Homework 2 by mohammed Qasm by using Sonar Dataset

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**Comprehensive Analysis of Cross-Validation and Bootstrap Validation Techniques**

**Introduction**

My report presents a detailed analysis of some deference cross-validation and bootstrap validation techniques applied to the Sonar dataset. my evaluation focuses on three popular machine learning algorithms: Decision Trees (DT), Naive Bayes (NB), and Support Vector Machine (SVM). Performance measures including recall, accuracy, and precision are used to evaluate how effective each method is.

**Bootstrap Validation Results**

I used bootstrap validation for the Sonar dataset, changing the number of iterations for each machine-learning method and the train-test split ratio.

**Decision Trees (DT) in Bootstrap Validation**

* I used a train-test split ratio of 0.5-0.5 with 5 iterations, the accuracy achieved was 66.44%, precision was 67.87%, and recall was 68.90%.
* By increasing the train-test split ratio to 0.80-0.20 with 10 iterations resulted in a slight decrease in accuracy to 64.98%, along with precision and recall metrics.

**Naive Bayes (NB) in Bootstrap Validation**

• Similar to Decision Trees, a train-test split ratio of 0.5-0.5 with 5 iterations give me an accuracy of 66.85%, precision of 73.36%, and recall of 57.93%.

• With a train-test split ratio of 0.80-0.20 and 10 iterations, the accuracy improved to 66.87%, along with higher precision and slightly lower recall metrics.

**SVM in Bootstrap Validation**

In my test Support Vector Machine (SVM) demonstrated competitive performance during bootstrap validation on the Sonar dataset when compared to Decision Trees (DT) and Naive Bayes (NB).

* SVM achieved an accuracy range of 74.41% to 76.64%, a precision range of 75.30% to 78.60%, and a recall range of 76.22% to 77.98% across different split ratios and iterations.
* These results indicate that SVM performs comparably to Decision Tree and Naive Bayes in terms of accuracy, precision, and recall on the Sonar dataset during bootstrap validation.

**Cross-Validation Results Analysis**

I also applied cross-validation techniques to the Sonar dataset, using different methods and parameters for each machine-learning algorithm, in addition to bootstrap validation.

**Decision Tree (DT) in Cross-Validation**

When I applied cross-validation using various methods and k-fold values for the Decision Tree (DT), I observed the following results:

* **Leave One Out**:
  + I achieved an accuracy of 64.90%, a precision of 65.83%, and a recall of 71.17%.
* **Linear Sampling**:
  + With different k-fold values, I obtained an accuracy ranging from 28.87% to 42.86%, precision ranging from 31.31% to 46.55%, and recall ranging from 27.93% to 48.65%.
* **Shuffled Sampling**:
  + The accuracy ranged from 61.08% to 65.40%, precision ranged from 60.87% to 65.12%, and recall ranged from 73.87% to 75.68%.
* **Stratified Sampling**:
  + The accuracy ranged from 59.13% to 65.88%, precision ranged from 59.56% to 67.54%, and recall ranged from 69.37% to 74.77%.

**Naive Bayes (NB) in Cross-Validation**

In the case of Naive Bayes (NB), when I applied cross-validation using different methods and k-fold values, I obtained the following outcomes:

* **Leave One Out**:
  + I achieved an accuracy of 67.31%, a precision of 77.22%, and a recall of 54.95%.
* **Linear Sampling**:
  + The accuracy ranged from 58.34% to 60.12%, precision ranged from 66.67% to 68.75%, and recall ranged from 39.64% to 46.85%.
* **Shuffled Sampling**:
  + The accuracy ranged from 67.78% to 71.56%, precision ranged from 78.21% to 83.33%, and recall ranged from 54.95% to 58.56%.
* **Stratified Sampling**:
  + The accuracy ranged from 66.90% to 68.75%, precision ranged from 76.25% to 78.75%, and recall ranged from 54.95% to 56.76%.

**SVM in Cross-Validation**

* For Support Vector Machine (SVM), when I applied cross-validation using various methods and k-fold values, I obtained the following results:
* **Leave One Out**:
  + I achieved an accuracy of 76.92%, a precision of 77.88%, and a recall of 79.28%.
* **Linear Sampling**:
  + The accuracy ranged from 49.41% to 54.21%, precision ranged from 53.19% to 58.51%, and recall ranged from 45.05% to 49.55%.
* **Shuffled Sampling**:
  + The accuracy ranged from 74.55% to 76.45%, precision ranged from 75.44% to 77.68%, and recall ranged from 76.58% to 78.38%.
* **Stratified Sampling**:
  + The accuracy ranged from 77.84% to 79.31%, precision ranged from 79.65% to 80.91%, and recall ranged from 78.38% to 81.08%.

**Analysis and Comparison**

* Across all models and sampling methods, Leave One Out cross-validation consistently resulted in higher accuracy and precision compared to other sampling methods.
* Shuffled sampling generally performed well across all models, particularly in terms of accuracy and precision.
* Linear sampling showed relatively lower performance compared to other methods, especially in terms of recall.
* Stratified sampling also demonstrated competitive performance, especially in terms of accuracy and precision.

Based on these observations, Leave One Out cross-validation and shuffled sampling appear to be the most effective methods across different models for the Sonar dataset, as they consistently give higher accuracy and precision compared to other sampling techniques.

**Conclusion**

In my analysis of the machine learning models on the Sonar dataset, I noted distinct patterns regarding the effectiveness of cross-validation techniques and sampling methods:

* I consistently observed that Leave One Out cross-validation resulted in higher accuracy and precision compared to other sampling methods across all models.
* I found that shuffled sampling consistently performed well across all models, particularly excelling in accuracy and precision metrics.
* I noticed that linear sampling showed relatively lower performance, especially in terms of recall, when compared to other methods.
* I observed that stratified sampling demonstrated competitive performance, especially in accuracy and precision metrics.

Based on these observations, I conclude that Leave One Out cross-validation and shuffled sampling are the most effective methods for evaluating machine learning models on the Sonar dataset. In my analysis, they consistently deliver higher accuracy and precision compared to other sampling techniques, ensuring robust and reliable model evaluation across various machine-learning algorithms.