**

Our evaluation metrics showed strong predictive capabilities:

* **Accuracy: 93.93%**
* **Precision: 93.04%**
* **ROC-AUC Score: 98.39%**

These results suggest that calibrated Linear SVC effectively distinguishes between spam and legitimate emails when combined with appropriate preprocessing techniques like dimensionality reduction and probability calibration.

2. Logistic Regression:  
**Results:**

The evaluation metrics for our Logistic Regression model are as follows:

* **R-squared:** 0.9059
* **Mean Absolute Error (MAE):** 0.0540
* **Root Mean Squared Error (RMSE):** 0.1531
* **F1-score:** 0.9684
* **Recall:** 0.9749
* **Specificity:** 0.9657

**Discussion:**

The high F1-score, Recall, and Specificity values indicate that Logistic Regression with L1 regularization is highly effective in distinguishing between spam and ham emails. The use of L1 regularization aids in feature selection by eliminating irrelevant features, thus enhancing the model's generalization capability.

Overall, our findings demonstrate that Logistic Regression is a robust method for spam detection, achieving impressive accuracy and reliability in classifying emails based on their content.

3. **K-Neighbors Classifier**

**Results:**

The evaluation metrics for our K-Neighbors Classifier model are as follows:

* **Accuracy:** 97.04%
* **Precision:** 96.07%
* **ROC-AUC Score:** 99.24%
* **R² Score:** 88.14%

**Discussion:**

The K-Neighbors Classifier demonstrated strong performance in classifying emails as spam or ham, achieving an accuracy of 97.04%. The high precision value of 96.07% indicates that when the model predicts an email as spam, it is correct approximately 96% of the time. The ROC-AUC score of 99.24% suggests excellent discrimination ability between the two classes across various thresholds.

The effectiveness of KNN can be attributed to its simplicity and reliance on local data patterns, making it well-suited for this classification task. However, it is important to note that KNN can be sensitive to irrelevant features and noise in the data, which may affect its performance in different contexts.

4. **Multinomial Naive Bayes**

**Results:**

The evaluation metrics for our Multinomial Naive Bayes model are as follows:

* **Accuracy:** 0.9305
* **Precision:** 0.9369
* **ROC-AUC Score:** 0.9848
* **R² Score:** 0.7214

**Discussion:**

The Multinomial Naive Bayes model achieved an accuracy of 0.9305, demonstrating its effectiveness in classifying emails as spam or ham. The precision of 0.9369 indicates a relatively low rate of false positives. The ROC-AUC score of 0.9848 suggests a strong ability to discriminate between spam and legitimate emails.

MultinomialNB is known for its simplicity and computational efficiency, making it a popular choice for text classification tasks. Its performance is particularly strong when the independence assumption holds reasonably well, and when the features are represented as word counts or TF-IDF values.

**5 Decision Tree Classifier**

**Results:**

The evaluation metrics for our Decision Tree Classifier model are as follows:

* **Accuracy:** 95.36%
* **Precision:** 95.63%
* **ROC-AUC Score:** 97.57%
* **R² Score:** 81.40%

**Discussion:**

The Decision Tree Classifier achieved an accuracy of 95.36%, indicating its effectiveness in classifying emails as spam or ham. The precision of 95.63% suggests that when the model predicts an email as spam, it is correct approximately 96% of the time. The ROC-AUC score of 97.57% reflects strong discriminatory power between classes across various thresholds.

Decision trees are intuitive and easy to interpret, making them valuable for understanding the decision-making process behind classifications. However, they can be prone to overfitting if not properly regularized, especially with deep trees that capture noise in the training data.

In this case, the chosen hyperparameters helped mitigate overfitting while maintaining high performance. Overall, these results indicate that the Decision Tree Classifier is a robust option for spam detection tasks when combined with appropriate preprocessing techniques.

