


Machine Learning Model Development

Import the necessary libraries

```
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split, cross_val_score, StratifiedKFold, StratifiedShuffleSplit,\
    cross_val_predict
from sklearn.preprocessing import RobustScaler, StandardScaler, LabelEncoder, OneHotEncoder
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
import xgboost as xgb
from sklearn.metrics import accuracy_score, precision_score,\
    recall_score, f1_score, roc_auc_score

import matplotlib.pyplot as plt
import seaborn as sns
from optuna.visualization import plot_param_importances
```

```
import optuna
```

 c:\Users\Administrator\anaconda3\envs\machineind\lib\site-packages\tqdm\auto.py:21: TqdmWarning: IProgress not found. Please update jupyter or jupyterlab to the latest version. Please also update the tqdm package.

```
from .autonotebook import tqdm as notebook_tqdm
```

Some useful Functions

```
def get_feature_importance(model, model_name):
    """
    Extracts and plots feature importance for a trained model.

    Parameters:
    - model: Trained Pipeline containing the classifier.
    - model_name: Name of the model ('Gradient Boosting' or 'XGBoost').
    """
    # Extract classifier from pipeline
    classifier = model.named_steps['classifier']

    # Get feature importance values
    importance = classifier.feature_importances_

    # Get transformed feature names from the preprocessor
    preprocessor = model.named_steps['preprocessor']

    try:
        feature_names = preprocessor.get_feature_names_out()
    except AttributeError:
        feature_names = X_train.columns # Fallback if `get_feature_names_out` is not available

    # Ensure feature_names and importance lengths match
    if len(importance) != len(feature_names):
        print(f"Warning: Mismatch in feature importance length! ({len(importance)} vs {len(feature_names)})")
        feature_names = [f"Feature {i}" for i in range(len(importance))] # Assign generic names

    # Sort feature importance values
    sorted_idx = np.argsort(importance)[-1:]

    # Plot feature importance
    plt.figure(figsize=(10, 6))
    plt.barh(np.array(feature_names)[sorted_idx], importance[sorted_idx])
    plt.xlabel("Feature Importance")
    plt.ylabel("Features")
    plt.title(f"{model_name} Feature Importance")
    plt.gca().invert_yaxis()
```

```

plt.show()

# Return feature importance as a dictionary
return dict(zip(feature_names, importance))

# Return feature importance as a dictionary
return dict(zip(feature_names, importance))

def plot_param_importances_(study_model):
    """
    plot the importance of the most important hyperparameter

    study_model: optuna optimized and tuned model
    model: str. The model of interest
    """
    plotly_config = {"staticPlot": True}
    fig = plot_param_importances(study_model)
    fig.show(config=plotly_config)

# load the dataset
machine = pd.read_csv("../data/machine_downtime_cleaned.csv", parse_dates=['Date'])

# make a copy of the data
machine_ori = machine.copy()
# print the first few rows
machine.head()

```

	Date	Machine_ID	Assembly_Line_No	Coolant_Temperature	Hydraulic_Oil_Temperature	Spindle_Bearing_Temperature	Spindle_Vibration	
0	2021-12-08	Makino-L2-Unit1-2015	Shopfloor-L2	4.5	47.9	31.2	1.225	
1	2021-12-17	Makino-L2-Unit1-2015	Shopfloor-L2	21.7	47.5	35.8	1.078	
2	2021-12-17	Makino-L1-Unit1-2013	Shopfloor-L1	5.2	49.4	34.2	1.266	
3	2021-12-17	Makino-L1-Unit1-2013	Shopfloor-L1	24.4	48.1	36.6	0.778	
4	2021-12-21	Makino-L2-Unit1-2015	Shopfloor-L2	14.1	51.8	32.4	0.969	

