Kaggle Playground

Problem Statement / Real World Implementations

In [1]:
```
!pip install optuna-integration[xgboost]
```

```
Collecting optuna-integration[xgboost]
  Downloading optuna_integration-4.5.0-py3-none-any.whl.metadata (12 kB)
Requirement already satisfied: optuna in /usr/local/lib/python3.11/dist-packages (fr
om optuna-integration[xgboost]) (4.5.0)
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ation[xgboost]) (2024.2.0)
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```

```
Installing collected packages: optuna-integration
Successfully installed optuna-integration-4.5.0
```

In [2]:

```python
# --- 1. Importing Libraries ---
import numpy as np
import pandas as pd
import warnings
import optuna
import matplotlib.pyplot as plt
import seaborn as sns
from IPython.display import display

from sklearn.model_selection import KFold, train_test_split, StratifiedKFold
from sklearn.preprocessing import OrdinalEncoder, StandardScaler, RobustScaler, Qua
from sklearn.metrics import roc_auc_score, mean_squared_error, mean_absolute_error,

from xgboost import XGBRegressor
from catboost import CatBoostRegressor
# (LightGBM imports have been removed)

# Notebook settings
warnings.filterwarnings('ignore')
pd.set_option('display.max_columns', None)
optuna.logging.set_verbosity(optuna.logging.WARNING)

N_TRIALS_XGB = 50
N_TRIALS_CATBOOST = 30
N_SPLITS_OOF_CHECK = 5
N_SPLITS_TUNE = 5
GLOBAL_RANDOM_STATE = 42

print("Version 10: AUC-Driven 2-Model (XGB + CAT) CV-Tuned Blend")
print(f"--- 1. Loading Data ---")

# Define file paths
TRAIN_PATH = "/kaggle/input/playground-series-s5e11/train.csv"
TEST_PATH = "/kaggle/input/playground-series-s5e11/test.csv"

# Load the datasets
train_df = pd.read_csv(TRAIN_PATH)
test_df = pd.read_csv(TEST_PATH)

print(f"Train shape: {train_df.shape}, Test shape: {test_df.shape}")

# --- 2. Preprocessing & Feature Engineering (V4 DNA + V10 Experimental) ---
print("--- 2. Defining Preprocessing & Feature Engineering Pipelines ---")

def create_financial_features_v4(df):
    """ V4 Champion DNA Features """
    df_feat = df.copy()
    df_feat['loan_to_income_ratio'] = df_feat['loan_amount'] / (df_feat['annual_inc
    df_feat['interest_x_loan'] = df_feat['interest_rate'] * df_feat['loan_amount']
    df_feat['available_income'] = df_feat['annual_income'] * (1 - df_feat['debt_to_
    df_feat['loan_to_available_income'] = df_feat['loan_amount'] / (df_feat['availa
    df_feat.replace([np.inf, -np.inf], np.nan, inplace=True)
    return df_feat
```

```python
def add_experimental_features(df):
    """ V10 Experimental Features (Point 1) """
    df_feat = df.copy()
    df_feat['interest_to_income_ratio'] = df_feat['interest_rate'] / (df_feat['annu
    df_feat['credit_score_x_interest'] = df_feat['credit_score'] * df_feat['interes
    df_feat['credit_score_to_loan'] = df_feat['credit_score'] / (df_feat['loan_amou
    df_feat.replace([np.inf, -np.inf], np.nan, inplace=True)
    return df_feat

# FIX: Create map from TRAIN data ONLY to prevent leakage
all_grades = train_df['grade_subgrade'].unique()
grades_sorted = sorted([g for g in all_grades if pd.notna(g)])
ALL_GRADES_MAP = {grade: i for i, grade in enumerate(grades_sorted)}

def apply_logical_encoding(df, all_grades_map):
    """ Applies logical ordinal mapping as per V4 DNA """
    df_encoded = df.copy()
    education_map = {'Other': 0, 'High School': 1, "Bachelor's": 2, "Master's": 3,
    df_encoded['education_level'] = df_encoded['education_level'].map(education_map
    df_encoded['grade_subgrade'] = df_encoded['grade_subgrade'].map(all_grades_map)
    return df_encoded

def preprocess(df, use_experimental_features=False, train_cols=None, encoder=None):
    """ Full preprocessing pipeline """
    df_proc = df.drop('id', axis=1, errors='ignore')

