**Machine Learning Model Evaluation**

Model evaluation is the process of assessing how well a machine learning model performs on unseen data using different metrics and techniques. It ensures that the model not only memorizes training data but also generalizes to new situations. By applying evaluation methods such as cross-validation, holdout testing and error metrics, we can identify whether a model has truly learned patterns, detect its weaknesses and decide if it is ready for real-world deployment.

**Cross Validation in Machine Learning**

Cross-validation is a technique used to check how well a machine learning model performs on unseen data while preventing overfitting. It works by:

* Splitting the dataset into several parts.
* Training the model on some parts and testing it on the remaining part.
* Repeating this resampling process multiple times by choosing different parts of the dataset.
* Averaging the results from each validation step to get the final performance.

**What is Cross Validation**

Cross-validation serves multiple purposes:

* [**Avoids Overfitting**](https://www.geeksforgeeks.org/machine-learning/how-to-avoid-overfitting-in-machine-learning/)**:**Ensures that the model does not perform well only on the training data but generalizes to unseen data.
* **Provides Robust Evaluation:**Averages results over multiple iterations, reducing bias and variance in the performance metrics.
* **Efficient Use of Data:** Maximizes the utilization of the dataset, especially when the data size is limited.

**Types of Cross-Validation**

There are several types of cross-validation techniques which are as follows:

**1. Holdout Validation**

In[Holdout Validation](https://www.geeksforgeeks.org/software-engineering/introduction-of-holdout-method/) method typically 50% data is used for training and 50% for testing. Making it simple and quick to apply. The major drawback of this method is that only 50% data is used for training, the model may miss important patterns in the other half which leads to high bias.

**2. LOOCV (Leave One Out Cross Validation)**

In this method the model is trained on the entire dataset except for one data point which is used for testing. This process is repeated for each data point in the dataset.

* All data points are used for training, resulting in low bias.
* Testing on a single data point can cause high variance, especially if the point is an outlier.
* It can be very time-consuming for large datasets as it requires one iteration per data point.

**3. Stratified Cross-Validation**

It is a technique that ensures each fold of the cross-validation process has the same class distribution as the full dataset. This is useful for imbalanced datasets where some classes are underrepresented.

* The dataset is divided into k folds, keeping class proportions consistent in each fold.
* In each iteration, one fold is used for testing and the remaining folds for training.
* This process is repeated k times so that each fold is used once as the test set.
* It helps classification models generalize better by maintaining balanced class representation.

**4. K-Fold Cross Validation**

[K-Fold Cross Validation](https://www.geeksforgeeks.org/r-language/k-fold-cross-validation-in-r-programming/) splits the dataset into *k* equal-sized folds. The model is trained on *k-1* folds and tested on the remaining fold. This process is repeated *k* times each time using a different fold for testing.

***Note:*** *It is always suggested that the value of k should be 10 as the lower value of k takes towards validation and higher value of k leads to LOOCV method.*

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**K- Fold Cross Validation in Machine Learning**

K-Fold Cross Validation is a statistical technique to measure the performance of a machine learning model by dividing the dataset into K subsets of equal size (folds). The model is trained on K − 1 folds and tested on the last fold. This process is repeated K times, with each fold being used as the testing set exactly once. The performance of the model is then averaged over all K iterations to provide a robust estimate of its generalization ability.

**Variants of K-Fold Cross Validation**

* [**Stratified K-Fold Cross Validation**](https://www.geeksforgeeks.org/machine-learning/stratified-k-fold-cross-validation/)**:** Maintains the same class distribution for each fold as for the entire dataset, particularly helpful for datasets that are imbalanced.
* [**Repeated K-Fold Cross Validation**](https://www.geeksforgeeks.org/r-language/repeated-k-fold-cross-validation-in-r-programming/)**:**Performs the K-Fold operation several times with varying splits, giving more stable performance estimates.
* [**Leave-One-Out Cross Validation (LOOCV)**](https://www.geeksforgeeks.org/r-language/loocvleave-one-out-cross-validation-in-r-programming/)**:**A special case where K is equal to the number of data points, so every fold will hold one data point.