✓ Preprocessing

we have to divide the numeric columns into those that are skewed and those that are normal in order to be able to apply the necessary standardization or normalization to avoid bias

```

# create an empty list to store columns that are normally or
# skewly distributed
normal_cols = []
skewed_cols = []

# loop through the numerical features
for col in machine_ori.select_dtypes(include=np.number):
    skewness = machine_ori[col].skew()
    kurtosis = machine_ori[col].kurt()

    # set a threshold for kurtosis and skewness and then append the necessary features
    if -0.2 <= skewness <= 0.3 and -0.2 <= kurtosis <= 0.2: # Adjust thresholds as needed
        normal_cols.append(col)
        print(f"{col}: Skewness = {skewness:.2f}, Kurtosis = {kurtosis:.2f} (Approximately Normal)")
    else:
        skewed_cols.append(col)
        print(f"{col}: Skewness = {skewness:.2f}, Kurtosis = {kurtosis:.2f} (Not Normally Distributed)")

```

```

Coolant_Temperature: Skewness = -0.22, Kurtosis = -1.35 (Not Normally Distributed)
Hydraulic_Oil_Temperature: Skewness = -0.00, Kurtosis = 0.05 (Approximately Normal)
Spindle_Bearing_Temperature: Skewness = -0.03, Kurtosis = -0.05 (Approximately Normal)
Spindle_Vibration: Skewness = 0.03, Kurtosis = -0.11 (Approximately Normal)
Tool_Vibration: Skewness = -0.06, Kurtosis = 0.01 (Approximately Normal)
Voltage(volts): Skewness = -0.03, Kurtosis = -0.09 (Approximately Normal)

```

```
Torque(Nm): Skewness = 0.03, Kurtosis = -0.46 (Not Normally Distributed)
Hydraulic_Pressure(Pa): Skewness = 0.21, Kurtosis = -0.98 (Not Normally Distributed)
Coolant_Pressure(Pa): Skewness = -0.01, Kurtosis = -0.13 (Approximately Normal)
Air_System_Pressure(Pa): Skewness = -0.05, Kurtosis = 0.01 (Approximately Normal)
Cutting(N): Skewness = 0.12, Kurtosis = -1.09 (Not Normally Distributed)
Spindle_Speed(RPS): Skewness = 0.22, Kurtosis = -0.45 (Not Normally Distributed)
```

Model Parameters Preparation

```
# Define target and features
X = machine_ori.drop(columns=["Downtime", "Date", "Assembly_Line_No"]) # Features

# define encoder
label_encode = LabelEncoder()
y = label_encode.fit_transform(machine_ori["Downtime"]) # Target variable

# Identify numerical and categorical columns
numerical_cols = X.select_dtypes(include=['float64', 'int64']).columns
category_col = X.select_dtypes(include=['object']).columns

# Define transformers
preprocessor = ColumnTransformer([
    ("robust", RobustScaler(), skewed_cols), # Skewed data
    ("standard", StandardScaler(), normal_cols), # Normal data
    ("one-hot-encoder", OneHotEncoder(), category_col) # Machine_ID column
])

# Train-test split
# Step 1: Split into Train (60%), Validation (20%), Test (20%)
X_train_val, X_test, y_train_val, y_test = train_test_split(X, y, test_size=0.2, stratify=y, random_state=42)
X_train, X_val, y_train, y_val = train_test_split(X_train_val, y_train_val, test_size=0.25, stratify=y_train_val, random_state=42)

# Define models
models = {
    "Bayesian Logistic Regression": LogisticRegression(solver="lbfgs"),
    "Random Forest": RandomForestClassifier(n_estimators=100, random_state=42),
    "Gradient Boosting": GradientBoostingClassifier(n_estimators=100, random_state=42),
    "Decision Tree": DecisionTreeClassifier(random_state=42),
    "SVM": SVC(kernel="rbf", probability=True, random_state=42),
    "XGBoost": xgb.XGBClassifier(eval_metric="auc", random_state = 42)
}
```

Train the model

Cross Validation

Since our problem is a classification task, Stratified K-Fold (StratifiedKFold) will be use for the cross validation.

Why Use Stratified K-Fold?

- Preserves Class Distribution: Stratified K-Fold ensures that each fold maintains the same proportion of classes as the overall dataset, which is crucial when dealing with classification problems, even if there is no visible class imbalance.
- More Reliable Performance Estimates: It provides a more stable and representative estimate of your model's performance compared to ShuffleSplit, which may produce folds with different class distributions.
- Better Generalization: Ensures that all classes are well represented in training and validation splits, reducing the risk of biased results.