    # 1. V4 Features
    df_proc = create_financial_features_v4(df_proc)

    # 2. Experimental Features
    if use_experimental_features:
        df_proc = add_experimental_features(df_proc)

    # 3. Logical Encoding
    df_proc = apply_logical_encoding(df_proc, ALL_GRADES_MAP)

    # 4. Other Categorical Features
    categorical_cols = list(df_proc.select_dtypes(include='object').columns)

    if encoder is None:
        df_proc[categorical_cols] = df_proc[categorical_cols].fillna('Missing')
        encoder = OrdinalEncoder(handle_unknown='use_encoded_value', unknown_value=
        df_proc[categorical_cols] = encoder.fit_transform(df_proc[categorical_cols]
    else:
        df_proc[categorical_cols] = df_proc[categorical_cols].fillna('Missing')
        df_proc[categorical_cols] = encoder.transform(df_proc[categorical_cols])

    # 5. Handle NaNs with sentinel value -1 (V4 DNA)
    df_proc = df_proc.fillna(-1)

    # 6. Align columns
    if train_cols is not None:
        missing_cols = set(train_cols) - set(df_proc.columns)
        for c in missing_cols:
            df_proc[c] = -1
```

```
        df_proc = df_proc[train_cols]

    return df_proc, encoder

# --- 3. Feature & Scaler Selection (Point 1 & 2) ---
print("--- 3. Testing Feature Sets and Scalers (Points 1 & 2) ---")

# Prepare data for testing
y_full = train_df['loan_paid_back']

# Base V4 features
train_proc_v4, cat_encoder_v4 = preprocess(train_df.drop('loan_paid_back', axis=1),
X_train_v4, X_val_v4, y_train_v4, y_val_v4 = train_test_split(train_proc_v4, y_full

# Experimental features
train_proc_exp, cat_encoder_exp = preprocess(train_df.drop('loan_paid_back', axis=1
X_train_exp, X_val_exp, y_train_exp, y_val_exp = train_test_split(train_proc_exp, y

# Scalers to test (Point 2)
scalers = {
    "Standard": StandardScaler(),
    "Robust": RobustScaler(),
    "Quantile": QuantileTransformer(output_distribution='normal', random_state=GLOB
}

results = []
# --- FIX: Use XGBRegressor for the quick test ---
xgb_test_params = {'tree_method': 'gpu_hist', 'predictor': 'gpu_predictor', 'gpu_id

# Test V4 Features
print("Testing V4 Features with different scalers...")
for name, scaler_obj in scalers.items():
    model = XGBRegressor(**xgb_test_params) # Use XGB for the test
    X_tr_s = scaler_obj.fit_transform(X_train_v4)
    X_val_s = scaler_obj.transform(X_val_v4)
    model.fit(X_tr_s, y_train_v4)
    preds = model.predict(X_val_s)
    auc = roc_auc_score(y_val_v4, preds)
    results.append({"features": "V4_Baseline", "scaler": name, "auc": auc})

# Test Experimental Features (Point 1)
print("Testing V10 Experimental Features with different scalers...")
for name, scaler_obj in scalers.items():
    model = XGBRegressor(**xgb_test_params) # Use XGB for the test
    X_tr_s = scaler_obj.fit_transform(X_train_exp)
    X_val_s = scaler_obj.transform(X_val_exp)
    model.fit(X_tr_s, y_train_exp)
    preds = model.predict(X_val_s)
    auc = roc_auc_score(y_val_exp, preds)
    results.append({"features": "V10_Experimental", "scaler": name, "auc": auc})

results_df = pd.DataFrame(results).sort_values(by="auc", ascending=False)
print("\n--- Scaler and Feature Validation Results ---")
print(results_df)

