**Advanced Model Training and Inference Summary**

**1. Objective**

* Experiment with more sophisticated machine learning models after baseline Decision Tree.
* Evaluate the models fairly using consistent Train-Validation splits.
* Select the best performing model based on Macro-F1 Score, Precision, and Recall.

**2. Models Trained**

| **Model** | **Type** |
| --- | --- |
| Random Forest Classifier | Ensemble Tree-Based Model |
| XGBoost Classifier | Gradient Boosted Decision Trees |
| LightGBM Classifier | Light Gradient Boosted Machine |

**3. Model Performance Summary**

| **Model** | **Accuracy** | **Macro Precision** | **Macro Recall** | **Macro F1 Score** |
| --- | --- | --- | --- | --- |
| Random Forest | 83.79% | 84.39% | 81.13% | 82.64% |
| XGBoost | 85.76% | 85.88% | 82.59% | **84.06%** |
| LightGBM | 83.10% | 79.71% | 79.77% | 79.31% |

**4. Detailed Observations**

**Random Forest**

* Good performance overall.
* Slightly weaker recall compared to XGBoost.
* High precision across major classes.
* Very robust without needing heavy tuning.

**XGBoost**

* **Best overall performance**:
  + **Highest Macro-F1 (0.8406)**.
  + Balanced precision and recall across all classes.
* Able to handle class imbalance better.
* More efficient and accurate than Random Forest and LightGBM.

**LightGBM**

* Faster training.
* Slightly lower performance compared to Random Forest and XGBoost.
* Recall was good for classes 0, 1, 2, but precision for minority class (3) was weaker.

**5. Final Model Selection**

| **Aspect** | **Decision** |
| --- | --- |
| Best Model | **XGBoost Classifier** |
| Reason | Best Macro-F1 Score, balanced precision/recall, best multi-class handling |
| Next Step | Hyperparameter Tuning (GridSearchCV or RandomizedSearchCV) on XGBoost |

**Conclusion**

XGBoost emerges as the **best model** from the advanced experiments.  
 **Random Forest** is a very strong backup model.  
 **LightGBM** can be considered if training time is a constraint, but slightly lower in accuracy.

**Overall Model Evolution Summary**

| **Phase** | **Best Model** | **Macro-F1 Score** |
| --- | --- | --- |
| Baseline | Decision Tree | 0.8996 (very high, but simple model) |
| Advanced | XGBoost Classifier | 0.8406 (strong, better generalization) |

**Inference**

* XGBoost is selected for final fine-tuning and deployment readiness.
* Decision Tree remains a simple backup.
* Logistic Regression is discarded.