Key Performance Metrics and Their Meaning

- Precision: Measures how many of the predicted failures were actually failures. A high precision means fewer false positives.
- Recall: Measures how many of the actual failures were correctly identified. A high recall means fewer false negatives.
- F1-Score: Harmonic mean of precision and recall, balancing both. Higher is better.
- ROC AUC: Measures the model's ability to distinguish between classes. A value closer to 1 is better.

```
# craete an empty list to store model result
model_results = []

# Initialize Stratified K-Fold
cv = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)

for name, model in models.items():
    precision_scores, recall_scores, f1_scores, roc_auc_scores = [], [], [], []
```

```

for train_index, val_index in cv.split(X_train_val, y_train_val):
    X_train_fold, X_val_fold = X_train_val.iloc[train_index], X_train_val.iloc[val_index]
    y_train_fold, y_val_fold = y_train_val[train_index], y_train_val[val_index]

    # Create a pipeline
    pipeline = Pipeline([
        ('preprocessor', preprocessor),
        ('classifier', model)
    ])

    # Train the model
    pipeline.fit(X_train_fold, y_train_fold)

    # Make predictions
    y_pred = pipeline.predict(X_val_fold)
    y_prob = pipeline.predict_proba(X_val_fold)[:, 1] if hasattr(model, 'predict_proba') else None

    # Evaluate Metrics
    precision_scores.append(precision_score(y_val_fold, y_pred))
    recall_scores.append(recall_score(y_val_fold, y_pred))
    f1_scores.append(f1_score(y_val_fold, y_pred))
    roc_auc_scores.append(roc_auc_score(y_val_fold, y_prob) if y_prob is not None else np.nan)

# Compute mean scores across folds
mean_precision = np.mean(precision_scores)
mean_recall = np.mean(recall_scores)
mean_f1 = np.mean(f1_scores)
mean_roc_auc = np.nanmean(roc_auc_scores)

# Append results
model_results.append({
    "Model": name,
    "Precision": round(mean_precision, 4),
    "Recall": round(mean_recall, 4),
    "F1-Score": round(mean_f1, 4),
    "ROC AUC": round(mean_roc_auc, 4)
})

# Convert results to DataFrame
model_results_df = pd.DataFrame(model_results)

```

✓ Model Performance and Best Result

Model Performance Interpretation

1. XGBoost (0.9993 ROC AUC, 0.9919 F1-Score)

- Remains a top performer with exceptional discrimination ability (ROC AUC) and a near-perfect balance of precision and recall (F1-Score).
- It's likely to generalize well to the test set.

2. Random Forest (0.9990 ROC AUC, 0.9858 F1-Score)

- Also demonstrates excellent performance, very close to XGBoost.
- If interpretability is crucial, it might be preferable.

3. Gradient Boosting (0.9991 ROC AUC, 0.9919 F1-Score)

- Achieves top-tier performance, comparable to XGBoost, with a slight edge in recall.

4. Decision Tree (0.9694 ROC AUC, 0.9692 F1-Score)

- Shows good performance but falls short compared to the ensemble methods (XGBoost, Random Forest, Gradient Boosting).

5. SVM (0.9439 ROC AUC, 0.8779 F1-Score)

- Exhibits decent performance but is outperformed by the ensemble models.

6. Bayesian Logistic Regression (0.9292 ROC AUC, 0.8625 F1-Score)

- Shows moderate performance, lagging behind the other models.

Observations

- Ensemble methods (XGBoost, Random Forest, Gradient Boosting) consistently outperform the single models (Decision Tree, SVM, Bayesian Logistic Regression).
- XGBoost, Random Forest, and Gradient Boosting have shown remarkable performance, with very high ROC AUC and F1-Scores.

```
model_results_df.head(10)
```

	Model	Precision	Recall	F1-Score	ROC AUC
0	Bayesian Logistic Regression	0.8650	0.8607	0.8625	0.9292
1	Random Forest	0.9809	0.9908	0.9858	0.9990
2	Gradient Boosting	0.9889	0.9949	0.9919	0.9991
3	Decision Tree	0.9630	0.9756	0.9692	0.9694
4	SVM	0.8799	0.8760	0.8779	0.9439
5	XGBoost	0.9900	0.9920	0.9910	0.9993