# Select best config
```

```
best_config = results_df.iloc[0]
best_feature_set_name = best_config['features']
BEST_SCALER_CLASS = scalers[best_config['scaler']].__class__ # Get the class, not t
USE_EXPERIMENTAL_FEATURES = (best_feature_set_name == "V10_Experimental")

# (Point 1 Check)
baseline_auc = results_df[results_df['features'] == 'V4_Baseline']['auc'].max()
exp_auc = results_df[results_df['features'] == 'V10_Experimental']['auc'].max()
auc_gain = exp_auc - baseline_auc

if (USE_EXPERIMENTAL_FEATURES and auc_gain > 0.002):
    print(f"\nDecision (Point 1): V10 Experimental features kept (AUC Gain: {auc_ga
else:
    if USE_EXPERIMENTAL_FEATURES:
        print(f"\nDecision (Point 1): V10 features gain ({auc_gain:+.6f}) < 0.002.
    else:
        print(f"\nDecision (Point 1): V4 features performed best. Sticking with V4
    USE_EXPERIMENTAL_FEATURES = False
    # Re-select the best scaler *just* for V4 features
    best_config_v4 = results_df[results_df['features'] == 'V4_Baseline'].iloc[0]
    BEST_SCALER_CLASS = scalers[best_config_v4['scaler']].__class__

print(f"Selected Features: {'V10_Experimental' if USE_EXPERIMENTAL_FEATURES else 'V
print(f"Selected Scaler (Point 2): {BEST_SCALER_CLASS.__name__}")


# --- 4. OOF Sanity Check ---
print(f"\n--- 4. OOF Sanity Check ({N_SPLITS_OOF_CHECK}-Folds) ---")
train_proc_final, cat_encoder_final = preprocess(train_df.drop('loan_paid_back', ax
                                                 use_experimental_features=USE_EXPE
y_full = train_df['loan_paid_back']
FINAL_TRAIN_COLS = train_proc_final.columns

kf = KFold(n_splits=N_SPLITS_OOF_CHECK, shuffle=True, random_state=GLOBAL_RANDOM_ST
oof_preds = np.zeros(len(train_proc_final))

# --- FIX: Use XGBRegressor for the sanity check ---
xgb_test_params = {'tree_method': 'gpu_hist', 'predictor': 'gpu_predictor', 'gpu_id
model_oof = XGBRegressor(**xgb_test_params)
# --- End Fix ---

for fold, (train_idx, val_idx) in enumerate(kf.split(train_proc_final, y_full)):
    print(f"Running OOF Fold {fold+1}/{N_SPLITS_OOF_CHECK}...")
    X_tr, X_v = train_proc_final.iloc[train_idx], train_proc_final.iloc[val_idx]
    y_tr, y_v = y_full.iloc[train_idx], y_full.iloc[val_idx]

    scaler_oof = BEST_SCALER_CLASS()
    X_tr_s = scaler_oof.fit_transform(X_tr)
    X_v_s = scaler_oof.transform(X_v)

    model_oof.fit(X_tr_s, y_tr)
    oof_preds[val_idx] = model_oof.predict(X_v_s)

oof_auc = roc_auc_score(y_full, oof_preds)
print(f"\nSanity Check OOF AUC: {oof_auc:.6f}")
```

```python
# --- 5. Unified AUC Tuning Function (CV-Based) ---
print(f"\n--- 5. AUC-Driven Optuna Tuning (with {N_SPLITS_TUNE}-Fold CV) ---")

