**Model Optimization and Tuning Phase**

**Project Name :** Amazon Instrument Analysis

### **Model Optimization and Tuning Phase**

The Model Optimization and Tuning Phase is a crucial step in the machine learning pipeline. Its goal is to improve **accuracy, efficiency, and generalization** by adjusting model hyperparameters and feature extraction settings. Hyperparameters control how the model learns and how well it adapts to imbalanced text data.

**Hyperparameter Tuning Documentation :**

| **Model** | **Tuned Hyperparameters** |
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| Model- A : Logistic Regression | Regularization (C): Adjusted to prevent overfitting .  Max Iterations: Increased to 5000 to ensure convergence.  Class Weights: Set to “balanced” to handle class imbalance. |
| Model - B : Random Forest | Number of Estimators: Tuned (100, 200, 300 trees) – final model used 200.  Max Depth: Optimized to prevent overfitting – best performance at depth = 30.  Min Samples Split: Tested values (2, 5, 10).  Class Weights: Balanced to ensure Neutral reviews were not ignored.  Random State: Fixed for reproducibility. |
| Model C – TF-IDF Feature Engineering | Max Features: Tested values (3000, 5000, 7000). Best performance with 5000.  N-gram Range: Compared unigram (1,1) vs bigram/trigram (1,3). Final choice: (1,3).  Stopwords Removal: Enabled English stopwords. |
| Model D – Resampling Strategy | SMOTE Oversampling: Applied to balance Positive, Neutral, Negative classes.  Test Size: Split ratio tuned between (70:30) and (75:25). Final choice: 75:25.  Stratification: Ensured equal class representation across splits. |

**Final Model Selection Justification :**

| **Final Model** | **Reasoning** |
| --- | --- |
| Model - B | Achieved the highest accuracy of ~97.6%, outperforming Logistic Regression (~95.2%).  Balanced performance across Positive, Neutral, and Negative classes after SMOTE.  Low generalization gap: training accuracy ≈ 98%, validation accuracy ≈ 97.6%.  Scalable and efficient: Handles large feature sets (5000 TF-IDF features) without overfitting.  Deployment-ready: Model size is lightweight, integrates seamlessly with Flask + Ngrok web app for real-time sentiment prediction.  Confusion matrix showed balanced recall, resolving the Neutral underrepresentation issue. |