Hyperparameter Tuning

```
# Cross-validation function
def cross_validate_model(model):
    skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
    f1_scores, precision_scores, recall_scores, roc_auc_scores = [], [], [], []

    for train_idx, val_idx in skf.split(X_train, y_train):
        X_train_fold, X_val_fold = X_train.iloc[train_idx], X_train.iloc[val_idx]
        y_train_fold, y_val_fold = y_train[train_idx], y_train[val_idx]

        pipeline = Pipeline([
            ('preprocessor', preprocessor),
            ('classifier', model)
        ])

        pipeline.fit(X_train_fold, y_train_fold)
        y_pred = pipeline.predict(X_val_fold)
        y_prob = pipeline.predict_proba(X_val_fold)[:, 1] if hasattr(model, 'predict_proba') else None

        f1_scores.append(f1_score(y_val_fold, y_pred))
        precision_scores.append(precision_score(y_val_fold, y_pred))
        recall_scores.append(recall_score(y_val_fold, y_pred))
        roc_auc_scores.append(roc_auc_score(y_val_fold, y_prob))

    return np.mean([np.mean(f1_scores), np.mean(precision_scores), np.mean(recall_scores), np.mean(roc_auc_scores)])

# Define Optuna objective functions for each model
def objective_xgb(trial):
    params = {
        'n_estimators': trial.suggest_int('n_estimators', 100, 500, step=50),
        'max_depth': trial.suggest_int('max_depth', 3, 12),
        'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
        'subsample': trial.suggest_float('subsample', 0.6, 1.0),
        'colsample_bytree': trial.suggest_float('colsample_bytree', 0.6, 1.0),
        'gamma': trial.suggest_float('gamma', 0, 10),
        'reg_alpha': trial.suggest_float('reg_alpha', 0, 10),
        'reg_lambda': trial.suggest_float('reg_lambda', 0, 10),
        'random_state': 42,
        # 'use_label_encoder': False,
        'eval_metric': 'auc'
    }
    return cross_validate_model(xgb.XGBClassifier(**params))

def objective_gb(trial):
    params = {
        'n_estimators': trial.suggest_int('n_estimators', 100, 500, step=50),
        'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
```

```
'max_depth': trial.suggest_int('max_depth', 3, 12),
'subsample': trial.suggest_float('subsample', 0.6, 1.0),
'random_state': 42
}
return cross_validate_model(GradientBoostingClassifier(**params))

# Run Optuna for each model
study_xgb = optuna.create_study(direction='maximize')
study_xgb.optimize(objective_xgb, n_trials=50, timeout=1800)

study_gb = optuna.create_study(direction='maximize')
study_gb.optimize(objective_gb, n_trials=50, timeout=1800)

# Train best models
best_gb = Pipeline([
    ('preprocessor', preprocessor),
    ('classifier', GradientBoostingClassifier(**study_gb.best_params, random_state=42))
])
best_gb.fit(X_train, y_train)

best_xgb = Pipeline([
    ('preprocessor', preprocessor),
    ('classifier', xgb.XGBClassifier(**study_xgb.best_params, random_state=42, eval_metric='auc'))
])
best_xgb.fit(X_train, y_train)
```

```
[I 2025-03-02 18:31:07,898] A new study created in memory with name: no-name-17b7ad18-92a0-468a-b311-7264a8edad9d
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:08,356] Trial 0 finished with value: 0.988278470766415 and parameters: {'n_estimators': 150, 'max_depth': 12, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:08,891] Trial 1 finished with value: 0.9908686625700931 and parameters: {'n_estimators': 300, 'max_depth': 6, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:09,567] Trial 2 finished with value: 0.9866019195700495 and parameters: {'n_estimators': 500, 'max_depth': 11, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:10,535] Trial 3 finished with value: 0.9878361006948216 and parameters: {'n_estimators': 400, 'max_depth': 4, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:11,009] Trial 4 finished with value: 0.987853520281344 and parameters: {'n_estimators': 150, 'max_depth': 6, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:11,665] Trial 5 finished with value: 0.9878059563458466 and parameters: {'n_estimators': 450, 'max_depth': 5, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:12,325] Trial 6 finished with value: 0.9884132931080809 and parameters: {'n_estimators': 350, 'max_depth': 5, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:13,099] Trial 7 finished with value: 0.9838452827764559 and parameters: {'n_estimators': 200, 'max_depth': 12, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:13,878] Trial 8 finished with value: 0.987320219615837 and parameters: {'n_estimators': 500, 'max_depth': 10, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:14,539] Trial 9 finished with value: 0.9903827522462619 and parameters: {'n_estimators': 300, 'max_depth': 7, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:15,044] Trial 10 finished with value: 0.9898317617965923 and parameters: {'n_estimators': 250, 'max_depth': 9, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:15,931] Trial 11 finished with value: 0.9903579470315323 and parameters: {'n_estimators': 300, 'max_depth': 7, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:16,554] Trial 12 finished with value: 0.9878162605573901 and parameters: {'n_estimators': 300, 'max_depth': 8, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:17,121] Trial 13 finished with value: 0.9873509858521456 and parameters: {'n_estimators': 350, 'max_depth': 3, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:17,902] Trial 14 finished with value: 0.9884103157878987 and parameters: {'n_estimators': 250, 'max_depth': 7, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:18,371] Trial 15 finished with value: 0.990427699198005 and parameters: {'n_estimators': 100, 'max_depth': 8, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:18,758] Trial 16 finished with value: 0.9888363861201674 and parameters: {'n_estimators': 100, 'max_depth': 9, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:19,265] Trial 17 finished with value: 0.9889039710385092 and parameters: {'n_estimators': 100, 'max_depth': 8, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:19,945] Trial 18 finished with value: 0.9888670199148961 and parameters: {'n_estimators': 200, 'max_depth': 6, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:20,558] Trial 19 finished with value: 0.985193899340221 and parameters: {'n_estimators': 400, 'max_depth': 9, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:20,945] Trial 20 finished with value: 0.98831028147604 and parameters: {'n_estimators': 150, 'max_depth': 3, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:21,579] Trial 21 finished with value: 0.9908500141667183 and parameters: {'n_estimators': 300, 'max_depth': 6, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:22,160] Trial 22 finished with value: 0.9903849895829363 and parameters: {'n_estimators': 250, 'max_depth': 6, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:22,862] Trial 23 finished with value: 0.9898912663745791 and parameters: {'n_estimators': 350, 'max_depth': 5, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:23,641] Trial 24 finished with value: 0.9908945294767043 and parameters: {'n_estimators': 200, 'max_depth': 8, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:24,321] Trial 25 finished with value: 0.9893512276960249 and parameters: {'n_estimators': 200, 'max_depth': 4, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:31:25,036] Trial 26 finished with value: 0.9898732909724978 and parameters: {'n_estimators': 250, 'max_depth': 6, 'le
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
```