X_train_final = train_proc_final
y_train_final = y_full

def train_auc_model(model_type="xgb", n_trials=30):
    """
    Unified Optuna-AUC pipeline function
    Uses K-Fold CV for robust tuning.
    """

    def objective(trial):
        # --- Create parameters ---
        if model_type == "xgb":
            param = {
                'tree_method': 'gpu_hist', 'predictor': 'gpu_predictor', 'gpu_id':
                'lambda': trial.suggest_loguniform('lambda', 1e-3, 10.0),
                'alpha': trial.suggest_loguniform('alpha', 1e-3, 10.0),
                'colsample_bytree': trial.suggest_categorical('colsample_bytree', [
                'subsample': trial.suggest_categorical('subsample', [0.6, 0.7, 0.8,
                'learning_rate': trial.suggest_float('learning_rate', 0.01, 0.05, l
                'n_estimators': trial.suggest_int('n_estimators', 400, 1500),
                'max_depth': trial.suggest_int('max_depth', 4, 10),
                'min_child_weight': trial.suggest_int('min_child_weight', 1, 300),
                'random_state': GLOBAL_RANDOM_STATE, 'verbosity': 0
            }

        elif model_type == "catboost":
            param = {
                'task_type': 'GPU', 'iterations': trial.suggest_int('iterations', 5
                'learning_rate': trial.suggest_float('learning_rate', 0.01, 0.05, l
                'depth': trial.suggest_int('depth', 4, 10),
                'l2_leaf_reg': trial.suggest_loguniform('l2_leaf_reg', 1.0, 10.0),
                'random_strength': trial.suggest_loguniform('random_strength', 1.0,
                'bagging_temperature': trial.suggest_loguniform('bagging_temperatur
                'eval_metric': 'AUC', 'od_type': 'Iter', 'od_wait': 50,
                'random_seed': GLOBAL_RANDOM_STATE, 'verbose': 0
            }

        # --- Run 5-Fold Cross-Validation ---
        kf = KFold(n_splits=N_SPLITS_TUNE, shuffle=True, random_state=GLOBAL_RANDOM
        fold_auc_scores = []

        for fold, (train_idx, val_idx) in enumerate(kf.split(X_train_final, y_train
            X_tr, X_v = X_train_final.iloc[train_idx], X_train_final.iloc[val_idx]
            y_tr, y_v = y_train_final.iloc[train_idx], y_train_final.iloc[val_idx]

            scaler_cv = BEST_SCALER_CLASS()
            X_tr_s = scaler_cv.fit_transform(X_tr)
            X_v_s = scaler_cv.transform(X_v)

            if model_type == "xgb":
                model = XGBRegressor(**param)
                model.fit(X_tr_s, y_tr,
```

```
                            eval_set=[(X_v_s, y_v)],
                            eval_metric='auc',
                            callbacks=[optuna.integration.XGBoostPruningCallback(tria
                            early_stopping_rounds=100,
                            verbose=0)

                elif model_type == "catboost":
                    model = CatBoostRegressor(**param)
                    model.fit(X_tr_s, y_tr,
                              eval_set=[(X_v_s, y_v)],
                              early_stopping_rounds=100,
                              verbose=0)

                preds = model.predict(X_v_s)
                auc = roc_auc_score(y_v, preds)
                fold_auc_scores.append(auc)

                trial.report(auc, fold)
                if trial.should_prune():
                    raise optuna.exceptions.TrialPruned()

            return np.mean(fold_auc_scores)

        # --- Run the study ---
        pruner = optuna.pruners.MedianPruner(n_warmup_steps=2)
        study = optuna.create_study(direction='maximize', pruner=pruner)
        study.optimize(objective, n_trials=n_trials, timeout=7200)

        print(f"Best {model_type.upper()} CV AUC: {study.best_value:.6f}")
        return study.best_params, study.best_value

    # --- Run tuners (LGBM removed) ---
    print(f"Tuning XGB for CV AUC ({N_TRIALS_XGB} trials)...")
    params_xgb, val_auc_xgb = train_auc_model("xgb", n_trials=N_TRIALS_XGB)

    print(f"Tuning CatBoost for CV AUC ({N_TRIALS_CATBOOST} trials)...")
    params_cat, val_auc_catboost = train_auc_model("catboost", n_trials=N_TRIALS_CATBOO