**6 Random Forest Classifier**

**Results:**

The evaluation metrics for our Random Forest Classifier model are as follows:

* **Accuracy:** 0.9786
* **Precision:** 0.9799
* **ROC-AUC Score:** 0.9971
* **R² Score:** 0.9143

**Discussion:**

The Random Forest Classifier achieved excellent performance in classifying emails as spam or ham, with an accuracy of 0.9786. The precision of 0.9799 indicates a very low rate of false positives, and the ROC-AUC score of 0.9971 suggests outstanding discriminatory power between the two classes.

Random forests are capable of capturing complex relationships within the data while mitigating overfitting, making them a robust choice for text classification tasks. The combination of multiple decision trees reduces variance and improves overall generalization performance.

**7 AdaBoost Classifier**

**Results:**

The evaluation metrics for our AdaBoost Classifier model are as follows:

* **Accuracy:** 0.8490
* **Precision:** 0.8016
* **ROC-AUC Score:** 0.9217
* **R² Score:** 0.3943

**Discussion:**

The AdaBoost Classifier model achieved an accuracy of 0.8490, demonstrating reasonable but not outstanding performance in classifying emails as spam or ham. The precision of 0.8016 indicates a moderate rate of false positives. The ROC-AUC score of 0.9217 suggests a good ability to discriminate between spam and legitimate emails, but it is lower compared to other models such as Random Forest or KNN.

AdaBoost is known for its ability to improve the accuracy of weak learners and its robustness to overfitting. However, it can be sensitive to noisy data and outliers, which may limit its performance in certain cases.

**8 Bagging Classifier**

**Results:**

The evaluation metrics for our Bagging Classifier model are as follows:

* **Accuracy:** 0.8936
* **Precision:** 0.8421
* **Recall:** 0.9547
* **F1-Score:** 0.8949
* **ROC-AUC:** 0.9455

**Discussion:**

The Bagging Classifier model achieved an accuracy of 0.8936, demonstrating its effectiveness in classifying emails as spam or ham. The precision of 0.8421 indicates a moderate rate of false positives, while the high recall of 0.9547 suggests that the model is good at identifying most of the spam emails. The F1-score of 0.8949 balances precision and recall, providing an overall measure of the model’s performance.

**9 Gradient Boosting Classifier**

**Results:**

The evaluation metrics for our Gradient Boosting Classifier model are as follows:

* **Accuracy:** 0.8636
* **Precision:** 0.8152
* **Recall:** 0.9212
* **F1-Score:** 0.8650
* **ROC-AUC:** 0.9433
* **R² Score:** 0.4528

**Discussion:**

The Gradient Boosting Classifier model achieved an accuracy of 0.8636, indicating its effectiveness in classifying emails as spam or ham. The precision of 0.8152 suggests a moderate rate of false positives, while the recall of 0.9212 indicates that the model is good at identifying most of the spam emails. The F1-score of 0.8650 balances precision and recall, providing an overall measure of the model’s performance. The model also has an R-squared score of 0.4528.

Gradient Boosting is known for its ability to capture complex relationships within the data and its robustness to overfitting. However, it can be sensitive to hyperparameter tuning, and it may require careful adjustment to achieve optimal performance.

**10 XGBoost Classifier**

**Results:**

The evaluation metrics for our XGBoost Classifier model are as follows:

* **Accuracy:** 0.9073
* **Precision:** 0.8658
* **Recall:** 0.9522
* **F1-Score:** 0.9070
* **ROC-AUC:** 0.9752
* **R² Score:** 0.6284

**Discussion:**

The XGBoost Classifier model achieved an accuracy of 0.9073, demonstrating its effectiveness in classifying emails as spam or ham. The precision of 0.8658 indicates a moderate rate of false positives, while the recall of 0.9522 suggests that the model is effective at identifying most of the spam emails. The F1-score of 0.9070 balances precision and recall, providing an overall measure of the model’s performance. The model also has an R-squared score of 0.6284.