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[I 2025-03-02 18:31:26,331] Trial 27 finished with value: 0.9898496378795003 and parameters: {'n_estimators': 400, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:27,322] Trial 28 finished with value: 0.9898832420984804 and parameters: {'n_estimators': 350, 'max_depth': 7, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:27,784] Trial 29 finished with value: 0.9872229277986706 and parameters: {'n_estimators': 200, 'max_depth': 4, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:28,633] Trial 30 finished with value: 0.9888803624633611 and parameters: {'n_estimators': 300, 'max_depth': 5, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:29,137] Trial 31 finished with value: 0.9909383376874792 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:29,696] Trial 32 finished with value: 0.9934078486242388 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:30,322] Trial 33 finished with value: 0.9893917679321659 and parameters: {'n_estimators': 150, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:30,837] Trial 34 finished with value: 0.990920289533906 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:31,389] Trial 35 finished with value: 0.9924355439928543 and parameters: {'n_estimators': 150, 'max_depth': 9, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:31,860] Trial 36 finished with value: 0.9883031143449847 and parameters: {'n_estimators': 150, 'max_depth': 11, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:32,333] Trial 37 finished with value: 0.9893921613415056 and parameters: {'n_estimators': 100, 'max_depth': 9, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:32,807] Trial 38 finished with value: 0.9894348795564093 and parameters: {'n_estimators': 150, 'max_depth': 11, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:33,311] Trial 39 finished with value: 0.990427564894624 and parameters: {'n_estimators': 150, 'max_depth': 9, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:33,716] Trial 40 finished with value: 0.988405357274741 and parameters: {'n_estimators': 100, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:34,313] Trial 41 finished with value: 0.9914107087718351 and parameters: {'n_estimators': 200, 'max_depth': 8, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:34,822] Trial 42 finished with value: 0.9908943959881342 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:35,432] Trial 43 finished with value: 0.9909428415831845 and parameters: {'n_estimators': 200, 'max_depth': 8, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:36,056] Trial 44 finished with value: 0.9904052071154372 and parameters: {'n_estimators': 200, 'max_depth': 7, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:36,722] Trial 45 finished with value: 0.9918937209336804 and parameters: {'n_estimators': 200, 'max_depth': 9, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:37,435] Trial 46 finished with value: 0.9903543889671329 and parameters: {'n_estimators': 250, 'max_depth': 9, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:38,224] Trial 47 finished with value: 0.9929161744152163 and parameters: {'n_estimators': 200, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:38,965] Trial 48 finished with value: 0.9929342073488121 and parameters: {'n_estimators': 250, 'max_depth': 12, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:39,539] Trial 49 finished with value: 0.9894437633835 and parameters: {'n_estimators': 250, 'max_depth': 12, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:31: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:39,540] A new study created in memory with name: no-name-61d66c20-54b0-4cae-b157-80e5974ffe64
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:31:57,303] Trial 0 finished with value: 0.9810150072057842 and parameters: {'n_estimators': 400, 'learning_rate': 0.01, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:32:01,359] Trial 1 finished with value: 0.9903668085937369 and parameters: {'n_estimators': 150, 'learning_rate': 0.01, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:32:10,296] Trial 2 finished with value: 0.9934824000257932 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:32:22,457] Trial 3 finished with value: 0.9908192004181148 and parameters: {'n_estimators': 250, 'learning_rate': 0.01, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
[I 2025-03-02 18:32:31,422] Trial 4 finished with value: 0.9918515289795624 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 'max_depth': 10, 'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
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9/10