    # --- 6. AUC-Weighted Ensemble & Submission ---
    print("\n--- 6. Final Training, Blending, and Submission ---")

    print("Calculating AUC-based blend weights...")
    total_auc = val_auc_xgb + val_auc_catboost
    weight_xgb = val_auc_xgb / total_auc
    weight_catboost = val_auc_catboost / total_auc

    print(f"XGB Weight:  {weight_xgb:.4f} (CV AUC: {val_auc_xgb:.6f})")
    print(f"CAT Weight:  {weight_catboost:.4f} (CV AUC: {val_auc_catboost:.6f})")

    # Retrain models on 100% of the *best* feature set
    print("Retraining models on 100% data...")
    scaler_final = BEST_SCALER_CLASS()
    X_full_final_s = scaler_final.fit_transform(train_proc_final)
    y_full = train_df['loan_paid_back']
```

```
# Initialize and train final models
xgb_final = XGBRegressor(**params_xgb, tree_method='gpu_hist', predictor='gpu_predi
xgb_final.fit(X_full_final_s, y_full)

if 'iterations' not in params_cat:
    params_cat['iterations'] = 1000
catboost_final = CatBoostRegressor(**params_cat, task_type='GPU', eval_metric='AUC'
catboost_final.fit(X_full_final_s, y_full)

# Prepare test data
print("Preprocessing test data...")
test_proc, _ = preprocess(test_df,
                          use_experimental_features=USE_EXPERIMENTAL_FEATURES,
                          train_cols=FINAL_TRAIN_COLS,
                          encoder=cat_encoder_final)
X_test_scaled = scaler_final.transform(test_proc)

# Predict
print("Generating predictions from both models...")
preds_xgb = xgb_final.predict(X_test_scaled)
preds_catboost = catboost_final.predict(X_test_scaled)

# Blend
blended_preds = (weight_xgb * preds_xgb) + \
                (weight_catboost * preds_catboost)

# Clip predictions to prevent AUC penalties
clipped_preds = np.clip(blended_preds, 0.001, 0.999)

# Create submission file
print("Creating submission.csv...")
submission = pd.DataFrame({'id': test_df['id'], 'loan_paid_back': clipped_preds})
submission.to_csv('submission_v10.csv', index=False)

print("✅ Version 10 Complete. Submission file generated.")
display(submission.head())

# Display prediction distribution
print("\nFinal Prediction Distribution:")
sns.histplot(clipped_preds, bins=50, kde=True)
plt.title("Version 10 Final Blended Prediction Distribution")
plt.xlabel("Predicted loan_paid_back")
plt.show()
```

```
Version 10: AUC-Driven 2-Model (XGB + CAT) CV-Tuned Blend
--- 1. Loading Data ---
Train shape: (593994, 13), Test shape: (254569, 12)
--- 2. Defining Preprocessing & Feature Engineering Pipelines ---
--- 3. Testing Feature Sets and Scalers (Points 1 & 2) ---
Testing V4 Features with different scalers...
Testing V10 Experimental Features with different scalers...

--- Scaler and Feature Validation Results ---
           features    scaler       auc
2       V4_Baseline  Quantile  0.918066
5  V10_Experimental  Quantile  0.918045
1       V4_Baseline    Robust  0.917813
0       V4_Baseline  Standard  0.917812
3  V10_Experimental  Standard  0.917790
4  V10_Experimental    Robust  0.917606

Decision (Point 1): V4 features performed best. Sticking with V4 features.
Selected Features: V4_Baseline
Selected Scaler (Point 2): QuantileTransformer

--- 4. OOF Sanity Check (5-Folds) ---
Running OOF Fold 1/5...
Running OOF Fold 2/5...
Running OOF Fold 3/5...
Running OOF Fold 4/5...
Running OOF Fold 5/5...