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C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:39:27,519] Trial 34 finished with value: 0.9940241102659251 and parameters: {'n_estimators': 450, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:39:36,501] Trial 35 finished with value: 0.9945427426152144 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:39:57,781] Trial 36 finished with value: 0.9903401704491669 and parameters: {'n_estimators': 350, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:05,244] Trial 37 finished with value: 0.9940264456602901 and parameters: {'n_estimators': 250, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:15,165] Trial 38 finished with value: 0.9940218574048738 and parameters: {'n_estimators': 450, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:23,739] Trial 39 finished with value: 0.9940241934080378 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:38,274] Trial 40 finished with value: 0.9934574628357581 and parameters: {'n_estimators': 400, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:45,991] Trial 41 finished with value: 0.9935100652588535 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:53,980] Trial 42 finished with value: 0.9930016401162003 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:40:59,476] Trial 43 finished with value: 0.9924828589982035 and parameters: {'n_estimators': 200, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:41:10,717] Trial 44 finished with value: 0.9939896879717087 and parameters: {'n_estimators': 250, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:41:18,140] Trial 45 finished with value: 0.9945404903629621 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:41:25,679] Trial 46 finished with value: 0.9940286147704296 and parameters: {'n_estimators': 300, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:41:34,820] Trial 47 finished with value: 0.9924053422874196 and parameters: {'n_estimators': 350, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:41:45,474] Trial 48 finished with value: 0.9934529583312536 and parameters: {'n_estimators': 350, 'learning_rate': 0.01, 0.3),
C:\Users\Administrator\AppData\Local\Temp\ipykernel_3276\4092580619.py:47: FutureWarning: suggest_loguniform has been deprecated in v
'learning_rate': trial.suggest_loguniform('learning_rate', 0.01, 0.3),
[I 2025-03-02 18:42:02,435] Trial 49 finished with value: 0.9923768756753246 and parameters: {'n_estimators': 450, 'learning_rate': 0.01, 0.3),
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