Sanity Check OOF AUC: 0.918671

--- 5. AUC-Driven Optuna Tuning (with 5-Fold CV) ---
Tuning XGB for CV AUC (50 trials)...
Best XGB CV AUC: 0.919579
Tuning CatBoost for CV AUC (30 trials)...
```

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Best CATBOOST CV AUC: 0.918577

--- 6. Final Training, Blending, and Submission ---
Calculating AUC-based blend weights...
XGB Weight:  0.5003 (CV AUC: 0.919579)
CAT Weight:  0.4997 (CV AUC: 0.918577)
Retraining models on 100% data...
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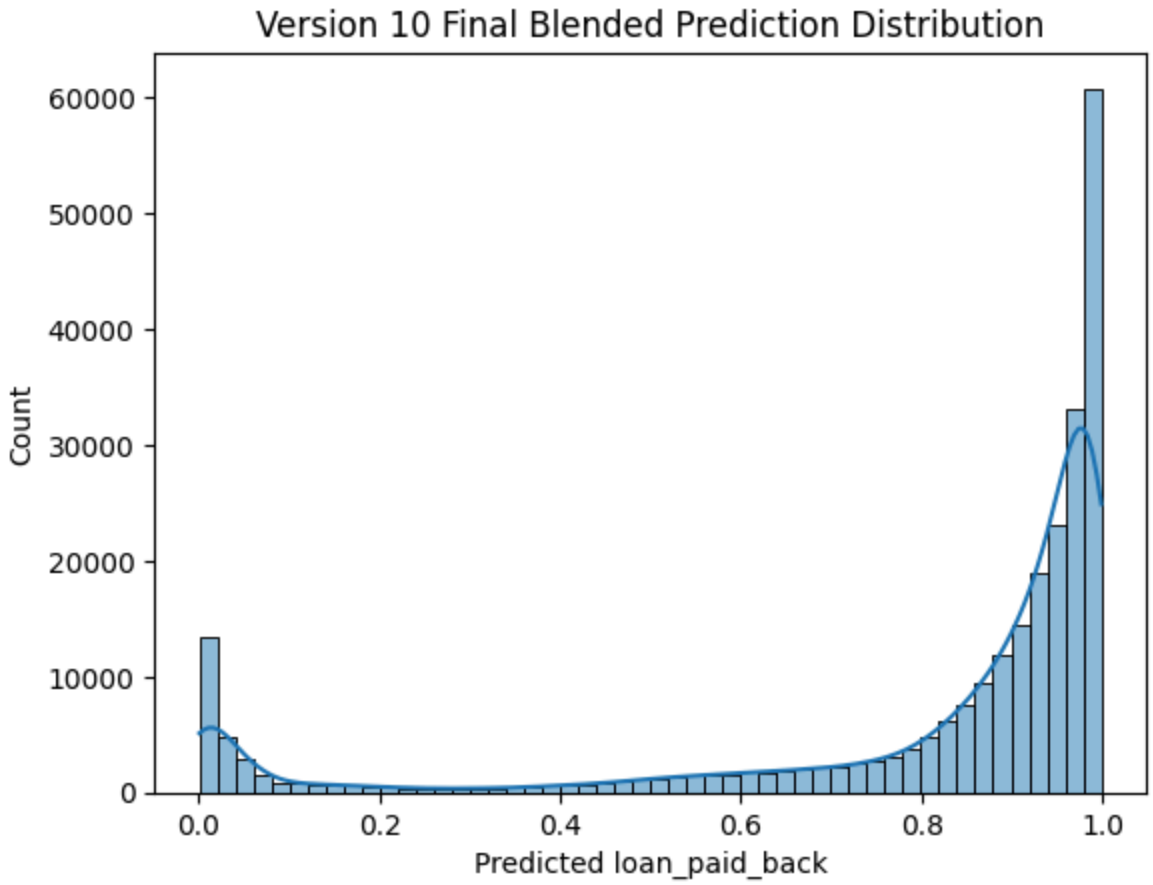
Preprocessing test data...
Generating predictions from both models...
Creating submission.csv...
✅ Version 10 Complete. Submission file generated.
```

	id	loan_paid_back
0	593994	0.938722
1	593995	0.972072
2	593996	0.382090
3	593997	0.928766
4	593998	0.967541

```
Final Prediction Distribution:
```



In [ ]: