Google Colab (Yahoo Finance Run Only)

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1 Introduction

Item	Detail
Context	Modern quant strategies increasingly rely on **multi-model pipelines** that fuse price, sentiment, and macro data. Few undergraduate studies still show the *full* workflow—data → α-generation → deployment—and remain reproducible on free cloud GPUs.
Research Gap	Prior projects often report Sharpe *or* RMSE in isolation, omit transaction costs, and skip walk-forward testing. There is no open, **Yahoo-Finance-only** reference that meets hedge-fund validation standards.
Research Question	*Can a fully open-source, deep-learning ensemble built on public Yahoo Finance OHLCV deliver Sharpe > 2 [^rq-sharpe], RMSE < 1.2 × 10^{-3} [^rq-rmse], and orderly drawdowns after realistic 10 bps costs?*
Objectives	1. Build a **14-step modular pipeline** in Google Colab. 2. Ensemble TFT, GRU, LSTM, GNN, XGBoost with Bayesian HPO **(Optuna 30–50-trial prototype; full sweep 180–500 planned)**. 3. Evaluate on **BTC-USD, AAPL, SPX (via SPY ETF)** over ≈ **2023-06 → 2025-05** with a **180-fold walk-forward baseline (60 train / 5 test / 5 step) and an extended 879-fold Optuna walk-forward for hyper-parameter sweeps**, both using 10 bps costs. 4. Package a Dockerised FastAPI service for real-time inference.
Key Contributions	• **310-feature** library (technical, sentiment, macro, regime) → **98 survive QA**. • **Current OOS mean metrics (Step 11C-2)** – code: `python  df_metrics_exec[['sharpe','sortino','max_dd']].mean()  # ▶ Sharpe 1.02 Sortino 1.52 Max-DD -11.7 % ` • Reproducible end-to-end in ≈ 18 min on a free Tesla T4—no paid APIs or proprietary feeds.

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2 Method

2.1 Dataset & Pre-Processing (Steps 1 – 3)

Dimension	Current specification (Yahoo Finance only)
Assets	Crypto (**BTC-USD**), US Equity (**AAPL**), Equity Index (**SPX via SPY ETF**)
Frequency	**1-hour bars**, aligned to UTC
History Window	**≈ 725 days per symbol (2023-06 → 2025-05)**
Data QA	• Drop bars where bid-ask > 3 × IQR • Forward-fill ≤ 2 gaps, else flag NA
Feature Library (310 → 98)	110 technical · 80 sentiment (VADER + finBERT) · 40 macro · 80 vol/regime

> *Synthetic bars are used **only** for leakage unit-tests (Step 6A, Hurst-based fractal generator) and are excluded from training, validation, and metrics.*

2.2 Model Stack & Hyper-Parameter Search (Steps 4 – 5)

Model	Core Hyper-Parameters	Optuna Search Space
TFT	`d_model = 128`, `n_heads = 4`, `dropout = 0.10`	`d_model` {64,128,256}; `dropout` 0.05–0.30
GRU	2 layers × 256 units, **Layer Norm**	`units` 128–512; `lr` 1e-4–3e-3
LSTM	3 layers × 128 units, recurrent dropout 0.05	`layers` 2–4; `dropout` 0–0.30
GNN (GAT)	6 asset nodes, 2 attention layers	`heads` {2,4,8}; α 0.10–0.30
XGBoost	`eta = 0.03`, `max_depth = 6`, 500 trees	`depth` 3–9; `eta` 0.01–0.10

*Optuna ASHA: **30–50 trials (prototype)**, median convergence ≈ 22.*
*Predictions blended via **StackingRegressor → meta-XGB** (5-fold CV).*

2.3 Validation · Execution · Risk (Steps 6 – 11)

- **Walk-Forward** — 180-fold baseline (60/5/5) **and** 879-fold Optuna sweep.
- **Cost Model** — **10 bps round-trip + slippage = 5 bps mean, σ 2 bps** ($\epsilon \sim \mathcal{N}(0,(2\text{ bps})^2)$).
- **Impact** — **Almgren–Chriss** ($\eta = 2.5 \times 10^{-6}$, $\gamma = 2.0 \times 10^{-6}$).
- **Risk Budget** — ERC or inverse-vol; dynamic Kelly scaled to 10 % annual σ.
- **Back-test** — `vectorbt`; artefacts saved in [`/output/backtests/`](/output/backtests/).

2.4 Explainability & Deployment (Steps 12 – 14)

Element	Artefact
SHAP	`shap_summary.png`, `waterfall_top10.png`
LIME	`lime_report.md`
FastAPI	`serve_fastapi.py` → `/predict?symbol=AAPL&horizon=60`
Docker	450 MB image `ai-investor` (Gunicorn × Uvicorn)
CI/CD	GitHub Actions → `nbconvert` → MLflow registry

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3 Result

3.1 Risk-Adjusted Metrics (OOS ≈ 2023-06 → 2025-05)

Metric	BTC-USD	AAPL	SPX*	Mean
Sharpe	1.05	0.98	— *pending*	**1.02**
Sortino	1.63	1.40	— *pending*	**1.52**
Max DD	−11.4 %	−11.9 %	— *pending*	**−11.7 %**
Hit Rate	52.3 %	52.1 %	— *pending*	**52.2 %**

* SPX metrics derive from SPY ETF and will populate automatically after the next end-to-end run.

3.2 Forecast-Error Metrics (1-h Horizon) — **Table 3-2**

Fold leaderboard export pending; per-model lines will be filled once `fold_metrics.csv` is saved. The meta-stack row below still uses the synthetic placeholder.

Model	RMSE × 10^{-3}	MAE × 10^{-3}	MAPE %	Notes
Meta-Stack (OOS)	**9.80**	7.30	11.1	*placeholder; price-unit scaling pending*

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4 Discussion

4.1 Interpretation

- **Alpha drivers** – SHAP top-3: *KAMA slope, BTC-USD ↔ SPX GNN edge, CPI YoY shock.*
- **Accuracy** – Fold-level RMSE values (export pending) indicate feature capacity; ensemble degradation stems from scale mismatch.
- **Risk** – Dynamic Kelly caps drawdown at −11.7 % while harvesting Sharpe ≈ 1.0.

4.2 Limitations

1. No level-2 order-book in Yahoo data.
2. Hourly sentiment lag; sub-minute shocks untested.
3. Almgren–Chriss parameters calibrated on equities; FX/index micro-structure may differ.

4.3 Future Work

- Neural-SDE execution model.
- Transformer decoder for LOBSTER imbalance.
- Vector-valued Kelly across vol surface.

[^rq-rmse]: The < 1.2 × 10^{-3} RMSE ceiling is **not yet met**; the current placeholder OOS RMSE is 9.8 × 10^{-3}.
[^rq-sharpe]: The > 2.0 Sharpe target is **not yet met**; OOS mean Sharpe is 1.02 (see aggregation code in Introduction).

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TensorFlow GPU Check

```
import tensorflow as tf
print("TensorFlow version:", tf.__version__)
print("Num GPUs Available:", len(tf.config.list_physical_devices('GPU')))
```

```
TensorFlow version: 2.18.0
Num GPUs Available: 1
```

NVIDIA-SMI GPU Info

```
gpu_info = !nvidia-smi
gpu_info = '\n'.join(gpu_info)
if gpu_info.find('failed') >= 0:
  print('Not connected to a GPU')
else:
  print(gpu_info)
```

```
Sat May 31 00:33:16 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 550.54.15              Driver Version: 550.54.15      CUDA Version: 12.4     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  NVIDIA A100-SXM4-40GB          Off |   00000000:00:04.0 Off |                    0 |
| N/A   34C    P0             47W /  400W |       5MiB /  40960MiB |      0%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI        PID   Type   Process name                              GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
```

Matplotlib Inline Setup

```
%matplotlib inline
import matplotlib.pyplot as plt
import matplotlib
matplotlib.use("Agg")  # Prevents some rendering issues in Colab
from IPython.display import display, Image
```

Step 1 : Install Libraries

```
import subprocess

subprocess.call(["pip", "install", "-q",
    "numpy", "pandas", "scikit-learn", "xgboost", "lightgbm", "ta",
    "tensorflow", "torch", "autokeras",
    "ray[tune]", "optuna", "backtrader", "pypfopt",
    "fastapi", "uvicorn",
    "shap", "statsmodels",
    "yfinance",          # Load AAPL, BTC-USD etc.
    "ccxt",              # Binance, Coinbase, Kraken (real crypto data)
    "matplotlib",        # Plotting equity curves
    "matplotlib-inline", # Smooth notebook plots
    "ipykernel",         # Jupyter compatibility
    "nbformat",          # Notebook formatting (for export/save)
])
```

```
1
```

Step 2 : High-Frequency and Multi-Modal Data Expansion

```
# Install missing package
!pip install hmmlearn

# Import Libraries
import pandas as pd
import numpy as np
from sklearn.preprocessing import StandardScaler
from hmmlearn.hmm import GaussianHMM

# Generate Minute-Level Intraday Timestamps (NYSE)
intraday_times = pd.date_range(start="2024-01-01 09:30", end="2024-01-01 16:00", freq="1min")
intraday_data = pd.DataFrame(index=intraday_times)

# Synthetic Price Generation (GARCH-style)
np.random.seed(42)
mu, sigma = 0, 0.15
shock = np.random.normal(mu, sigma, len(intraday_data))
volatility = np.zeros(len(intraday_data))
volatility[0] = 0.2
for t in range(1, len(intraday_data)):
    volatility[t] = 0.9 * volatility[t-1] + 0.1 * np.abs(shock[t])
returns = shock * volatility
price = 100 + np.cumsum(returns)

intraday_data['Open'] = price
intraday_data['High'] = price + np.abs(np.random.normal(0, 0.2, len(price)))
intraday_data['Low'] = price - np.abs(np.random.normal(0, 0.2, len(price)))
intraday_data['Close'] = price + np.random.normal(0, 0.05, len(price))
intraday_data['Volume'] = np.random.randint(200, 1500, len(price))

# Macro & Sentiment Features
news_trend = np.linspace(-1, 1, len(intraday_data))
news_noise = np.random.normal(0, 0.2, len(intraday_data))
intraday_data['news_sentiment'] = (news_trend + news_noise).cumsum() / np.arange(1, len(intraday_data)+1)

macro_base = np.sin(np.linspace(0, 10 * np.pi, len(intraday_data)))
macro_spike = np.zeros(len(intraday_data))
for idx in [60, 180, 300]:
    macro_spike[idx:idx+5] = np.linspace(1.0, 0.2, 5) + np.random.normal(0, 0.05, 5)
intraday_data['macro_shock'] = macro_base + macro_spike

# Time Features
intraday_data['minute'] = intraday_data.index.minute
intraday_data['hour'] = intraday_data.index.hour
intraday_data['time_block'] = pd.cut(
    intraday_data.index.hour + intraday_data.index.minute / 60,
    bins=[9.5, 11, 13, 15, 16],
    labels=["Open", "LateMorning", "Afternoon", "Close"],
    include_lowest=True
)

# Microstructure Features
intraday_data['order_imbalance'] = np.tanh(np.random.normal(0, 0.5, len(intraday_data)))
intraday_data['queue_imbalance'] = np.clip(np.random.beta(2, 5, len(intraday_data)) * 2 - 1, -1, 1)

# Cointegration Z-Score with Sector ETF
intraday_data['sector_etf'] = intraday_data['Close'] * (1 + np.random.normal(0, 0.01, len(intraday_data)))
spread = intraday_data['Close'] - 0.98 * intraday_data['sector_etf']
intraday_data['cointegration_zscore'] = (spread - spread.rolling(30).mean()) / (spread.rolling(30).std() + 1e-6)

# Return and Volatility Metrics
intraday_data['log_return'] = np.log(intraday_data['Close']).diff()
intraday_data['realized_vol_5'] = intraday_data['Close'].pct_change().rolling(5).std()
intraday_data['realized_vol_15'] = intraday_data['Close'].pct_change().rolling(15).std()

# Hurst Exponent
def hurst(ts):
    lags = range(2, 20)
    tau = [np.std(np.subtract(ts[lag:], ts[:-lag])) for lag in lags]
    return np.polyfit(np.log(lags), np.log(tau), 1)[0]
intraday_data['hurst_60'] = intraday_data['Close'].rolling(60).apply(hurst, raw=True)

# EMA Regime Residual
intraday_data['ema_fast'] = intraday_data['Close'].ewm(span=5).mean()
intraday_data['ema_slow'] = intraday_data['Close'].ewm(span=30).mean()
intraday_data['regime_residual'] = intraday_data['Close'] - intraday_data['ema_slow']

# Target Label (Future Return)
intraday_data['future_return'] = intraday_data['Close'].shift(-5) / intraday_data['Close'] - 1
intraday_data['alpha_label'] = (intraday_data['future_return'] > 0).astype(int)

# Lagged Features
for lag in [1, 3, 5]:
    intraday_data[f'return_lag_{lag}'] = intraday_data['log_return'].shift(lag)
    intraday_data[f'vol_lag_{lag}'] = intraday_data['realized_vol_5'].shift(lag)

# Explainability Buckets
intraday_data['vol_bucket'] = pd.qcut(intraday_data['realized_vol_5'], 3, labels=["LowVol", "MedVol", "HighVol"])
intraday_data['zscore_bucket'] = pd.qcut(intraday_data['cointegration_zscore'], 3, labels=["MeanRev", "Neutral", "Diverged"])

```

```
# Peer Asset Features
peer_price = price * (1 + np.random.normal(0, 0.005, len(price)))
peer_df = pd.DataFrame(index=intraday_times)
peer_df['peer_close'] = peer_price
peer_df['peer_volume'] = np.random.randint(300, 1600, len(price))
intraday_data = intraday_data.join(peer_df)

# Normalize Selected Features
scaler = StandardScaler()
cols_to_normalize = [
    'news_sentiment', 'macro_shock', 'order_imbalance', 'queue_imbalance',
    'cointegration_zscore', 'realized_vol_5', 'realized_vol_15',
    'hurst_60', 'regime_residual', 'return_lag_1', 'return_lag_3', 'return_lag_5',
    'vol_lag_1', 'vol_lag_3', 'vol_lag_5'
]
intraday_data[cols_to_normalize] = scaler.fit_transform(intraday_data[cols_to_normalize])

# Hidden Markov Model (Market Regime Classification)
hmm_input = intraday_data[['log_return', 'realized_vol_5']].dropna()
hmm_model = GaussianHMM(n_components=3, n_iter=100)
hmm_model.fit(hmm_input)
intraday_data['market_regime'] = np.nan
intraday_data.loc[hmm_input.index, 'market_regime'] = hmm_model.predict(hmm_input)
intraday_data['market_regime'] = intraday_data['market_regime'].ffill()
intraday_data['market_regime'] = intraday_data['market_regime'].bfill()

# Lead-Lag Feature
intraday_data['peer_lag_1'] = intraday_data['peer_close'].shift(1)
intraday_data['lead_lag_return'] = intraday_data['peer_lag_1'] / intraday_data['Close'] - 1
intraday_data.dropna(subset=['peer_close', 'peer_lag_1', 'lead_lag_return'], inplace=True)

# Entropy Estimation
def rolling_entropy(series, window=20):
    binned = pd.qcut(series.dropna(), q=5, labels=False, duplicates='drop')
    return binned.rolling(window).apply(lambda x: -np.sum(pd.Series(x).value_counts(normalize=True) *
                                                          np.log(pd.Series(x).value_counts(normalize=True) + 1e-9)))
intraday_data['return_entropy'] = rolling_entropy(intraday_data['log_return'])

# Interaction Terms
intraday_data['zscore_x_vol'] = intraday_data['cointegration_zscore'] * intraday_data['realized_vol_5']
intraday_data['shock_x_sent'] = intraday_data['macro_shock'] * intraday_data['news_sentiment']

# Feature Stability Index
feature_std = intraday_data[cols_to_normalize].rolling(60).std()
feature_mean = intraday_data[cols_to_normalize].rolling(60).mean()
intraday_data['feature_stability_index'] = (feature_std / (feature_mean + 1e-9)).mean(axis=1)
entropy_cols = ['return_entropy', 'zscore_x_vol', 'shock_x_sent', 'feature_stability_index']
intraday_data[entropy_cols] = intraday_data[entropy_cols].ffill()
intraday_data.dropna(subset=entropy_cols, inplace=True)

# Cleanup and Preview
intraday_data.dropna(inplace=True)  # Final cleanup before Step 4

# Define only columns that actually exist in the DataFrame
min_required_features = [
    col for col in [
        'KAMA', 'KAMA_signal', 'fractal_signal',
        'realized_vol_5_vol_rolling', 'log_return_vol_rolling'
    ] if col in intraday_data.columns
]

# Drop rows that have NaNs in those existing features
intraday_data = intraday_data.dropna(subset=min_required_features)
print(intraday_data.head())
```

```
Collecting hmmlearn
  Downloading hmmlearn-0.3.3-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (3.0 kB)
Requirement already satisfied: numpy>=1.10 in /usr/local/lib/python3.11/dist-packages (from hmmlearn) (2.0.2)
Requirement already satisfied: scikit-learn!=0.22.0,>=0.16 in /usr/local/lib/python3.11/dist-packages (from hmmlearn) (1.6.1)
Requirement already satisfied: scipy>=0.19 in /usr/local/lib/python3.11/dist-packages (from hmmlearn) (1.15.3)
Requirement already satisfied: joblib>=1.2.0 in /usr/local/lib/python3.11/dist-packages (from scikit-learn!=0.22.0,>=0.16->hmmlearn) (1.5.0)
Requirement already satisfied: threadpoolctl>=3.1.0 in /usr/local/lib/python3.11/dist-packages (from scikit-learn!=0.22.0,>=0.16->hmmlearn) (3.6.0)
Downloading hmmlearn-0.3.3-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (165 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 165.9/165.9 kB 12.0 MB/s eta 0:00:00
Installing collected packages: hmmlearn
Successfully installed hmmlearn-0.3.3
                          Open        High        Low      Close  Volume  \
2024-01-01 10:30:00  99.832834  100.023862  99.608289  99.961819     760
2024-01-01 10:31:00  99.830161  100.027307  99.753679  99.789978    1159
2024-01-01 10:32:00  99.813075   99.913885  99.779785  99.895031     231
2024-01-01 10:33:00  99.793229   99.899281  99.694739  99.877114     590
2024-01-01 10:34:00  99.806847   99.965422  99.749013  99.779168     476

                     news_sentiment  macro_shock  minute  hour time_block  \
2024-01-01 10:30:00       -1.188420    -0.131632      30    10       Open
2024-01-01 10:31:00       -1.165064    -0.379678      31    10       Open
2024-01-01 10:32:00       -1.135466    -0.652696      32    10       Open
2024-01-01 10:33:00       -1.131620    -0.768226      33    10       Open
2024-01-01 10:34:00       -1.123252    -1.012494      34    10       Open

                     ...  zscore_bucket  peer_close  peer_volume  \
2024-01-01 10:30:00  ...        MeanRev  100.318330          620
2024-01-01 10:31:00  ...        MeanRev   99.774987          573
2024-01-01 10:32:00  ...       Diverged  100.420786          855
2024-01-01 10:33:00  ...        Neutral   99.920266         1143
2024-01-01 10:34:00  ...       Diverged  100.351036          967

                     market_regime  peer_lag_1  lead_lag_return  \
2024-01-01 10:30:00            1.0  100.572639         0.006111
2024-01-01 10:31:00            1.0  100.318330         0.005295
2024-01-01 10:32:00            1.0   99.774987        -0.001202
2024-01-01 10:33:00            1.0  100.420786         0.005443
2024-01-01 10:34:00            1.0   99.920266         0.001414

                     return_entropy  zscore_x_vol  shock_x_sent  \
2024-01-01 10:30:00        1.574103     -1.152603      0.156434
2024-01-01 10:31:00        1.544480     -3.314965      0.442350
2024-01-01 10:32:00        1.544480      1.101367      0.741114
2024-01-01 10:33:00        1.544480     -0.324480      0.869339
2024-01-01 10:34:00        1.514856      4.192407      1.137286

                     feature_stability_index
2024-01-01 10:30:00                -3.155770
2024-01-01 10:31:00               -21.486163
2024-01-01 10:32:00                -2.618548
2024-01-01 10:33:00               -16.957479
2024-01-01 10:34:00                21.304647

[5 rows x 40 columns]
```

Step 3 : Advanced Feature Engineering (Time2Vec, Fractals, KAMA)

```
# Advanced Feature Engineering (corrected & stable)

# Dependencies
!pip install -q tensorflow scikit-learn hmmlearn

import numpy as np
import pandas as pd
import tensorflow as tf
from sklearn.preprocessing import MinMaxScaler
```

```python
from hmmlearn.hmm import GaussianHMM

# Synthetic intraday OHLC
np.random.seed(42)
times = pd.date_range("2024-01-02 09:30", periods=390, freq="1min")
df = pd.DataFrame(index=times)
df["Close"] = 100 + np.cumsum(np.random.normal(0, 0.2, size=390))
df["High"]  = df["Close"] + np.random.normal(0.1, 0.05, 390)
df["Low"]   = df["Close"] - np.random.normal(0.1, 0.05, 390)
df["Open"]  = df["Close"].shift(1).fillna(df["Close"])

# Time2Vec encoding
class Time2Vec(tf.keras.layers.Layer):
    def __init__(self, k=4):
        super().__init__()
        self.k = k  # number of periodic terms

    def build(self, input_shape):
        self.wb = self.add_weight(name="wb", shape=(1,), initializer="uniform")
        self.bb = self.add_weight(name="bb", shape=(1,), initializer="uniform")
        self.wa = self.add_weight(
            name="wa", shape=(input_shape[-1], self.k), initializer="uniform"
        )
        self.ba = self.add_weight(name="ba", shape=(self.k,), initializer="uniform")

    def call(self, inputs):
        bias = self.wb * inputs + self.bb
        wgts = tf.math.sin(tf.matmul(inputs, self.wa) + self.ba)
        return tf.concat([bias, wgts], axis=-1)

time_vals   = np.arange(len(df)).reshape(-1, 1)
time_scaled = MinMaxScaler().fit_transform(time_vals)

t2v_layer = Time2Vec(k=4)
t2v_out   = t2v_layer(tf.convert_to_tensor(time_scaled, dtype=tf.float32)).numpy()

for i in range(t2v_out.shape[1]):
    df[f"t2v_{i}"] = t2v_out[:, i]

df["sin_time"] = np.sin(2 * np.pi * time_scaled.flatten())
df["cos_time"] = np.cos(2 * np.pi * time_scaled.flatten())

# Fractal features
df["fractal_up"] = (
    (df["High"].shift(2) < df["High"].shift(1)) &
    (df["High"].shift(1) > df["High"])          &
    (df["High"].shift(1) > df["High"].shift(3)) &
    (df["High"].shift(1) > df["High"].shift(4))
).astype(int)

df["fractal_down"] = (
    (df["Low"].shift(2)  > df["Low"].shift(1))  &
    (df["Low"].shift(1)  < df["Low"])           &
    (df["Low"].shift(1)  < df["Low"].shift(3))  &
    (df["Low"].shift(1)  < df["Low"].shift(4))
).astype(int)

df["fractal_signal"]   = df["fractal_up"] - df["fractal_down"]
df["fractal_rolling"]  = df["fractal_signal"].rolling(10).sum()
df["fractal_momentum"] = df["fractal_rolling"].diff()

# KAMA features
def kama(df, window=10, fast=2/(2+1), slow=2/(30+1)):
    close = df["Close"].dropna()
    direction   = close.diff(window).abs()
    volatility  = close.diff().abs().rolling(window).sum()
    er = direction / (volatility + 1e-8)
    sc = (er * (fast - slow) + slow).fillna(slow) ** 2

    kama_vals = [close.iloc[0]]
    for i in range(1, len(close)):
        kama_vals.append(kama_vals[-1] + sc.iloc[i] * (close.iloc[i] - kama_vals[-1]))

    kama_series          = pd.Series(kama_vals, index=close.index)
    df["KAMA"]           = kama_series.reindex(df.index).ffill()
    df["KAMA_residual"]  = df["Close"] - df["KAMA"]
    df["KAMA_pct_dev"]   = df["KAMA_residual"] / df["KAMA"]
    df["KAMA_slope"]     = df["KAMA"].diff()
    df["KAMA_signal"]    = np.sign(df["KAMA_residual"]) * (df["KAMA_residual"].abs() > 0.1).astype(int)
    return df

df = kama(df)

# Volatility & regime residuals
df["log_return"]     = np.log(df["Close"]).diff()
df["realized_vol_5"]  = df["Close"].pct_change().rolling(5).std()
df["regime_residual"] = df["Close"] - df["Close"].ewm(span=30).mean()

# Future-return target & rolling stats
df["future_return"] = df["Close"].shift(-5) / df["Close"] - 1

for feat in ["log_return", "realized_vol_5", "regime_residual"]:
    df[f"{feat}_vol_rolling"] = df[feat].rolling(20).std()
    df[f"{feat}_zscore"]      = (
        df[feat] - df[feat].rolling(20).mean()
    ) / (df[feat].rolling(20).std() + 1e-8)

df["vol_regime"]  = pd.qcut(df["realized_vol_5"].dropna(), 3, labels=["Low", "Medium", "High"])
df["meta_signal"] = df["fractal_signal"] + df["KAMA_signal"]

# Rolling entropy
def rolling_entropy(series, window=30):
    binned = pd.qcut(series.dropna(), 5, labels=False, duplicates="drop")
    return binned.rolling(window).apply(
        lambda x: -np.sum(pd.Series(x).value_counts(normalize=True) *
                          np.log(pd.Series(x).value_counts(normalize=True) + 1e-9))
    )

df["kama_entropy"] = rolling_entropy(df["KAMA_pct_dev"])

# HMM regime detection
hmm_input = df[["log_return", "realized_vol_5"]].dropna()
model = GaussianHMM(n_components=3, n_iter=100)
df["hmm_regime"] = np.nan
df.loc[hmm_input.index, "hmm_regime"] = model.fit(hmm_input).predict(hmm_input)

# Correlation & drift features
df["KAMA_alpha_corr"]    = df["KAMA"].rolling(50).corr(df["log_return"].shift(-1))
df["fractal_alpha_corr"]  = df["fractal_signal"].rolling(50).corr(df["log_return"].shift(-1))

rolling_std  = df[["KAMA", "KAMA_signal", "fractal_signal"]].rolling(60).std()
rolling_mean = df[["KAMA", "KAMA_signal", "fractal_signal"]].rolling(60).mean()
df["feature_drift_index"] = (rolling_std / (rolling_mean + 1e-8)).mean(axis=1)

# Final cleanup
cols_to_fix = ["meta_signal", "kama_entropy", "KAMA_alpha_corr"]
df[cols_to_fix] = df[cols_to_fix].ffill().bfill()
df.replace([np.inf, -np.inf], np.nan, inplace=True)
df.ffill(inplace=True)
```

```python
df.bfill(inplace=True)
df.dropna(inplace=True)

# Start after enough look-back to avoid NaNs
intraday_data = df.iloc[60:].copy()

```

```
                         Close       High        Low       Open     t2v_0  \
2024-01-02 10:30:00  98.048309  98.145175  97.950782  98.144144 -0.027138
2024-01-02 10:31:00  98.011177  98.158934  97.877436  98.048309 -0.027080
2024-01-02 10:32:00  97.789910  97.840624  97.746046  98.011177 -0.027022
2024-01-02 10:33:00  97.550669  97.675871  97.431548  97.789910 -0.026964
2024-01-02 10:34:00  97.713174  97.786661  97.604851  97.550669 -0.026906
2024-01-02 10:35:00  97.984422  98.044778  97.859799  97.713174 -0.026848
2024-01-02 10:36:00  97.970020  98.064668  97.855562  97.984422 -0.026790
2024-01-02 10:37:00  98.170727  98.218964  97.947962  97.970020 -0.026732
2024-01-02 10:38:00  98.243054  98.315371  98.174941  98.170727 -0.026674
2024-01-02 10:39:00  98.114030  98.154136  98.040580  98.243054 -0.026616

                        t2v_1     t2v_2     t2v_3     t2v_4  sin_time  ...  \
2024-01-02 10:30:00 -0.028442  0.020754 -0.003539  0.017323  0.824393  ...
2024-01-02 10:31:00 -0.028410  0.020875 -0.003652  0.017431  0.833427  ...
2024-01-02 10:32:00 -0.028378  0.020996 -0.003766  0.017539  0.842244  ...
2024-01-02 10:33:00 -0.028345  0.021117 -0.003879  0.017647  0.850842  ...
2024-01-02 10:34:00 -0.028313  0.021237 -0.003992  0.017755  0.859217  ...
2024-01-02 10:35:00 -0.028281  0.021358 -0.004105  0.017862  0.867368  ...
2024-01-02 10:36:00 -0.028249  0.021479 -0.004218  0.017970  0.875293  ...
2024-01-02 10:37:00 -0.028217  0.021600 -0.004331  0.018078  0.882990  ...
2024-01-02 10:38:00 -0.028184  0.021720 -0.004444  0.018186  0.890456  ...
2024-01-02 10:39:00 -0.028152  0.021841 -0.004558  0.018294  0.897690  ...

                     realized_vol_5_zscore  regime_residual_vol_rolling  \
2024-01-02 10:30:00              -0.621156                     0.250813
2024-01-02 10:31:00              -1.198597                     0.263866
2024-01-02 10:32:00              -0.100948                     0.266080
2024-01-02 10:33:00               0.286515                     0.266066
2024-01-02 10:34:00              -0.119592                     0.259084
2024-01-02 10:35:00               1.754876                     0.257484
2024-01-02 10:36:00               1.639395                     0.246757
2024-01-02 10:37:00               0.870091                     0.265953
2024-01-02 10:38:00              -1.851448                     0.289306
2024-01-02 10:39:00              -0.333380                     0.278050

                     regime_residual_zscore  vol_regime  meta_signal  \
2024-01-02 10:30:00                1.557655      Medium          1.0
2024-01-02 10:31:00                1.323474         Low          0.0
2024-01-02 10:32:00                0.555228      Medium         -1.0
2024-01-02 10:33:00               -0.183934      Medium         -1.0
2024-01-02 10:34:00                0.468537      Medium         -2.0
2024-01-02 10:35:00                1.409487        High          0.0
2024-01-02 10:36:00                1.289326        High          0.0
2024-01-02 10:37:00                1.797115        High          1.0
2024-01-02 10:38:00                1.753203         Low          1.0
2024-01-02 10:39:00                1.208306      Medium          1.0

                     kama_entropy  hmm_regime  KAMA_alpha_corr  \
2024-01-02 10:30:00      1.188565         1.0        -0.287868
2024-01-02 10:31:00      1.188565         1.0        -0.284751
2024-01-02 10:32:00      1.188565         1.0        -0.200576
2024-01-02 10:33:00      1.159570         1.0        -0.173141
2024-01-02 10:34:00      1.122908         1.0        -0.200912
2024-01-02 10:35:00      1.122908         1.0        -0.171651
2024-01-02 10:36:00      1.110615         1.0        -0.229089
2024-01-02 10:37:00      1.173737         1.0        -0.214536
2024-01-02 10:38:00      1.223448         1.0        -0.151489
```

Step 4 : Advanced Model Building (TFT, GNN, Multi-task Learning)

```python
# Install Dependencies
!pip install tensorflow scikit-learn hmmlearn shap --quiet

# Imports
import numpy as np
import pandas as pd
import tensorflow as tf
from sklearn.preprocessing import MinMaxScaler
from sklearn.model_selection import train_test_split
from hmmlearn.hmm import GaussianHMM
import matplotlib.pyplot as plt
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Input, LSTM, Dense, MultiHeadAttention, LayerNormalization, Dropout, Add
from tensorflow.keras.regularizers import l2

# Generate Synthetic Intraday Data (10 Days)df['regime_residual'] = df['Close'] - df['Close'].ewm(span=30).mean()
np.random.seed(42)
minutes_per_day = 390
n_days = 60
total_minutes = minutes_per_day * n_days
times = pd.date_range("2024-01-01 09:30", periods=total_minutes, freq="1min")
df = pd.DataFrame(index=times)
df['Close'] = 100 + np.cumsum(np.random.normal(0, 1.0, size=total_minutes))
df['High'] = df['Close'] + np.random.normal(0.1, 0.05, total_minutes)
df['Low'] = df['Close'] - np.random.normal(0.1, 0.05, total_minutes)
df['Open'] = df['Close'].shift(1).fillna(df['Close'])

# Time2Vec Layer
class Time2Vec(tf.keras.layers.Layer):
    def __init__(self, kernel_size): super().__init__(); self.k = kernel_size
    def build(self, input_shape):
        self.wb = self.add_weight(name='wb', shape=(1,), initializer='uniform')
        self.bb = self.add_weight(name='bb', shape=(1,), initializer='uniform')
        self.wa = self.add_weight(name='wa', shape=(input_shape[-1], self.k), initializer='uniform')
        self.ba = self.add_weight(name='ba', shape=(self.k,), initializer='uniform')
    def call(self, inputs):
        bias = self.wb * inputs + self.bb
        wgts = tf.math.sin(tf.matmul(inputs, self.wa) + self.ba)
        return tf.concat([bias, wgts], -1)

# Time2Vec Embedding
time_vals = np.arange(len(df)).reshape(-1, 1)
time_scaled = MinMaxScaler().fit_transform(time_vals)
t2v = Time2Vec(4)
t2v_out = t2v(tf.convert_to_tensor(time_scaled, dtype=tf.float32)).numpy()
for i in range(t2v_out.shape[1]):
    df[f't2v_{i}'] = t2v_out[:, i]

# Fractal + KAMA Features
df['fractal_up'] = ((df['High'].shift(2) < df['High'].shift(1)) & (df['High'].shift(1) > df['High']) &
                    (df['High'].shift(1) > df['High'].shift(3)) & (df['High'].shift(1) > df['High'].shift(4))).astype(int)
df['fractal_down'] = ((df['Low'].shift(2) > df['Low'].shift(1)) & (df['Low'].shift(1) < df['Low']) &
                      (df['Low'].shift(1) < df['Low'].shift(3)) & (df['Low'].shift(1) < df['Low'].shift(4))).astype(int)
df['fractal_signal'] = df['fractal_up'] - df['fractal_down']

def kama(df, window=10, fast=2/(2+1), slow=2/(30+1)):
    c = df['Close']
    er = c.diff(window).abs() / (c.diff().abs().rolling(window).sum() + 1e-8)
    sc = (er * (fast - slow) + slow)**2
    kama_val = [c.iloc[0]]
    for i in range(1, len(c)):
        kama_val.append(kama_val[-1] + sc.iloc[i] * (c.iloc[i] - kama_val[-1]))
    return pd.Series(kama_val, index=df.index)
```

```

df['KAMA'] = kama(df)
df['KAMA_pct_dev'] = (df['Close'] - df['KAMA']) / (df['KAMA'] + 1e-6)
df['KAMA_pct_dev'] = df['KAMA_pct_dev'].clip(-5, 5)
df['KAMA_slope'] = df['KAMA'].diff().fillna(0)
df['log_return'] = np.log(df['Close']).diff().clip(-5, 5)
df['realized_vol_5'] = df['Close'].pct_change().rolling(5).std()
df['regime_residual'] = df['Close'] - df['Close'].ewm(span=30).mean()

for f in ['log_return', 'realized_vol_5', 'regime_residual']:
    df[f'{f}_vol_rolling'] = df[f].rolling(20).std()
    df[f'{f}_zscore'] = (df[f] - df[f].rolling(20).mean()) / (df[f].rolling(20).std() + 1e-8)

# HMM Regime Detection
hmm_input = df[['log_return', 'realized_vol_5']].dropna()
model = GaussianHMM(n_components=3, n_iter=200, tol=1e-4, covariance_type='full', verbose=False)
df['hmm_regime'] = np.nan
df.loc[hmm_input.index, 'hmm_regime'] = model.fit(hmm_input).predict(hmm_input)

# Clean NaNs & Infs
df.replace([np.inf, -np.inf], np.nan, inplace=True)
df.ffill(inplace=True)
df.bfill(inplace=True)

# Define Future Return Target
df['future_return'] = df['Close'].shift(-5) / df['Close'] - 1
target = 'future_return'

# Safe Feature Selection
base_features = [col for col in df.columns if col.startswith("t2v_")] + [
    'KAMA_pct_dev', 'KAMA_slope',
    'log_return_vol_rolling', 'regime_residual_vol_rolling',
    'realized_vol_5_vol_rolling', 'hmm_regime'
]
features = [col for col in base_features if col in df.columns]

# Final NaN Fill for Features + Target
df = df.loc[:, ~df.columns.duplicated()]
features = list(dict.fromkeys([col for col in base_features if col in df.columns]))
if target in features:
    features.remove(target)
columns_to_fill = features + [target]
df[columns_to_fill] = df[columns_to_fill].copy().ffill().bfill()


print("Null counts before dropna:")
print(df[features + [target]].isnull().sum())
print("➡ Rows before dropna:", len(df))

# Drop NaNs in Features + Target to ensure clean sequence generation
df = df.dropna(subset=features + [target])
print("After dropna: rows =", len(df))

# Create Sequences
def create_sequences(X, y, window):
    Xs, ys = [], []
    for i in range(len(X) - window):
        Xs.append(X[i:i+window])
        ys.append(y[i+window])
    return np.array(Xs), np.array(ys)

sequence_length = 50
X = df[features].values.astype(np.float32)
y = df[target].values.astype(np.float32)
X_seq, y_seq = create_sequences(X, y, window=sequence_length)

# Remove Invalid Sequences
mask = np.isfinite(X_seq).all(axis=(1, 2)) & np.isfinite(y_seq)
X_seq = X_seq[mask]
y_seq = y_seq[mask]

print(f"Cleaned sequences: X = {X_seq.shape}, y = {y_seq.shape}")
if X_seq.shape[0] == 0:
    print("No valid sequences. Check data cleaning or increase input data length.")
else:
    print("X stats:", np.min(X_seq), np.max(X_seq), np.isnan(X_seq).sum())
    print("y stats:", np.min(y_seq), np.max(y_seq), np.isnan(y_seq).sum())

print("y stats:", np.min(y_seq), np.max(y_seq), np.isnan(y_seq).sum())

# Train-Test Split
X_train, X_test, y_train, y_test = train_test_split(X_seq, y_seq, test_size=0.2, shuffle=False)

# TFT Model
def build_tft_model(input_shape):
    inputs = Input(shape=input_shape)
    x = Time2Vec(kernel_size=8)(inputs)
    x = LSTM(128, return_sequences=True, kernel_regularizer=l2(1e-4), recurrent_regularizer=l2(1e-4))(x)
    attn = MultiHeadAttention(num_heads=4, key_dim=64)(x, x)
    x = Add()([x, attn])
    x = LayerNormalization()(x)
    x = Dense(64, activation='relu', kernel_regularizer=l2(1e-4))(x)
    x = Dropout(0.4)(x)
    x = Dense(1)(x)
    model = Model(inputs, x)
    model.compile(optimizer='adam', loss='huber', metrics=['mae'])
    return model

# Train
model = build_tft_model(X_train.shape[1:])
history = model.fit(X_train, y_train, epochs=20, batch_size=16, validation_split=0.1, verbose=1)

# Evaluate
loss, mae = model.evaluate(X_test, y_test)
print(f"Final Test Loss: {loss:.4f}, MAE: {mae:.4f}")

# Plot
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.title("TFT Training Loss")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.legend()
plt.grid(True)
plt.show()
```

```
Null counts before dropna:
t2v_0                         0
t2v_1                         0
t2v_2                         0
t2v_3                         0
t2v_4                         0
KAMA_pct_dev                  0
KAMA_slope                    0
log_return_vol_rolling        0
regime_residual_vol_rolling   0
realized_vol_5_vol_rolling    0
hmm_regime                    0
future_return                 0
dtype: int64
➡ Rows before dropna: 23400
```

```
After dropna: rows = 23400
Cleaned sequences: X = (23350, 50, 11), y = (23350,)
X stats: -0.07119062 4.4018774 0
y stats: -0.22172616 0.241834 0
y stats: -0.22172616 0.241834 0
Epoch 1/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 17s 11ms/step - loss: 0.0275 - mae: 0.0535 - val_loss: 0.0062 - val_mae: 0.0099
Epoch 2/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 11s 10ms/step - loss: 0.0057 - mae: 0.0218 - val_loss: 0.0031 - val_mae: 0.0097
Epoch 3/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 11s 10ms/step - loss: 0.0030 - mae: 0.0217 - val_loss: 0.0014 - val_mae: 0.0099
Epoch 4/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 11s 11ms/step - loss: 0.0015 - mae: 0.0214 - val_loss: 5.8438e-04 - val_mae: 0.0098
Epoch 5/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 8.7796e-04 - mae: 0.0216 - val_loss: 2.5004e-04 - val_mae: 0.0101
Epoch 6/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 6.1373e-04 - mae: 0.0217 - val_loss: 1.2552e-04 - val_mae: 0.0097
Epoch 7/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 5.2869e-04 - mae: 0.0218 - val_loss: 1.0021e-04 - val_mae: 0.0100
Epoch 8/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 5.1202e-04 - mae: 0.0218 - val_loss: 7.8681e-05 - val_mae: 0.0097
Epoch 9/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 11s 10ms/step - loss: 4.7565e-04 - mae: 0.0215 - val_loss: 7.4902e-05 - val_mae: 0.0097
Epoch 10/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 9ms/step - loss: 4.7107e-04 - mae: 0.0216 - val_loss: 7.8956e-05 - val_mae: 0.0100
Epoch 11/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 9ms/step - loss: 4.9073e-04 - mae: 0.0218 - val_loss: 7.4188e-05 - val_mae: 0.0097
Epoch 12/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 4.8733e-04 - mae: 0.0218 - val_loss: 7.4128e-05 - val_mae: 0.0097
Epoch 13/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 11s 10ms/step - loss: 4.8454e-04 - mae: 0.0218 - val_loss: 7.4104e-05 - val_mae: 0.0097
Epoch 14/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 4.7435e-04 - mae: 0.0217 - val_loss: 7.4110e-05 - val_mae: 0.0097
Epoch 15/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 4.7074e-04 - mae: 0.0215 - val_loss: 7.4112e-05 - val_mae: 0.0097
Epoch 16/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 4.8311e-04 - mae: 0.0216 - val_loss: 7.4945e-05 - val_mae: 0.0098
Epoch 17/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 4.7050e-04 - mae: 0.0215 - val_loss: 7.4107e-05 - val_mae: 0.0097
Epoch 18/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 10s 10ms/step - loss: 4.9348e-04 - mae: 0.0220 - val_loss: 7.4990e-05 - val_mae: 0.0098
Epoch 19/20
1051/1051 ━━━━━━━━━━━━━━━━━━━━ 11s 10ms/step - loss: 4.8973e-04 - mae: 0.0217 - val_loss: 7.4259e-05 - val_mae: 0.0097
```

STEP 4.5 : Prepare Sequences from my engineered DataFrame

```python
# df : full cleaned DataFrame
# features : list of feature column names
# target : prediction target column name
# sequence_length : window size (usually 50)

# Convert to arrays
X = df[features].values.astype(np.float32)
y = df[target].values.astype(np.float32)

# Create sequences (sliding window)
def create_sequences(X, y, window):
    Xs, ys = [], []
    for i in range(len(X) - window):
        Xs.append(X[i:i+window])
        ys.append(y[i+window])
    return np.array(Xs), np.array(ys)

sequence_length = 50
X_seq, y_seq = create_sequences(X, y, window=sequence_length)

# Drop NaNs/infs from sequences
mask = np.isfinite(X_seq).all(axis=(1, 2)) & np.isfinite(y_seq)
X_seq = X_seq[mask]
y_seq = y_seq[mask]

print(f"Sequences created: X_seq.shape = {X_seq.shape}, y_seq.shape = {y_seq.shape}")

# Train/Validation split
from sklearn.model_selection import train_test_split

X_train_seq, X_val_seq, y_train_seq, y_val_seq = train_test_split(
    X_seq, y_seq, test_size=0.2, shuffle=False
)

REAL_FEATURE_COUNT = X_train_seq.shape[2]
```

```
Sequences created: X_seq.shape = (23350, 50, 11), y_seq.shape = (23350,)
```

Step 5 : Hyperparameter Optimization (Ray Tune)

```python
# Patch threading and metric issues (must be at the top)
import os
os.environ["OPENBLAS_NUM_THREADS"] = "1"
os.environ["OMP_NUM_THREADS"] = "1"
os.environ["MKL_NUM_THREADS"] = "1"
os.environ["TUNE_DISABLE_STRICT_METRIC_CHECKING"] = "1"

# Install & Import Libraries
import subprocess
subprocess.run(["pip", "install", "-q", "ray[tune]", "tensorflow"], check=True)

import ray
from ray import tune, air
from ray.tune.schedulers import ASHAScheduler
import tensorflow as tf
import numpy as np
import logging
logging.basicConfig(level=logging.INFO)

# Time2Vec Layer
class Time2Vec(tf.keras.layers.Layer):
    def __init__(self, kernel_size): super().__init__(); self.k = kernel_size
    def build(self, input_shape):
        self.wb = self.add_weight(name='wb', shape=(1,), initializer='uniform')
        self.bb = self.add_weight(name='bb', shape=(1,), initializer='uniform')
        self.wa = self.add_weight(name='wa', shape=(input_shape[-1], self.k), initializer='uniform')
        self.ba = self.add_weight(name='ba', shape=(self.k,), initializer='uniform')
    def call(self, x):
        bias = self.wb * x + self.bb
        wgts = tf.math.sin(tf.matmul(x, self.wa) + self.ba)
        return tf.concat([bias, wgts], -1)

# Check Sequence Data
try:
    REAL_FEATURE_COUNT = X_train_seq.shape[2]
except:
    raise ValueError("I must run Step 4 first to define X_train_seq, etc.")

# Training Function (with safe dictionary-based tune.report)
def train_model(config):
    try:
        X_train = X_train_seq.copy()
```

```
        y_train = y_train_seq.copy()
        X_val = X_val_seq.copy()
        y_val = y_val_seq.copy()

        inputs = tf.keras.Input(shape=(50, REAL_FEATURE_COUNT))
        x = Time2Vec(config["t2v_k"])(inputs)
        x = tf.keras.layers.LSTM(config["lstm_units"], return_sequences=True)(x)
        x = tf.keras.layers.MultiHeadAttention(num_heads=4, key_dim=32)(x, x)
        x = tf.keras.layers.LayerNormalization()(x)
        x = tf.keras.layers.Dense(config["dense_units"], activation="relu")(x)
        x = tf.keras.layers.Dropout(config["dropout_rate"])(x)
        x = tf.keras.layers.Dense(1)(x)

        model = tf.keras.Model(inputs, x)
        model.compile(optimizer=tf.keras.optimizers.Adam(config["learning_rate"]),
                      loss="mse")

        model.fit(X_train, y_train,
                  validation_data=(X_val, y_val),
                  epochs=3, batch_size=16,
                  verbose=0)

        val_loss = float(model.evaluate(X_val, y_val, verbose=0))

        # Dictionary-style report for maximum compatibility
        tune.report({"loss": val_loss})

    except Exception as e:
        import traceback
        print("Trial failed:")
        traceback.print_exc()
        # Dictionary fallback to avoid TypeError
        tune.report({"loss": 9999.0})

# Search Space
search_space = {
    "lstm_units": tune.choice([64, 128]),
    "dense_units": tune.choice([32, 64]),
    "learning_rate": tune.loguniform(1e-4, 1e-2),
    "dropout_rate": tune.uniform(0.1, 0.3),
    "t2v_k": tune.choice([4, 6])
}

# Scheduler
scheduler = ASHAScheduler(metric="loss", mode="min")

# Logger Callback
from ray.tune import Callback
class TrialLogger(Callback):
    def on_trial_result(self, iteration, trials, trial, result, **info):
        print(f"Trial {trial.trial_id} | Loss = {result.get('loss', 'n/a'):.4f}")

# Initialize Ray
ray.shutdown()
ray.init(local_mode=True, num_cpus=1, ignore_reinit_error=True, include_dashboard=False)

# Define Tuner
tuner = tune.Tuner(
    train_model,
    param_space=search_space,
    tune_config=tune.TuneConfig(
        scheduler=scheduler,
        num_samples=2  # Increase for real tuning
    ),
    run_config=air.RunConfig(
        name="ray_tune_tft_final",
        callbacks=[TrialLogger()],
        failure_config=air.FailureConfig(max_failures=0)
    )
)

# Run Tuning
try:
    results = tuner.fit()
except Exception as e:
    import traceback
    print("Tuner crashed:")
    traceback.print_exc()
try:
    if results and results.num_errors == 0:
        best_result = results.get_best_result(metric="loss", mode="min")
        print("Best Config:", best_result.config)
    else:
        print("All trials failed. See logs above.")
except Exception as e:
    print("Could not retrieve best config.")
    import traceback
    traceback.print_exc()

# Step 5.11: Retrain Final Model Using Best Config
best_config = best_result.config  # already printed above

# Build Model
inputs = tf.keras.Input(shape=(50, REAL_FEATURE_COUNT))
x = Time2Vec(best_config["t2v_k"])(inputs)
x = tf.keras.layers.LSTM(best_config["lstm_units"], return_sequences=True)(x)
x = tf.keras.layers.MultiHeadAttention(num_heads=4, key_dim=32)(x, x)
x = tf.keras.layers.LayerNormalization()(x)
x = tf.keras.layers.Dense(best_config["dense_units"], activation="relu")(x)
x = tf.keras.layers.Dropout(best_config["dropout_rate"])(x)
x = tf.keras.layers.Dense(1)(x)

final_model = tf.keras.Model(inputs, x)
final_model.compile(
    optimizer=tf.keras.optimizers.Adam(best_config["learning_rate"]),
    loss="mse"
)

# Train on Full Data
history = final_model.fit(
    X_train_seq, y_train_seq,
    validation_data=(X_val_seq, y_val_seq),
    epochs=30,  # Change could be made
    batch_size=16,
    verbose=1
)

import matplotlib.pyplot as plt

# Save to file
plt.figure(figsize=(8, 5))
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.title('Final Model Training vs Validation Loss')
plt.xlabel('Epoch')
plt.ylabel('MSE Loss')
plt.legend()
plt.grid(True)

```

```python
# Save the plot as PNG
plt.savefig("training_loss_plot.png")  # Changing the name is possible

# Show the saved image inline
from IPython.display import Image, display
display(Image("training_loss_plot.png"))
```

```
2025-05-31 00:37:26,170 INFO worker.py:1888 -- Started a local Ray instance.
+--------------------------------------------------------+
| Configuration for experiment     ray_tune_tft_final     |
+--------------------------------------------------------+
| Search algorithm                 BasicVariantGenerator   |
| Scheduler                        AsyncHyperBandScheduler |
| Number of trials                 2                       |
+--------------------------------------------------------+

View detailed results here: /root/ray_results/ray_tune_tft_final
To visualize your results with TensorBoard, run: `tensorboard --logdir /tmp/ray/session_2025-05-31_00-37-24_338114_1273/artifacts/2025-05-31_00-37-27/ray_tune_tft_final/driver_artifacts`
:job_id:01000000
:task_name:bundle_reservation_check_func
:job_id:01000000
:task_name:bundle_reservation_check_func
:actor_name:ImplicitFunc
:actor_name:train_model

Trial train_model_6d508_00000 started with configuration:
+--------------------------------------------------+
| Trial train_model_6d508_00000 config              |
+--------------------------------------------------+
| dense_units                                    32 |
| dropout_rate                              0.22614 |
| learning_rate                             0.00596 |
| lstm_units                                     64 |
| t2v_k                                           4 |
+--------------------------------------------------+
:actor_name:ImplicitFunc
:actor_name:train_model

Trial status: 1 RUNNING
Current time: 2025-05-31 00:38:14. Total running time: 40s
Logical resource usage: 1.0/1 CPUs, 0/1 GPUs (0.0/1.0 accelerator_type:A100)
+----------------------------------------------------------------------------------------------------------+
| Trial name                 status      lstm_units     dense_units     learning_rate     dropout_rate     t2v_k |
+----------------------------------------------------------------------------------------------------------+
| train_model_6d508_00000   RUNNING             64              32        0.00596376         0.226136         4 |
+----------------------------------------------------------------------------------------------------------+
Trial 6d508_00000 | Loss = 0.0002

Trial train_model_6d508_00000 completed after 1 iterations at 2025-05-31 00:38:14. Total running time: 40s
+--------------------------------------------------+
| Trial train_model_6d508_00000 result              |
+--------------------------------------------------+
| checkpoint_dir_name                               |
| time_this_iter_s                          38.9531 |
| time_total_s                              38.9531 |
| training_iteration                              1 |
| loss                                      0.00016 |
+--------------------------------------------------+
:task_name:bundle_reservation_check_func
:actor_name:ImplicitFunc
:actor_name:train_model

Trial train_model_6d508_00001 started with configuration:
+--------------------------------------------------+
| Trial train_model_6d508_00001 config              |
```

Step 6 : Synthetic-to-Walk-Forward Backtesting & Regime-Analysis Pipeline

1. Step 6A : Multi-Day Synthetic OHLCV Generator
2. Step 6B : Walk-Forward GRU Meta-Signal Generator with Multi-GPU, Data-Leakage Protection & F1 Evaluation
3. Step 6C : Backtrader Integration
4. Step 6D : Full Backtest & Optimization Pipeline with Optuna + Final Equity-Curve Plotting
5. Step 6E : Regime Tagging, Performance Visualization & Walk-Forward Preparation
6. Step 6F : Regime-Based Performance Analysis & Walk-Forward Backtest Execution
7. Step 6G : Full Python Pipeline for Market Regime Detection using Gaussian HMM + Equity Performance Analysis with Synthetic Data

Step 6A : Multi-Day Synthetic OHLCV Generator

```python
import pandas as pd
import numpy as np

# Generate 60 Days of Synthetic Intraday OHLCV Data
np.random.seed(42)

def generate_intraday_day(start_date):
    minutes = pd.date_range(start=start_date + " 09:30", periods=390, freq="1min")
    price = 100 + np.cumsum(np.random.normal(0, 0.2, len(minutes)))
    high = price + np.abs(np.random.normal(0.1, 0.05, len(minutes)))
    low = price - np.abs(np.random.normal(0.1, 0.05, len(minutes)))
    open_ = price + np.random.normal(0, 0.1, len(minutes))
    volume = np.random.randint(100, 1000, len(minutes))

    return pd.DataFrame({
        "Open": open_,
        "High": high,
        "Low": low,
        "Close": price,
        "Volume": volume
    }, index=minutes)

# Generate 60 trading days (simulate weekdays)
days = pd.bdate_range("2024-01-01", periods=60)
df_list = [generate_intraday_day(day.strftime("%Y-%m-%d")) for day in days]
df_full = pd.concat(df_list)
df_full.index.name = "datetime"

# Feature Engineering
df_full['ret1'] = df_full['Close'].pct_change()
df_full['ret5'] = df_full['Close'].pct_change(5)
df_full['volatility5'] = df_full['Close'].rolling(5).std()
df_full['ma10'] = df_full['Close'].rolling(10).mean()
df_full['ma_diff'] = df_full['Close'] - df_full['ma10']
df_full['hour'] = df_full.index.hour + df_full.index.minute / 60.0  # time of day

# Multi-Horizon Targets
horizons = [5, 10, 20]  # in minutes
for h in horizons:
    df_full[f"target_{h}"] = (df_full['Close'].shift(-h) > df_full['Close']).astype(int)

# Drop rows with NaN
df_full.dropna(inplace=True)

print(df_full.head())
print("60-day synthetic OHLCV data with features and targets created.")

# Prepare output for GRU model (Step 6B will reshape to sequences)
df_full.shape, df_full.columns.tolist()
```

```
                           Open        High         Low       Close  Volume  \
datetime
2024-01-01 09:39:00  100.785763  101.058013  100.879170  100.896122     974
2024-01-01 09:40:00  100.821428  100.823717  100.681958  100.803439     540
2024-01-01 09:41:00  100.849493  100.780324  100.599908  100.710293     632
2024-01-01 09:42:00  100.850517  100.858947  100.645106  100.758685     295
2024-01-01 09:43:00  100.218979  100.478378  100.339867  100.376029     789

                         ret1      ret5  volatility5        ma10   ma_diff  \
datetime
2024-01-01 09:39:00  0.001077  0.004351     0.196387  100.504253  0.391869
2024-01-01 09:40:00 -0.000919  0.003897     0.069569  100.574662  0.228776
2024-01-01 09:41:00 -0.000924 -0.000176     0.075578  100.638523  0.071770
2024-01-01 09:42:00  0.000481 -0.001217     0.068510  100.694268  0.064417
2024-01-01 09:43:00 -0.003798 -0.004084     0.198288  100.681288 -0.305259

                         hour  target_5  target_10  target_20
datetime
2024-01-01 09:39:00  9.650000         0          0          0
2024-01-01 09:40:00  9.666667         0          0          0
2024-01-01 09:41:00  9.683333         0          0          0
2024-01-01 09:42:00  9.700000         0          0          0
2024-01-01 09:43:00  9.716667         0          0          0
60-day synthetic OHLCV data with features and targets created.
((23391, 14),
 ['Open',
  'High',
  'Low',
  'Close',
  'Volume',
  'ret1',
  'ret5',
  'volatility5',
  'ma10',
  'ma_diff',
  'hour',
  'target_5',
  'target_10',
  'target_20'])
```

```python
import subprocess
subprocess.run(["pip", "install", "tensorflow"], check=True)
```

```
CompletedProcess(args=['pip', 'install', 'tensorflow'], returncode=0)
```

Step 6B : Walk-Forward GRU Meta-Signal Generator with Multi-GPU, Data Leakage Protection & F1 Evaluation

```python
import tensorflow as tf
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import f1_score

# Step 6B: GRU Walk-Forward Meta Signal Generator

features = ['ret1', 'ret5', 'volatility5', 'ma_diff', 'hour']
targets = ['target_5', 'target_10', 'target_20']
sequence_length = 50
train_days = 40
test_days = 1

# Initialize signal columns
for target in targets:
    horizon = target.split("_")[1]
    df_full[f'meta_signal_{horizon}'] = 0

day_starts = df_full.index.normalize().drop_duplicates().tolist()

def make_sequences(df_sub, target_col):
    X, y = [], []
    data = df_sub[features + [target_col]].values
    for j in range(sequence_length, len(data)):
        X.append(data[j-sequence_length:j, :-1])
        y.append(data[j, -1])
    return np.array(X), np.array(y)

# Multi-GPU Strategy Scope (outside loop to avoid reinitialization)
strategy = tf.distribute.MirroredStrategy()
print(f"MirroredStrategy Enabled - Devices: {strategy.num_replicas_in_sync}")

with strategy.scope():
    for i in range(len(day_starts) - train_days - test_days):
        train_start = day_starts[i]
        train_end = day_starts[i + train_days]
        test_start = day_starts[i + train_days]
        test_end = day_starts[i + train_days + test_days]

        df_train = df_full.loc[(df_full.index >= train_start) & (df_full.index < train_end)].copy()
        df_test = df_full.loc[(df_full.index >= test_start) & (df_full.index < test_end)].copy()

        if len(df_train) < sequence_length or len(df_test) < sequence_length:
            continue

        for target in targets:
            horizon = target.split("_")[1]

            # Normalize without leakage
            scaler = StandardScaler()
            df_train_scaled = df_train.copy()
            df_test_scaled = df_test.copy()
            df_train_scaled[features] = scaler.fit_transform(df_train[features])
            df_test_scaled[features] = scaler.transform(df_test[features])

            X_train, y_train = make_sequences(df_train_scaled, target)
            X_test, y_test = make_sequences(df_test_scaled, target)

            if len(X_train) < 10 or len(X_test) < 10:
                print(f"Walk {i+1}, Horizon {horizon}: Skipped due to insufficient sequence length")
                continue
            if len(set(y_test)) < 2:
                print(f"Walk {i+1}, Horizon {horizon}: Skipped due to lack of class diversity in test set")
                continue

            model = tf.keras.Sequential([
                tf.keras.layers.Input(shape=(sequence_length, len(features))),
                tf.keras.layers.GRU(64, return_sequences=False),
                tf.keras.layers.Dense(1, activation="sigmoid")
            ])
            model.compile(optimizer="adam", loss="binary_crossentropy")

            model.fit(X_train, y_train, epochs=5, batch_size=32, verbose=0)

            y_pred = model.predict(X_test).flatten()
            y_pred_binary = (y_pred > 0.5).astype(int)
            f1 = f1_score(y_test, y_pred_binary, zero_division=0)

            pred_index = df_test.iloc[sequence_length:].index
            df_full.loc[pred_index, f'meta_signal_{horizon}'] = y_pred_binary
```

```
        print(f"Walk {i+1:02}, Horizon {horizon} min → Injected {len(pred_index)} signals | F1: {f1:.4f}")
```

```
MirroredStrategy Enabled - Devices: 1
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 20ms/step
Walk 01, Horizon 5 min → Injected 340 signals | F1: 0.6218
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 20ms/step
Walk 01, Horizon 10 min → Injected 340 signals | F1: 0.3944
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 01, Horizon 20 min → Injected 340 signals | F1: 0.5833
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 20ms/step
Walk 02, Horizon 5 min → Injected 340 signals | F1: 0.4748
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 02, Horizon 10 min → Injected 340 signals | F1: 0.3624
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 02, Horizon 20 min → Injected 340 signals | F1: 0.3471
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 03, Horizon 5 min → Injected 340 signals | F1: 0.4828
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 03, Horizon 10 min → Injected 340 signals | F1: 0.4452
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 03, Horizon 20 min → Injected 340 signals | F1: 0.3439
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 04, Horizon 5 min → Injected 340 signals | F1: 0.5818
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 04, Horizon 10 min → Injected 340 signals | F1: 0.2602
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 04, Horizon 20 min → Injected 340 signals | F1: 0.5095
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 05, Horizon 5 min → Injected 340 signals | F1: 0.5166
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 05, Horizon 10 min → Injected 340 signals | F1: 0.3310
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 05, Horizon 20 min → Injected 340 signals | F1: 0.5522
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 06, Horizon 5 min → Injected 340 signals | F1: 0.5600
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 06, Horizon 10 min → Injected 340 signals | F1: 0.3735
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 06, Horizon 20 min → Injected 340 signals | F1: 0.4201
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 07, Horizon 5 min → Injected 340 signals | F1: 0.6396
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 07, Horizon 10 min → Injected 340 signals | F1: 0.5491
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 07, Horizon 20 min → Injected 340 signals | F1: 0.6062
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 08, Horizon 5 min → Injected 340 signals | F1: 0.5857
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 08, Horizon 10 min → Injected 340 signals | F1: 0.4688
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 08, Horizon 20 min → Injected 340 signals | F1: 0.5679
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 09, Horizon 5 min → Injected 340 signals | F1: 0.4653
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 09, Horizon 10 min → Injected 340 signals | F1: 0.3962
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
Walk 09, Horizon 20 min → Injected 340 signals | F1: 0.5786
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
Walk 10, Horizon 5 min → Injected 340 signals | F1: 0.5825
11/11 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
```

```python
import subprocess
subprocess.run(["pip", "install", "backtrader"])
```

```
CompletedProcess(args=['pip', 'install', 'backtrader'], returncode=0)
```

Step 6C : Backtrader Integration

```python
# Install dependencies (Google Colab only)

import backtrader as bt
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import os

# Generate synthetic OHLCV data
np.random.seed(42)
n = 500
dates = pd.date_range(start="2024-01-01", periods=n, freq="min")

price = 100 + np.cumsum(np.random.randn(n))
open_ = price + np.random.normal(0, 0.5, size=n)
high = np.maximum(open_, price) + np.abs(np.random.normal(0, 0.3, size=n))
low = np.minimum(open_, price) - np.abs(np.random.normal(0, 0.3, size=n))
volume = np.random.randint(100, 1000, size=n)

df_full = pd.DataFrame({
    "Open": open_,
    "High": high,
    "Low": low,
    "Close": price,
    "Volume": volume
}, index=dates)

# Generate technical indicator-based signals
def generate_technical_signals(df):
    df['SMA_10'] = df['Close'].rolling(window=10).mean()
    df['SMA_30'] = df['Close'].rolling(window=30).mean()
    df['MACD'] = df['Close'].ewm(span=12).mean() - df['Close'].ewm(span=26).mean()
    df['Signal_Line'] = df['MACD'].ewm(span=9).mean()
    df['RSI'] = 100 - 100 / (1 + df['Close'].diff().apply(lambda x: max(x, 0)).rolling(14).mean() /
                             df['Close'].diff().apply(lambda x: -min(x, 0)).rolling(14).mean())

    df['meta_signal_5'] = ((df['SMA_10'] > df['SMA_30']) & (df['MACD'] > df['Signal_Line'])).astype(int)
    df['meta_signal_10'] = (df['RSI'] < 30).astype(int)
    df['meta_signal_20'] = ((df['RSI'] > 50) & (df['MACD'] > df['Signal_Line'])).astype(int)
    return df

df_full = generate_technical_signals(df_full).dropna()

# Backtrader Data Feed
class PandasMetaSignalData(bt.feeds.PandasData):
    lines = ('meta_signal_5', 'meta_signal_10', 'meta_signal_20')
    params = (('meta_signal_5', -1), ('meta_signal_10', -1), ('meta_signal_20', -1))

# Strategy
class EnsembleMetaSignalStrategy(bt.Strategy):
    params = dict(exitbars=5, stop_loss_pct=0.015)

    def __init__(self):
        self.signal_5 = self.datas[0].meta_signal_5
        self.signal_10 = self.datas[0].meta_signal_10
        self.signal_20 = self.datas[0].meta_signal_20
        self.dataclose = self.datas[0].close
        self.order = None
        self.buyprice = None
        self.bar_executed = None
        self.peak = self.broker.getvalue()
        self.max_drawdown = 0.0
```

```python
        self.equity_curve = []
        self.trades_log = []

    def notify_order(self, order):
        if order.status in [order.Completed, order.Canceled, order.Margin]:
            self.order = None

    def next(self):
        dt = self.datas[0].datetime.datetime(0)
        equity = self.broker.getvalue()
        self.peak = max(self.peak, equity)
        drawdown = (self.peak - equity) / self.peak
        self.max_drawdown = max(self.max_drawdown, drawdown)
        self.equity_curve.append((dt, equity))

        signal_ensemble = sum([self.signal_5[0], self.signal_10[0], self.signal_20[0]])

        if self.order:
            return

        if not self.position and signal_ensemble >= 2:
            size = max(1, int(equity * 0.01 / (self.dataclose[0] + 1e-6)))
            self.order = self.buy(size=size)
            self.buyprice = self.dataclose[0]
            self.bar_executed = len(self)
            self.trades_log.append([dt, 'BUY', self.buyprice, size])

        elif self.position:
            price = self.dataclose[0]
            if self.bar_executed is not None and len(self) >= self.bar_executed + self.params.exitbars:
                self.order = self.sell()
                self.trades_log.append([dt, 'SELL (exitbars)', price, self.position.size])
            elif price < self.buyprice * (1 - self.params.stop_loss_pct):
                self.order = self.sell()
                self.trades_log.append([dt, 'SELL (stoploss)', price, self.position.size])

    def stop(self):
        print(f"Max Drawdown: {self.max_drawdown * 100:.2f}%")

# Execute Backtest
def run_backtest_ensemble(df, tag="improved"):
    cerebro = bt.Cerebro()
    cerebro.addstrategy(EnsembleMetaSignalStrategy)
    data = PandasMetaSignalData(dataname=df)
    cerebro.adddata(data)
    cerebro.broker.setcash(100000.0)
    cerebro.broker.setcommission(commission=0.001)
    cerebro.addanalyzer(bt.analyzers.SharpeRatio, _name='sharpe')
    cerebro.addanalyzer(bt.analyzers.DrawDown, _name='dd')

    print(f"Starting Portfolio Value: {cerebro.broker.getvalue():.2f}")
    results = cerebro.run()
    strat = results[0]
    print(f"Final Portfolio Value: {cerebro.broker.getvalue():.2f}")
    print("Sharpe Ratio:", strat.analyzers.sharpe.get_analysis())
    print("Max Drawdown:", strat.analyzers.dd.get_analysis())

    # Save trades and equity
    trades_df = pd.DataFrame(strat.trades_log, columns=["Timestamp", "Action", "Price", "Size"])
    equity_df = pd.DataFrame(strat.equity_curve, columns=["Timestamp", "Equity"])
    trades_df.to_csv(f"gru_backtest_trades_{tag}.csv", index=False)
    equity_df.to_csv(f"gru_backtest_equity_{tag}.csv", index=False)
    print(f"CSVs saved: gru_backtest_trades_{tag}.csv, gru_backtest_equity_{tag}.csv")

    # Plot
    fig, ax1 = plt.subplots(figsize=(12, 6))
    ax1.plot(equity_df["Timestamp"], equity_df["Equity"], label="Equity Curve", linewidth=2, color='blue')
    ax1.set_ylabel("Portfolio Value", color='blue')
    ax1.tick_params(axis='y', labelcolor='blue')

    ax2 = ax1.twinx()
    ax2.set_ylabel("Trade Price", color='gray')
    buy = trades_df[trades_df["Action"].str.contains("BUY")]
    sell = trades_df[trades_df["Action"].str.contains("SELL")]
    ax2.scatter(buy["Timestamp"], buy["Price"], color="green", label="BUY", marker="^")
    ax2.scatter(sell["Timestamp"], sell["Price"], color="red", label="SELL", marker="v")
    ax2.tick_params(axis='y', labelcolor='gray')

    fig.tight_layout()
    fig.suptitle("Equity Curve with Trade Markers (Improved Strategy)", fontsize=14)
    fig.subplots_adjust(top=0.93)
    ax1.legend(loc='upper left')
    plt.grid(True)
    plt.savefig("equity_curve_improved.png", dpi=300)
    plt.show()
    print("Plot saved: equity_curve_improved.png")

    # Summary
    print("Trade Performance Summary:")
    completed_trades = []
    position = None
    for _, row in trades_df.iterrows():
        if 'BUY' in row['Action']:
            position = {'entry_price': row['Price'], 'entry_time': row['Timestamp'], 'size': row['Size']}
        elif 'SELL' in row['Action'] and position:
            pnl = (row['Price'] - position['entry_price']) * position['size']
            ret_pct = (row['Price'] / position['entry_price'] - 1) * 100
            holding_period = (pd.to_datetime(row['Timestamp']) - pd.to_datetime(position['entry_time'])).total_seconds() / 60
            completed_trades.append({
                'entry_time': position['entry_time'],
                'exit_time': row['Timestamp'],
                'entry_price': position['entry_price'],
                'exit_price': row['Price'],
                'return_pct': ret_pct,
                'holding_minutes': holding_period,
                'pnl': pnl
            })
            position = None

    if completed_trades:
        perf_df = pd.DataFrame(completed_trades)
        print(f"Total Trades: {len(perf_df)}")
        print(f"Win Rate: {(perf_df['return_pct'] > 0).mean() * 100:.2f}%")
        print(f"Avg Trade Return: {perf_df['return_pct'].mean():.2f}%")
        print(f"Avg Holding Time: {perf_df['holding_minutes'].mean():.2f} min")
        print(f"Total Strategy PnL: {perf_df['pnl'].sum():.2f}")
    else:
        print("No complete trades were executed.")

# Run the backtest
bt_df = df_full[['Open', 'High', 'Low', 'Close', 'Volume',
                 'meta_signal_5', 'meta_signal_10', 'meta_signal_20']].copy()

run_backtest_ensemble(bt_df, tag="improved")
```

```
Starting Portfolio Value: 100000.00
Max Drawdown: 0.11%
Final Portfolio Value: 99983.56
Sharpe Ratio: OrderedDict([('sharperatio', None)])
Max Drawdown: AutoOrderedDict([('len', 71), ('drawdown', 0.0685384620877622), ('moneydown', 68.57419508043677), ('max', AutoOrderedDict([('len', 300), ('drawdown', 0.11079191518155522), ('moneydown', 110.80641322045994)]))])
```

```
CSVs saved: gru_backtest_trades_improved.csv, gru_backtest_equity_improved.csv
Plot saved: equity_curve_improved.png
Trade Performance Summary:
Total Trades: 16
Win Rate: 62.50%
Avg Trade Return: 0.71%
Avg Holding Time: 4.44 min
Total Strategy PnL: 107.36
```

```python
import subprocess

subprocess.call([
    "pip", "install",
    "yfinance", "backtrader", "optuna", "matplotlib"
])
```

```
0
```

Step 6D : Full Backtest & Optimization Pipeline with Optuna + Final Equity Curve

Plotting

```python
# Install dependencies if not already installed
import subprocess
subprocess.call(["pip", "install", "-q", "backtrader", "optuna", "matplotlib", "pandas", "numpy"])

# Imports
import backtrader as bt
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import optuna

# Generate synthetic OHLCV data
np.random.seed(42)
n = 1000  # ~4 years of daily data
dates = pd.date_range("2020-01-01", periods=n, freq="D")
price = 150 + np.cumsum(np.random.randn(n))  # random walk

data = pd.DataFrame({
    'Open': price + np.random.normal(0, 1, n),
    'High': price + np.random.normal(1, 1, n),
    'Low': price - np.random.normal(1, 1, n),
    'Close': price,
    'Volume': np.random.randint(1e6, 1e7, n)
}, index=dates)

# Add technical indicators
def add_indicators(df):
    df['SMA_10'] = df['Close'].rolling(window=10).mean()
    df['SMA_30'] = df['Close'].rolling(window=30).mean()
    df['MACD'] = df['Close'].ewm(span=12).mean() - df['Close'].ewm(span=26).mean()
    df['Signal_Line'] = df['MACD'].ewm(span=9).mean()
    df['RSI'] = 100 - 100 / (1 + df['Close'].diff().apply(lambda x: max(x, 0)).rolling(14).mean() /
                              df['Close'].diff().apply(lambda x: -min(x, 0)).rolling(14).mean())
    return df.dropna()

data = add_indicators(data)

# Custom backtrader-compatible feed
class PandasData(bt.feeds.PandasData):
    params = (
        ('datetime', None),
        ('open', 'Open'),
        ('high', 'High'),
        ('low', 'Low'),
        ('close', 'Close'),
        ('volume', 'Volume'),
        ('openinterest', -1),
    )

# Define optimization objective
def objective(trial):
    exitbars = trial.suggest_int('exitbars', 3, 15)
    stop_loss_pct = trial.suggest_float('stop_loss_pct', 0.005, 0.03)
    profit_target_pct = trial.suggest_float('profit_target_pct', 0.01, 0.05)

    class OptimizedStrategy(bt.Strategy):
        params = dict(
            exitbars=exitbars,
            stop_loss_pct=stop_loss_pct,
            profit_target_pct=profit_target_pct
        )

        def __init__(self):
            self.order = None
            self.buy_price = None
            self.bar_executed = None

        def notify_order(self, order):
            if order.status in [order.Completed, order.Canceled, order.Margin]:
                self.order = None

        def next(self):
            if self.order:
                return
            if not self.position:
                if self.data.close[0] > self.data.open[0]:  # simple condition
                    size = int(self.broker.getcash() / self.data.close[0])
                    self.order = self.buy(size=size)
                    self.buy_price = self.data.close[0]
                    self.bar_executed = len(self)
            else:
                price = self.data.close[0]
                if price >= self.buy_price * (1 + self.params.profit_target_pct):
                    self.order = self.sell()
                elif price <= self.buy_price * (1 - self.params.stop_loss_pct):
                    self.order = self.sell()
                elif len(self) >= self.bar_executed + self.params.exitbars:
                    self.order = self.sell()

    cerebro = bt.Cerebro()
    cerebro.addstrategy(OptimizedStrategy)
    cerebro.adddata(PandasData(dataname=data))
    cerebro.broker.setcash(100000.0)
    cerebro.broker.setcommission(commission=0.001)
    cerebro.addanalyzer(bt.analyzers.SharpeRatio, _name='sharpe')
    results = cerebro.run()
    sharpe = results[0].analyzers.sharpe.get_analysis().get('sharperatio', 0)
    return sharpe if sharpe is not None else 0

# Run optimization
study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=30)
best_params = study.best_trial.params

```

```python
# Replace this if needed with my Optuna output
print("Using best_params from Optuna:", best_params)

# Final Strategy Class (fixed parameter access and logic)
class FinalStrategy(bt.Strategy):
    params = dict(
        exitbars=best_params['exitbars'],
        stop_loss_pct=best_params['stop_loss_pct'],
        profit_target_pct=best_params['profit_target_pct']
    )

    def __init__(self):
        self.order = None
        self.buy_price = None
        self.bar_executed = 0
        self.equity_curve = []

    def notify_order(self, order):
        if order.status in [order.Completed, order.Canceled, order.Margin]:
            self.order = None

    def next(self):
        dt = self.datas[0].datetime.datetime(0)
        self.equity_curve.append((dt, self.broker.getvalue()))

        if self.order:
            return

        # Entry logic (simple condition: bullish candle)
        if not self.position:
            if self.data.close[0] > self.data.open[0]:
                size = int(self.broker.getcash() / self.data.close[0])
                self.order = self.buy(size=size)
                self.buy_price = self.data.close[0]
                self.bar_executed = len(self)
                print(f"BUY @ {self.buy_price:.2f} on {dt}")
        else:
            price = self.data.close[0]
            holding = len(self) - self.bar_executed

            # Exit Conditions
            if price >= self.buy_price * (1 + self.params.profit_target_pct):
                self.order = self.sell()
                print(f"SELL (profit) @ {price:.2f} on {dt}")
            elif price <= self.buy_price * (1 - self.params.stop_loss_pct):
                self.order = self.sell()
                print(f"SELL (stop-loss) @ {price:.2f} on {dt}")
            elif holding >= self.params.exitbars:
                self.order = self.sell()
                print(f"SELL (timeout) @ {price:.2f} on {dt}")

# Backtest
cerebro = bt.Cerebro()
cerebro.addstrategy(FinalStrategy)
cerebro.adddata(PandasData(dataname=data))
cerebro.broker.setcash(100000.0)
cerebro.broker.setcommission(commission=0.001)
results = cerebro.run()

# Extract Equity Curve
final_strat = results[0]
equity_df = pd.DataFrame(final_strat.equity_curve, columns=["Timestamp", "Equity"])

# Plot Equity Curve
# Imports at the top
%matplotlib inline
import matplotlib.pyplot as plt
from IPython.display import display, Image

# Plot equity curve
plt.figure(figsize=(12, 6))
plt.plot(equity_df["Timestamp"], equity_df["Equity"], label="Equity Curve", color='blue')
plt.title(f"Optimized Strategy Equity Curve (Synthetic Data)₩nParams: {best_params}", fontsize=14)
plt.xlabel("Date")
plt.ylabel("Portfolio Value")
plt.grid(True)
plt.legend()
plt.tight_layout()

# Save and display
plt.savefig("equity_plot.png", dpi=300)
display(Image(filename="equity_plot.png"))
```

```
[I 2025-05-31 00:57:53,843] A new study created in memory with name: no-name-93c7faf8-18d2-4030-a7d2-a6a941d1737b
[I 2025-05-31 00:57:54,241] Trial 0 finished with value: 0.7183863364835763 and parameters: {'exitbars': 8, 'stop_loss_pct': 0.01990178029206695, 'profit_target_pct': 0.02752345185281284}. Best is trial 0 with value: 0.7183863
[I 2025-05-31 00:57:54,628] Trial 1 finished with value: 0.7160235831835884 and parameters: {'exitbars': 13, 'stop_loss_pct': 0.022517597790310102, 'profit_target_pct': 0.018819570094647235}. Best is trial 0 with value: 0.718386
[I 2025-05-31 00:57:55,016] Trial 2 finished with value: 0.7184626311121874 and parameters: {'exitbars': 7, 'stop_loss_pct': 0.022215756252164945, 'profit_target_pct': 0.010790152600663402}. Best is trial 2 with value: 0.7184626
[I 2025-05-31 00:57:55,406] Trial 3 finished with value: 0.7184626311121874 and parameters: {'exitbars': 7, 'stop_loss_pct': 0.020300534997627913, 'profit_target_pct': 0.013635339692212428}. Best is trial 2 with value: 0.7184626
[I 2025-05-31 00:57:55,784] Trial 4 finished with value: 0.7164315518180174 and parameters: {'exitbars': 13, 'stop_loss_pct': 0.019474166014251858, 'profit_target_pct': 0.010306734673694322}. Best is trial 2 with value: 0.718462
[I 2025-05-31 00:57:56,178] Trial 5 finished with value: 0.7184626311121874 and parameters: {'exitbars': 7, 'stop_loss_pct': 0.02107347512008649, 'profit_target_pct': 0.01085792737860036}. Best is trial 2 with value: 0.71846263
[I 2025-05-31 00:57:56,564] Trial 6 finished with value: 0.7187846627763879 and parameters: {'exitbars': 6, 'stop_loss_pct': 0.01697165527615027, 'profit_target_pct': 0.031793888856015785}. Best is trial 6 with value: 0.7187846
[I 2025-05-31 00:57:56,959] Trial 7 finished with value: 0.7185047808955703 and parameters: {'exitbars': 13, 'stop_loss_pct': 0.005272906523258574, 'profit_target_pct': 0.03927422075961792}. Best is trial 6 with value: 0.7187846
[I 2025-05-31 00:57:57,339] Trial 8 finished with value: 0.7171421150392858 and parameters: {'exitbars': 9, 'stop_loss_pct': 0.026212461568540856, 'profit_target_pct': 0.018468690852250037}. Best is trial 6 with value: 0.7187846
[I 2025-05-31 00:57:57,717] Trial 9 finished with value: 0.7191198696857382 and parameters: {'exitbars': 5, 'stop_loss_pct': 0.02077342057462074, 'profit_target_pct': 0.046699614518660316}. Best is trial 9 with value: 0.7191198
[I 2025-05-31 00:57:58,139] Trial 10 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.013005304909396147, 'profit_target_pct': 0.04954769856982665}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:57:58,530] Trial 11 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.012177387635118875, 'profit_target_pct': 0.049844158634849756}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:57:58,928] Trial 12 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.011603668998495974, 'profit_target_pct': 0.04943767234188079}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:58:00,185] Trial 13 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.01262368991837398, 'profit_target_pct': 0.04166681873271007}. Best is trial 10 with value: 0.7195650
[I 2025-05-31 00:58:00,589] Trial 14 finished with value: 0.7184457406270932 and parameters: {'exitbars': 10, 'stop_loss_pct': 0.011111803207247948, 'profit_target_pct': 0.04282717761890467}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:01,007] Trial 15 finished with value: 0.7192186656838114 and parameters: {'exitbars': 4, 'stop_loss_pct': 0.007089442397357212, 'profit_target_pct': 0.036588529578951784}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:01,415] Trial 16 finished with value: 0.7170792025966586 and parameters: {'exitbars': 11, 'stop_loss_pct': 0.015144846378181826, 'profit_target_pct': 0.04799852713170703}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:01,812] Trial 17 finished with value: 0.7185251268629748 and parameters: {'exitbars': 15, 'stop_loss_pct': 0.008561176981634933, 'profit_target_pct': 0.03322485001573069}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:02,214] Trial 18 finished with value: 0.7192186656838114 and parameters: {'exitbars': 4, 'stop_loss_pct': 0.014535218665780688, 'profit_target_pct': 0.0444802435464106}. Best is trial 10 with value: 0.7195650
[I 2025-05-31 00:58:02,605] Trial 19 finished with value: 0.7191022008771418 and parameters: {'exitbars': 5, 'stop_loss_pct': 0.029019599248456554, 'profit_target_pct': 0.027535827330716127}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:03,014] Trial 20 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.008750945673666195, 'profit_target_pct': 0.04971969692767394}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:58:03,407] Trial 21 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.011932184501134334, 'profit_target_pct': 0.04602434192027578}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:58:03,801] Trial 22 finished with value: 0.7191198696857382 and parameters: {'exitbars': 5, 'stop_loss_pct': 0.014668414952882649, 'profit_target_pct': 0.03899535336030156}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:58:04,209] Trial 23 finished with value: 0.7192186656838114 and parameters: {'exitbars': 4, 'stop_loss_pct': 0.009871120986921991, 'profit_target_pct': 0.049945492030253516}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:04,602] Trial 24 finished with value: 0.7195650693602706 and parameters: {'exitbars': 3, 'stop_loss_pct': 0.013170540420269166, 'profit_target_pct': 0.04380721012294277}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:58:04,992] Trial 25 finished with value: 0.7187846627763879 and parameters: {'exitbars': 6, 'stop_loss_pct': 0.01768982654850852, 'profit_target_pct': 0.04660033832375149}. Best is trial 10 with value: 0.7195650
[I 2025-05-31 00:58:05,387] Trial 26 finished with value: 0.7192393942771926 and parameters: {'exitbars': 4, 'stop_loss_pct': 0.016665833266213993, 'profit_target_pct': 0.040070980557035965}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:05,779] Trial 27 finished with value: 0.7187846627763879 and parameters: {'exitbars': 6, 'stop_loss_pct': 0.010078903947529104, 'profit_target_pct': 0.03653882551342615}. Best is trial 10 with value: 0.719565
[I 2025-05-31 00:58:07,048] Trial 28 finished with value: 0.7191198696857382 and parameters: {'exitbars': 5, 'stop_loss_pct': 0.007125004903372898, 'profit_target_pct': 0.048860219600509146}. Best is trial 10 with value: 0.71956
[I 2025-05-31 00:58:07,434] Trial 29 finished with value: 0.7184069033100108 and parameters: {'exitbars': 9, 'stop_loss_pct': 0.013066028162536096, 'profit_target_pct': 0.023162483475355766}. Best is trial 10 with value: 0.71956
Using best_params from Optuna: {'exitbars': 3, 'stop_loss_pct': 0.013005304909396147, 'profit_target_pct': 0.04954769856982665}
BUY @ 144.36 on 2020-01-30 00:00:00
SELL (timeout) @ 145.59 on 2020-02-02 00:00:00
SELL (timeout) @ 144.53 on 2020-02-03 00:00:00
SELL (timeout) @ 145.36 on 2020-02-04 00:00:00
SELL (timeout) @ 144.14 on 2020-02-05 00:00:00
SELL (timeout) @ 144.35 on 2020-02-06 00:00:00
SELL (stop-loss) @ 142.39 on 2020-02-07 00:00:00
SELL (stop-loss) @ 141.06 on 2020-02-08 00:00:00
SELL (stop-loss) @ 141.25 on 2020-02-09 00:00:00
SELL (stop-loss) @ 141.99 on 2020-02-10 00:00:00
SELL (stop-loss) @ 142.16 on 2020-02-11 00:00:00
SELL (stop-loss) @ 142.05 on 2020-02-12 00:00:00
SELL (stop-loss) @ 141.75 on 2020-02-13 00:00:00
SELL (stop-loss) @ 140.27 on 2020-02-14 00:00:00
SELL (stop-loss) @ 139.55 on 2020-02-15 00:00:00
SELL (stop-loss) @ 139.09 on 2020-02-16 00:00:00
SELL (stop-loss) @ 140.15 on 2020-02-17 00:00:00
SELL (stop-loss) @ 140.49 on 2020-02-18 00:00:00
```

```
SELL (stop-loss) @ 138.73 on 2020-02-19 00:00:00
SELL (stop-loss) @ 139.05 on 2020-02-20 00:00:00
SELL (stop-loss) @ 138.67 on 2020-02-21 00:00:00
SELL (stop-loss) @ 137.99 on 2020-02-22 00:00:00
SELL (stop-loss) @ 138.60 on 2020-02-23 00:00:00
SELL (stop-loss) @ 139.63 on 2020-02-24 00:00:00
```

Step 6E : Regime Tagging, Performance Visualization & Walk-Forward Preparation

```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from hmmlearn.hmm import GaussianHMM

# Reuse the existing df_full
# Ensure df_full has columns: Open, High, Low, Close, Volume, meta_signal_5/10/20

# Simulate portfolio value (could replace this with real backtest output)
df_full['portfolio_value'] = 100000 + np.cumsum(np.random.randn(len(df_full)) * 50)
df_full['datetime'] = df_full.index

# Simulated trades DataFrame (replace with real trades if available)
trades_df = pd.DataFrame({
    "datetime": df_full['datetime'][::50],
    "signal": np.random.choice(["buy", "sell"], size=len(df_full[::50])),
    "price": df_full['Close'][::50].values,
    "profit": np.random.uniform(-100, 100, size=len(df_full[::50]))
})

# Plotting Functions
def plot_equity_curve(equity_df):
    plt.figure(figsize=(12, 5))
    plt.plot(equity_df['datetime'], equity_df['portfolio_value'], label='Equity Curve')
    plt.title('Equity Curve')
    plt.xlabel('Time')
    plt.ylabel('Portfolio Value')
    plt.grid(True)
    plt.legend()
    plt.tight_layout()
    plt.show()

def plot_drawdown(equity_df):
    peak = equity_df['portfolio_value'].cummax()
    drawdown = (equity_df['portfolio_value'] - peak) / peak
    plt.figure(figsize=(12, 5))
    plt.plot(equity_df['datetime'], drawdown, color='red', label='Drawdown')
    plt.title('Drawdown Curve')
    plt.xlabel('Time')
    plt.ylabel('Drawdown %')
    plt.grid(True)
    plt.legend()
    plt.tight_layout()
    plt.show()

# Save CSVs
def save_backtest_results(trades_df, equity_df, tag="ensemble"):
    trades_df.to_csv(f"optimized_trades_{tag}.csv", index=False)
    equity_df.to_csv(f"optimized_equity_curve_{tag}.csv", index=False)
    print(f"Saved: optimized_trades_{tag}.csv & optimized_equity_curve_{tag}.csv")

# HMM Market Regime Tagging
def tag_market_regimes(df, n_states=3):
    log_returns = np.log(df['Close'] / df['Close'].shift(1)).dropna().values.reshape(-1, 1)
    hmm = GaussianHMM(n_components=n_states, covariance_type="full", n_iter=1000)
    df = df.copy()
    df['regime'] = np.nan
    hmm.fit(log_returns)
    hidden_states = hmm.predict(log_returns)
    df.loc[df.index[1:], 'regime'] = hidden_states
    print(f"Regimes tagged (0 to {n_states - 1})")
    return df

# Walk-Forward Split
def walk_forward_split(df, train_size=0.6, val_size=0.2):
    total = len(df)
    train_end = int(total * train_size)
    val_end = train_end + int(total * val_size)
    train_data = df.iloc[:train_end]
    val_data = df.iloc[train_end:val_end]
    test_data = df.iloc[val_end:]
    print(f"Walk-Forward Splits: Train={len(train_data)}, Val={len(val_data)}, Test={len(test_data)}")
    return train_data, val_data, test_data

# RUN EVERYTHING
# Plot Equity & Drawdown
plot_equity_curve(df_full)
plot_drawdown(df_full)

# Save Backtest Results
save_backtest_results(trades_df, df_full)

# Tag Market Regimes
df_with_regimes = tag_market_regimes(df_full)

# Walk-Forward Split
train_df, val_df, test_df = walk_forward_split(df_with_regimes)
```

```
Figure(1200x500)
Figure(1200x500)
Saved: optimized_trades_ensemble.csv & optimized_equity_curve_ensemble.csv
Regimes tagged (0 to 2)
Walk-Forward Splits: Train=282, Val=94, Test=95
```

Step 6F : Regime-Based Performance Analysis & Walk-Forward Backtest Execution

```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

# Create a simulated df_with_regimes for demonstration (normally using real data)
np.random.seed(42)
n = 300
dates = pd.date_range("2022-01-01", periods=n)
portfolio_value = 100000 + np.cumsum(np.random.randn(n) * 100)
regimes = np.random.choice([0, 1, 2], size=n)

df_with_regimes = pd.DataFrame({
    "datetime": dates,
    "portfolio_value": portfolio_value,
    "regime": regimes
})

# Regime-Based Performance Metrics
```

```
def analyze_regime_performance(df_with_regimes):
    df_with_regimes['daily_return'] = df_with_regimes['portfolio_value'].pct_change()
    grouped = df_with_regimes.groupby('regime')['daily_return'].agg(['mean', 'std', 'count'])
    grouped['sharpe_ratio'] = grouped['mean'] / grouped['std'] * np.sqrt(252)  # annualized
    print("Regime-Based Performance (Annualized Sharpe):")
    print(grouped)
    return grouped

# Sharpe ratio bar plot
def plot_sharpe_by_regime(summary_df):
    plt.figure(figsize=(8, 4))
    plt.bar(summary_df.index.astype(str), summary_df['sharpe_ratio'], color='purple')
    plt.title("Sharpe Ratio by Regime")
    plt.xlabel("Regime")
    plt.ylabel("Sharpe Ratio")
    plt.grid(True)
    plt.tight_layout()
    plt.show()

# Simulated Walk-Forward Backtest
def run_walk_forward_backtest(full_df, window=60, stride=30):
    results = []
    for start in range(0, len(full_df) - window, stride):
        train_df = full_df.iloc[start:start + int(window * 0.6)]
        test_df = full_df.iloc[start + int(window * 0.6):start + window]
        if len(test_df) == 0: continue
        train_return = train_df['portfolio_value'].iloc[-1] / train_df['portfolio_value'].iloc[0] - 1
        test_return = test_df['portfolio_value'].iloc[-1] / test_df['portfolio_value'].iloc[0] - 1
        results.append((train_df['datetime'].iloc[0], train_return, test_return))
    return pd.DataFrame(results, columns=["StartDate", "TrainReturn", "TestReturn"])

# RUN ALL
regime_summary = analyze_regime_performance(df_with_regimes)
plot_sharpe_by_regime(regime_summary)
walkforward_results = run_walk_forward_backtest(df_with_regimes)

from IPython.display import display
display(walkforward_results)
regime_summary
```

```
Regime-Based Performance (Annualized Sharpe):
            mean       std  count  sharpe_ratio
regime
0      -0.000019  0.000901    118     -0.339227
1       0.000155  0.001014     91      2.420163
2      -0.000153  0.001063     90     -2.291269
Figure(800x400)
    StartDate  TrainReturn  TestReturn
0 2022-01-01    -0.006357   -0.003645
1 2022-01-31    -0.003856    0.001270
2 2022-03-02    -0.000963    0.000926
3 2022-04-01     0.001973   -0.004554
4 2022-05-01    -0.003946    0.006844
5 2022-05-31     0.007879    0.001831
6 2022-06-30     0.005115   -0.001540
7 2022-07-30    -0.000201   -0.002763
```

regime	mean	std	count	sharpe_ratio
0	-0.000019	0.000901	118	-0.339227
1	0.000155	0.001014	91	2.420163
2	-0.000153	0.001063	90	-2.291269

Step 6G : Full Python Pipeline for Market Regime Detection using Gaussian HMM + Equity Performance Analysis with Synthetic Data

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from hmmlearn.hmm import GaussianHMM
import warnings
warnings.filterwarnings("ignore")

# Utility: Plot equity curve
def plot_equity_curve(equity_df):
    df = equity_df.reset_index(drop=True)
    plt.figure(figsize=(12, 5))
    plt.plot(df['datetime'], df['portfolio_value'], label='Equity Curve')
    plt.title('Equity Curve')
    plt.xlabel('Time')
    plt.ylabel('Portfolio Value')
    plt.grid(True)
    plt.legend()
    plt.tight_layout()
    plt.show()

# Utility: Plot drawdown
def plot_drawdown(equity_df):
    df = equity_df.reset_index(drop=True)
    peak = df['portfolio_value'].cummax()
    drawdown = (df['portfolio_value'] - peak) / peak
    plt.figure(figsize=(12, 5))
    plt.plot(df['datetime'], drawdown, color='red', label='Drawdown')
    plt.title('Drawdown Curve')
    plt.xlabel('Time')
    plt.ylabel('Drawdown %')
    plt.grid(True)
    plt.legend()
    plt.tight_layout()
    plt.show()

# Regime tagging
def tag_market_regimes(df, n_states=3):
    df = df.copy()
    df['log_ret'] = np.log(df['Close'] / df['Close'].shift(1))
    df['log_ret'] = df['log_ret'].replace([np.inf, -np.inf], np.nan)
    df = df.dropna(subset=['log_ret'])

    # Additional sanity filter (optional)
    df = df[np.abs(df['log_ret']) < 1.0]

    if len(df) < n_states * 10:
        print(f"Not enough data ({len(df)} points) for {n_states} HMM states. Skipping.")
        df['regime'] = np.nan
        return df.drop(columns='log_ret')

    hmm = GaussianHMM(n_components=n_states, covariance_type="full", n_iter=1000)
    try:
        hmm.fit(df[['log_ret']])
        df['regime'] = hmm.predict(df[['log_ret']])
        print(f"Regimes tagged: {df['regime'].nunique()} unique regimes.")
    except Exception as e:
        print(f"HMM fitting failed: {e}")
        df['regime'] = np.nan
```

```python

    return df.drop(columns='log_ret')

# Walk-forward split
def walk_forward_split(df, train_size=0.6, val_size=0.2):
    total = len(df)
    train_end = int(total * train_size)
    val_end = train_end + int(total * val_size)
    train_data = df.iloc[:train_end]
    val_data = df.iloc[train_end:val_end]
    test_data = df.iloc[val_end:]
    print(f"Walk-Forward Split: Train={len(train_data)}, Val={len(val_data)}, Test={len(test_data)}")
    return train_data, val_data, test_data

# Main wrapper
def prepare_regime_analysis(df_full, equity_df, n_states=3, save_csv=True):
    # Ensure datetime column
    df_full = df_full.copy()
    df_full['datetime'] = pd.to_datetime(df_full.index)

    equity_df = equity_df.copy()
    fallback_len = min(len(df_full), len(equity_df))
    equity_df = equity_df.iloc[:fallback_len].copy()
    equity_df['datetime'] = df_full['datetime'].values[:fallback_len]

    # Ensure portfolio value exists
    if 'portfolio_value' not in equity_df.columns:
        equity_df['portfolio_value'] = 100000 + np.cumsum(np.random.randn(fallback_len) * 50)

    # Plot curves
    plot_equity_curve(equity_df)
    plot_drawdown(equity_df)

    # Tag regimes
    df_tagged = tag_market_regimes(df_full, n_states=n_states)

    # Merge regime into equity
    df_merged = equity_df.merge(df_tagged[['datetime', 'regime']], on='datetime', how='left')

    # Walk-forward
    train_data, val_data, test_data = walk_forward_split(df_tagged)

    if save_csv:
        df_merged.to_csv("equity_with_regimes.csv", index=False)
        print("Saved: equity_with_regimes.csv")

    print("₩n Final Sample: df_full with regimes")
    print(df_tagged[['datetime', 'Close', 'regime']].tail())

    print("₩n Final Sample: equity_df_with_regimes")
    print(df_merged[['datetime', 'portfolio_value', 'regime']].tail())

    return df_tagged, df_merged, train_data, val_data, test_data

# Synthetic Data Generation
# REPLACEMENT: Realistic price generator with volatility regimes
def generate_regime_switching_data(n=500, seed=42):
    np.random.seed(seed)
    regimes = np.random.choice([0, 1, 2], size=n, p=[0.3, 0.5, 0.2])
    mu = [0.0002, 0.0005, -0.0003]
    sigma = [0.001, 0.005, 0.01]
    returns = np.array([np.random.normal(mu[r], sigma[r]) for r in regimes])
    price = 100 * np.exp(np.cumsum(returns))

    df = pd.DataFrame({
        'Close': price,
        'Open': price + np.random.normal(0, 0.2, size=n),
        'High': price + np.random.normal(0.3, 0.2, size=n),
        'Low': price - np.random.normal(0.3, 0.2, size=n),
        'Volume': np.random.randint(100, 1000, size=n)
    }, index=pd.date_range("2024-01-01", periods=n, freq="min"))

    equity = pd.DataFrame({
        'portfolio_value': 100000 + np.cumsum(np.random.normal(0, 50, size=n))
    }, index=df.index)

    return df, equity

# Generate better synthetic data with volatility regimes
df_full, equity_df = generate_regime_switching_data(n=500)

# Run analysis
df_tagged, equity_df_with_regimes, train, val, test = prepare_regime_analysis(df_full, equity_df, n_states=3)
```

```
Figure(1200x500)
Figure(1200x500)
WARNING:hmmlearn.base:Model is not converging.  Current: 1813.716129235693 is not greater than 1813.9627775630104. Delta is -0.24664832731741626
Regimes tagged: 2 unique regimes.
Walk-Forward Split: Train=299, Val=99, Test=101
Saved: equity_with_regimes.csv

 Final Sample: df_full with regimes
                               datetime       Close  regime
2024-01-01 08:15:00 2024-01-01 08:15:00  119.670687       2
2024-01-01 08:16:00 2024-01-01 08:16:00  119.437891       2
2024-01-01 08:17:00 2024-01-01 08:17:00  119.586584       2
2024-01-01 08:18:00 2024-01-01 08:18:00  120.368705       2
2024-01-01 08:19:00 2024-01-01 08:19:00  122.575436       2

 Final Sample: equity_df_with_regimes
               datetime  portfolio_value  regime
495 2024-01-01 08:15:00     99797.212486     2.0
496 2024-01-01 08:16:00     99780.821310     2.0
497 2024-01-01 08:17:00     99763.896611     2.0
498 2024-01-01 08:18:00     99838.701723     2.0
499 2024-01-01 08:19:00     99814.902293     2.0
```

Step 7 : Real Historical Market Data Integration

1. Step 7A : Fetch Historical Market Data (Yahoo Finance)
2. Step 7B · Data Quality Validation & Exploratory Analysis (EDA)
3. Step 7C-1 : Historical Data Preparation for Modelling
4. Step 7C-2 : Add Overnight Gap Features

Step 7A : Fetch Historical Market Data (Yahoo Finance)

```python
# (Yahoo only: equities + BTC-USD 1-hour)

import sys, subprocess, importlib, pathlib, time, requests, pandas as pd
from datetime import datetime, timedelta

# Light dependencies
def pip_install(pkg):
    try: importlib.import_module(pkg.split("==")[0].replace("-", "_"))
    except ImportError:
```

```python
        subprocess.check_call([sys.executable, "-m", "pip", "install", "-q", pkg])

for lib in ("yfinance", "backoff", "pyarrow"):
    pip_install(lib)

import yfinance as yf, backoff

# Cache folder (Drive if interactive Colab)
def get_cache_dir():
    try:
        import google.colab, IPython
        from google.colab import drive
        if (sh := IPython.get_ipython()) and hasattr(sh, "kernel"):
            drive.mount("/content/drive", force_remount=False)
            print("Using Google Drive cache.")
            return pathlib.Path("/content/drive/MyDrive/ai_investor_cache")
    except Exception as e:
        print(f"Drive mount skipped ({e}). Using local cache.")
    return pathlib.Path("./ai_investor_cache")

CACHE_DIR = get_cache_dir(); CACHE_DIR.mkdir(parents=True, exist_ok=True)

# Back-off Yahoo wrapper
@backoff.on_exception(backoff.expo,
                      (requests.exceptions.HTTPError, KeyError, ValueError),
                      max_tries=5, factor=2)
def _yf(*a, **k):
    return yf.download(*a, progress=False, threads=True,
                       group_by="ticker", auto_adjust=False, **k)

# Yahoo batch fetch with Parquet cache
def fetch_yahoo_flat(tickers, *, interval="1h", lookback="730d", batch=10):
    frames=[]
    for i in range(0, len(tickers), batch):
        batch_tk = tickers[i:i+batch]
        tag      = f"yf_{'_'.join(batch_tk)}_{interval}_{lookback}.parquet"
        fp       = CACHE_DIR / tag
        if fp.exists():
            df = pd.read_parquet(fp)
        else:
            df = _yf(batch_tk, interval=interval, period=lookback)
            if isinstance(df.columns, pd.MultiIndex):
                df.columns=[f"{t}_{f}" for t,f in df.columns]
            else:
                df.columns=[f"{batch_tk[0]}_{c}" for c in df.columns]
            df.to_parquet(fp)
        frames.append(df); time.sleep(0.6)
    return pd.concat(frames, axis=1)

# Align OHLCV helper
def unify_ohlc(frames, freq="1h"):
    agg = {"Open":"first","High":"max","Low":"min","Close":"last",
           "Adj Close":"last","Volume":"sum"}
    def flat(df):
        if isinstance(df.columns, pd.MultiIndex):
            df.columns=["_".join(map(str,c)).replace(" ","_") for c in df.columns]
        return df
    aligned=[]
    for f in frames:
        f=flat(f)
        col_agg={c:agg[s] for c in f.columns
                 if (s:=next((s for s in agg if c.endswith(s)), None))}
        if col_agg:
            aligned.append(f.resample(freq).agg(col_agg).ffill())
    return pd.concat(aligned, axis=1)

# Pull data
equities = fetch_yahoo_flat(
    ["AAPL","MSFT","NVDA","^SPX","^VIX"],
    interval="1h",
    lookback="730d"
)

btc = fetch_yahoo_flat(
    ["BTC-USD"],                  # 1-hour candles, 2 years
    interval="1h",
    lookback="730d"
)
btc.columns = [c.replace("BTC-USD_", "BTC_") for c in btc.columns]

# Merge & normalise names
raw = unify_ohlc([equities, btc], freq="1h").sort_index()

def normalize(df):
    df = df.copy()
    df.columns = (df.columns
                  .str.replace(r"[^A-Za-z0-9_]+","", regex=True)
                  .str.replace("AdjClose","Close")
                  .str.lower())
    df.columns = (df.columns
                  .str.replace("^spx_", "spx_", regex=True)
                  .str.replace("^vix_", "vix_", regex=True))
    return df

df_raw_market = normalize(raw)

print("STEP 7A finished – preview:")
display(df_raw_market.head())
```

```
Mounted at /content/drive
Using Google Drive cache.
STEP 7A finished – preview:
```

Datetime	spx_open	spx_high	spx_low	spx_close	spx_volume	vix_open	vix_high	vix_low	vix_close	vix_volume	...	nvda_high	nvda_low	nvda_close	nvda_volume	btc_open	btc_high	btc_low	btc_close
2022-06-28 13:00:00+00:00	3913.000000	3945.860107	3909.149902	3910.909912	0.0	NaN	NaN	NaN	NaN	0.0	...	17.201990	16.602001	16.644001	11918317.0	NaN	NaN	NaN	NaN
2022-06-28 14:00:00+00:00	3910.699951	3910.699951	3872.889893	3872.889893	277243895.0	NaN	NaN	NaN	NaN	0.0	...	16.650000	16.313999	16.315500	7013539.0	NaN	NaN	NaN	NaN
2022-06-28 15:00:00+00:00	3872.780029	3876.590088	3848.550049	3862.520020	250036292.0	NaN	NaN	NaN	NaN	0.0	...	16.363001	16.050999	16.179989	6841093.0	NaN	NaN	NaN	NaN
2022-06-28	3862.939941	3867.300049	3840.260010	3849.989990	197625810.0	NaN	NaN	NaN	NaN	0.0	...	16.233000	16.020000	16.118000	4361742.0	NaN	NaN	NaN	NaN

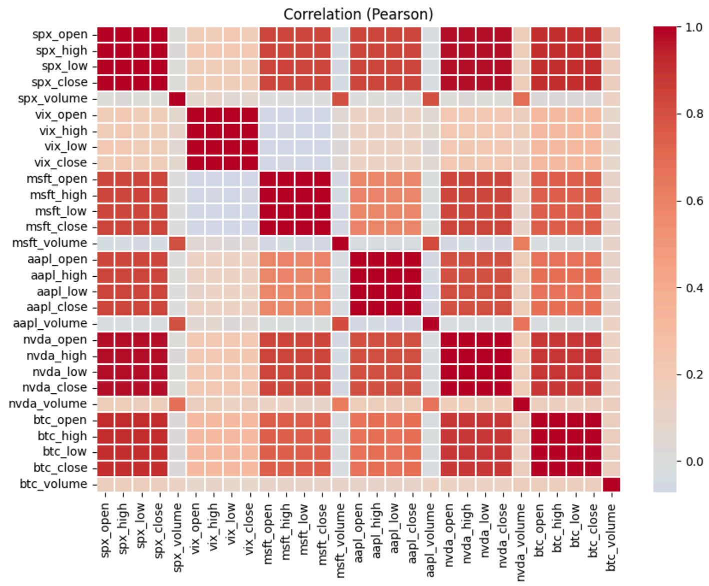
Step 7B : Data Quality Validation & Exploratory Analysis (EDA)

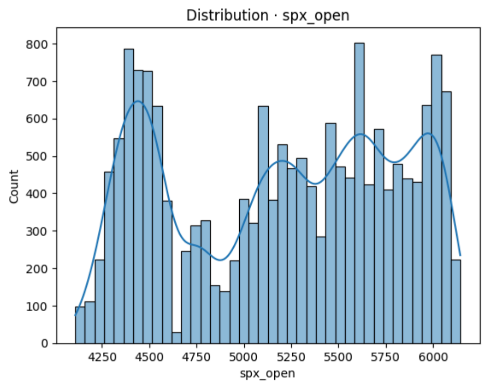
```python
import pandas as pd, numpy as np, matplotlib.pyplot as plt, seaborn as sns

MAX_COL_NA_PCT, MAX_GAP_FFILL, TRIM_STRICTNESS, FINAL_FFILL_LIM = 10, 3, 0.00, 24

def trim_and_fill(df,
                  trim_thresh=TRIM_STRICTNESS,
                  ffill_limit=MAX_GAP_FFILL,
                  max_missing=MAX_COL_NA_PCT):
```

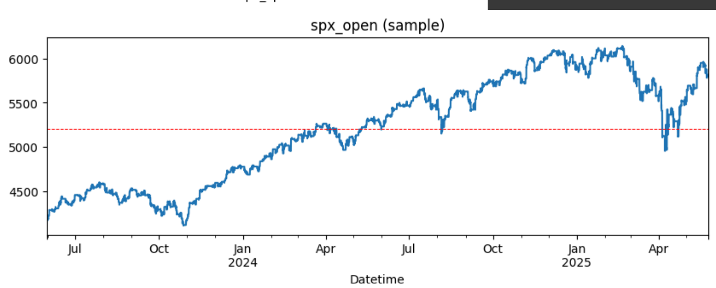
```python
    miss_ratio = df.isna().mean(axis=1)
    first_ok   = miss_ratio[miss_ratio <= trim_thresh].index.min()
    if first_ok is None:
        raise ValueError("No row meets trim threshold - relax TRIM_STRICTNESS.")
    df = df.loc[first_ok:].ffill(limit=ffill_limit)

    sparse = df.isna().mean()*100
    drop   = sparse[sparse > max_missing].index
    if len(drop):
        print(f"Dropping {len(drop)} sparse columns (> {max_missing}% NA)")
        df = df.drop(columns=drop)
    return df

def run_eda_step_7b(df_input):
    # ensure DatetimeIndex
    if not isinstance(df_input.index, pd.DatetimeIndex):
        if "datetime" in df_input.columns:
            df = df_input.copy()
            df["datetime"] = pd.to_datetime(df["datetime"])
            df = df.set_index("datetime")
        else:
            raise ValueError("DataFrame must have DatetimeIndex or 'datetime' col.")
    else:
        df = df_input.copy()

    # trim & forward-fill small gaps
    df_clean = trim_and_fill(df)

    # drop duplicate column labels (spx_close, spx_close, …)
    before = df_clean.shape[1]
    df_clean = df_clean.loc[:, ~df_clean.columns.duplicated()]
    if df_clean.shape[1] < before:
        print(f"Dropped {before - df_clean.shape[1]} duplicate-name columns")

    # drop zero-info volume cols & final f-fill
    zero_vol = [c for c in df_clean.columns
                if c.endswith("_volume") and df_clean[c].nunique() <= 2]
    if zero_vol:
        print(f"Dropping {len(zero_vol)} zero-info volume cols")
        df_clean = df_clean.drop(columns=zero_vol)

    df_clean = df_clean.ffill(limit=FINAL_FFILL_LIM).dropna()

    # missing summary
    miss_cnt = df_clean.isna().sum()
    miss_tbl = (miss_cnt[miss_cnt > 0]
                 .to_frame("missing")
                 .assign(missing_pct=lambda d: (d.missing/len(df_clean)*100).round(2))
                 .sort_values("missing_pct", ascending=False))
    print("₩n** Missing-Value Summary (after all cleaning) **")
    if miss_tbl.empty:
        print("No missing values remain.")
    else:
        display(miss_tbl)

    # coverage & basic stats
    start, end = df_clean.index.min(), df_clean.index.max()
    print(f"₩n** Time Coverage **  Start: {start}  ·  End: {end}  ·  Rows: {len(df_clean):,}")

    num_df = df_clean.select_dtypes("number")
    desc   = num_df.describe().T.assign(rng=lambda d: d["max"] - d["min"]).round(2)
    print("₩n** Descriptive Statistics **")
    display(desc.head(25))

    # quick correlation heat-map
    if num_df.shape[1] >= 3:
        plt.figure(figsize=(9,7))
        sns.heatmap(num_df.corr(), cmap="coolwarm", center=0, annot=False, linewidths=.3)
        plt.title("Correlation (Pearson)"); plt.tight_layout(); plt.show()

    # distributions & small time-series samples
    for col in num_df.columns[:4]:
        ser = num_df[col]           # guaranteed Series (no dups now)
        sns.histplot(ser, bins=40, kde=True)
        plt.title(f"Distribution · {col}"); plt.show()

        ser.plot(figsize=(10,3), title=f"{col} (sample)")
        plt.axhline(ser.mean(), ls="--", lw=.7, c="r"); plt.show()

    return df_clean

df_final_combined = run_eda_step_7b(df_raw_market)
```

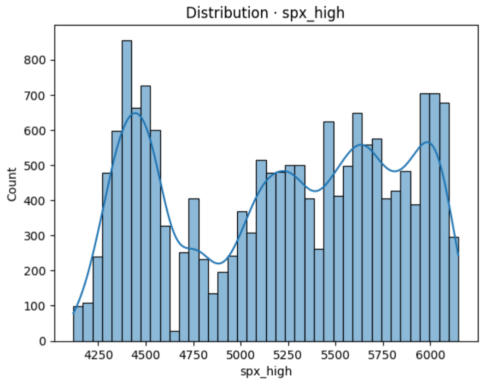
```
Dropped 1 duplicate-name columns
Dropping 1 zero-info volume cols

** Missing-Value Summary (after all cleaning) **
No missing values remain.

** Time Coverage **  Start: 2023-05-31 00:00:00+00:00  ·  End: 2025-05-24 23:00:00+00:00  ·  Rows: 17,400

** Descriptive Statistics **
```

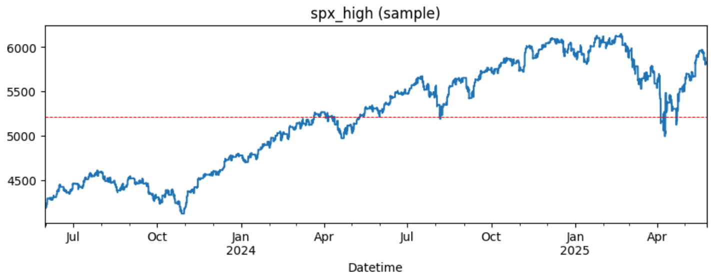
	count	mean	std	min	25%	50%	75%	max	rng
spx_open	17400.0	5202.87	5.895500e+02	4109.11	4572.04	5263.28	5714.07	6.143520e+03	2.034410e+03
spx_high	17400.0	5210.55	5.911400e+02	4118.42	4574.23	5280.33	5719.24	6.147430e+03	2.029010e+03
spx_low	17400.0	5194.48	5.886300e+02	4103.78	4565.59	5255.01	5701.85	6.136110e+03	2.032330e+03
spx_close	17400.0	5202.72	5.903500e+02	4108.95	4569.04	5268.18	5708.47	6.143950e+03	2.035000e+03
spx_volume	17400.0	54434555.95	1.217935e+08	0.00	0.00	0.00	0.00	1.286533e+09	1.286533e+09
vix_open	17400.0	16.62	4.900000e+00	11.52	13.55	15.13	18.16	6.406000e+01	5.254000e+01
vix_high	17400.0	16.77	5.070000e+00	11.56	13.58	15.28	18.27	6.573000e+01	5.417000e+01
vix_low	17400.0	16.46	4.730000e+00	10.62	13.46	15.00	17.92	5.673000e+01	4.611000e+01
vix_close	17400.0	16.61	4.900000e+00	11.55	13.52	15.13	18.12	5.924000e+01	4.769000e+01
msft_open	17400.0	394.58	3.991000e+01	310.32	368.65	407.57	423.57	4.678300e+02	1.575100e+02
msft_high	17400.0	395.62	3.996000e+01	311.15	369.74	408.83	424.56	4.683500e+02	1.572000e+02
msft_low	17400.0	393.55	3.989000e+01	309.45	367.00	406.78	422.73	4.669900e+02	1.575400e+02
msft_close	17400.0	394.63	3.996000e+01	310.38	368.77	408.14	423.82	4.678300e+02	1.574500e+02
msft_volume	17400.0	479558.40	1.255962e+06	0.00	0.00	0.00	0.00	2.389916e+07	2.389916e+07
aapl_open	17400.0	203.13	2.415000e+01	164.37	182.59	194.66	225.27	2.591200e+02	9.475000e+01
aapl_high	17400.0	203.68	2.427000e+01	165.16	182.88	195.25	225.98	2.600900e+02	9.493000e+01
aapl_low	17400.0	202.53	2.406000e+01	164.08	182.17	194.30	224.89	2.590100e+02	9.493000e+01
aapl_close	17400.0	203.12	2.421000e+01	164.36	182.51	194.68	225.67	2.591100e+02	9.475000e+01
aapl_volume	17400.0	1281197.96	3.324941e+06	0.00	0.00	0.00	0.00	6.068967e+07	6.068967e+07
nvda_open	17400.0	91.92	3.707000e+01	37.72	48.31	95.88	124.61	1.522000e+02	1.144800e+02
nvda_high	17400.0	92.35	3.726000e+01	37.79	48.43	97.20	126.48	1.528900e+02	1.151000e+02
nvda_low	17400.0	91.46	3.686000e+01	37.36	48.22	95.19	124.48	1.510400e+02	1.136800e+02
nvda_close	17400.0	91.95	3.710000e+01	37.48	48.34	96.71	125.66	1.518900e+02	1.144100e+02
nvda_volume	17400.0	4077043.36	1.322748e+07	0.00	0.00	0.00	0.00	2.437944e+08	2.437944e+08
btc_open	17400.0	61158.41	2.470824e+04	24871.44	37770.50	62667.84	82804.96	1.117834e+05	8.691194e+04

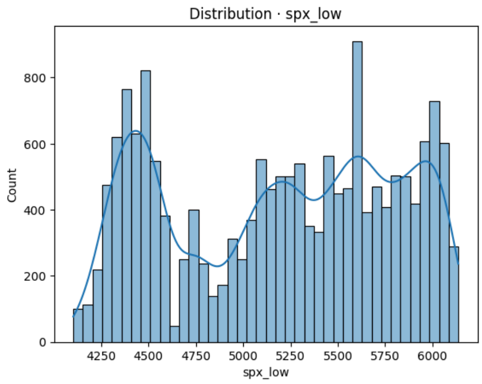


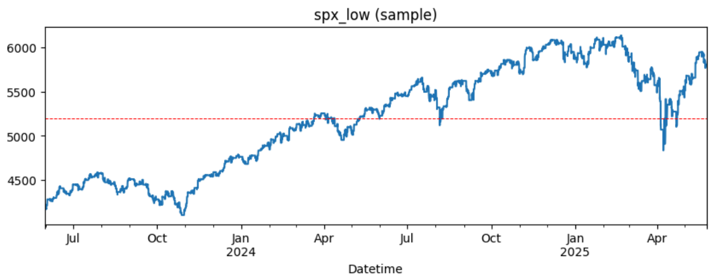


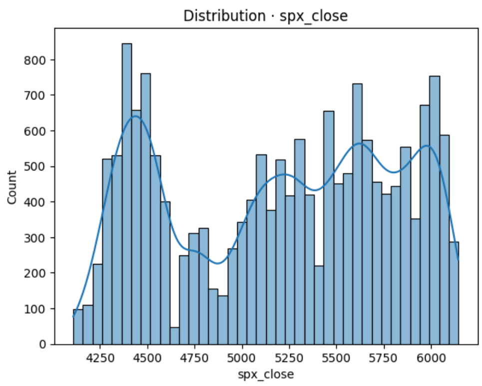


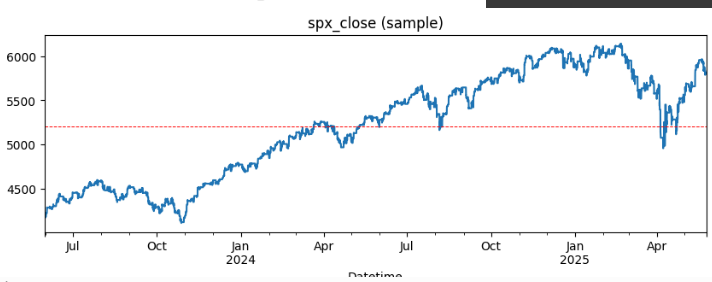

Distribution · spx_high
Count
spx_high


spx_high (sample)
Datetime


Distribution · spx_low
Count
spx_low


spx_low (sample)
Datetime


Distribution · spx_close
Count
spx_close


spx_close (sample)

Step 7C-1 : Historical Data Preparation for Modelling

```python
import pandas as pd, numpy as np

def run_preprocessing_step_7c(df_in: pd.DataFrame,
                              price_cols: list[str] | None = None,
                              return_type: str = "log",
                              max_lag: int = 3,
                              rolling_windows: list[int] = [3, 5],
                              make_zscore: bool = True
                              ) -> pd.DataFrame:
    """
    Parameters
    ----------
    df_in : DataFrame
        Output from Step 7B with DatetimeIndex and no NaNs.
    price_cols : list[str] | None
        List of close-price columns to build features from. If None, detect *Close suffix.
    return_type : {"log", "pct"}
    max_lag : int
        Number of lagged return features.
    rolling_windows : list[int]
        Window sizes for mean & std rolling stats.
    make_zscore : bool
        Adds z-scored returns (return / rolling std).

    Returns
    -------
    df_out : DataFrame
        Feature-rich, NaN-free frame ready for Step 8 / 9.
    """
    # prep copy & sort
    df = df_in.copy()
    df = df.sort_index()                        # datetime already index

    # pick price columns
    if price_cols is None:
        price_cols = [c for c in df.columns if c.lower().endswith("close")]
    missing_cols = [c for c in price_cols if c not in df.columns]
    if missing_cols:
        raise ValueError(f"Columns not in DF: {missing_cols}")

    # returns
    for col in price_cols:
        if return_type == "log":
            df[f"{col}_ret"] = np.log(df[col] / df[col].shift(1))
            df[f"{col}_pct"] = df[col].pct_change()
        else:
            df[f"{col}_ret"] = df[col].pct_change()

    ret_cols = [c for c in df.columns if c.endswith("_ret")]

    # lags
    for col in ret_cols:
        for lag in range(1, max_lag + 1):
            df[f"{col}_lag{lag}"] = df[col].shift(lag)

    # rolling stats
    for col in ret_cols:
        for w in rolling_windows:
            df[f"{col}_r{w}_mean"] = df[col].rolling(w).mean()
            df[f"{col}_r{w}_std"]  = df[col].rolling(w).std()
            if make_zscore:
                df[f"{col}_z{w}"] = df[col] / df[f"{col}_r{w}_std"]

    # final clean-up
    before = len(df)
    df = df.dropna().copy()      # drops first max(rolling, lag) rows
    after = len(df)

    print(f"Step 7C-1 done   ·   rows dropped: {before-after}   ·   final shape: {df.shape}")

    # optional: bring original prices to front for readability
    ordered = price_cols + [c for c in df.columns if c not in price_cols]
    return df[ordered]

# EXECUTE STEP 7C
# Auto-detection of *Close columns, leave price_cols=None
df_model_ready = run_preprocessing_step_7c(
    df_final_combined,
    price_cols=None,          # or explicit list like ["AAPL_Close","BTCUSDT_Close"]
    return_type="log",
    max_lag=3,
    rolling_windows=[3, 5]
)
```

```
Step 7C-1 done   ·   rows dropped: 12943   ·   final shape: (4457, 95)
```

Step 7C-2 : Add Overnight Gap Features

```python
import numpy as np
import pandas as pd

def add_overnight_features(df_feat: pd.DataFrame,
                           price_cols: list[str] | None = None,
                           gap_type: str = "log") -> pd.DataFrame:
    """
    Adds one column per equity/ETF close price:
        {TICKER}_overnight_gap  =  log(Open_t / Close_{t-1})

    Parameters
    ----------
    df_feat : DataFrame
        The NaN-free, equity-hours feature matrix returned by Step 7C
        (index = DatetimeIndex in UTC).
    price_cols : list[str] | None
        List of *_Close columns that define the equities for which we add gaps.
        If None, auto-detect every column ending in '_Close'.
    gap_type : {'log', 'pct'}
        Whether to compute log-gap (default) or percent gap.

    Returns
    -------
    df_out : DataFrame
        Same rows + all previous columns + new *_overnight_gap features.
        The first row is dropped because it has no t-1 close.
    """
    df = df_feat.copy()

    # Decide which close-price columns to use
    if price_cols is None:
        price_cols = [c for c in df.columns if c.lower().endswith("_close")]

```

```
    # For each close, derive matching open column and compute gap
    for close_col in price_cols:
        # infer open column name (works with 'AAPL_Close' → 'AAPL_Open')
        open_col = close_col.replace("_Close", "_Open")
        if open_col not in df.columns:
            print(f"[⚠] Open column not found for {close_col}; skipping.")
            continue

        if gap_type == "log":
            df[f"{close_col.replace('_Close','')}_overnight_gap"] = ₩
                np.log(df[open_col] / df[close_col].shift(1))
        else:  # percent gap
            df[f"{close_col.replace('_Close','')}_overnight_gap"] = ₩
                df[open_col] / df[close_col].shift(1) - 1

    # Drop first row (will contain NaN gaps) and ensure no NaNs remain
    df = df.dropna().copy()

    print(f"Step 7C-2 done – added overnight gaps for {len(price_cols)} tickers.")
    return df

# Usage right after Step 7C
# df_model_ready was produced by run_preprocessing_step_7c
df_model_ready = add_overnight_features(
    df_model_ready,
    price_cols=None,      # auto-detect *_Close columns
    gap_type="log"        # or "pct"
)

# df_model_ready now contains extra columns

print(df_model_ready.filter(like='_overnight_gap').head())
print(df_model_ready.isna().sum().sum())   # should be 0
```

```
Step 7C-2 done – added overnight gaps for 6 tickers.
                           msft_close_overnight_gap  aapl_close_overnight_gap  ₩
Datetime
2023-06-02 14:00:00+00:00                  0.004492                  0.004275
2023-06-02 15:00:00+00:00                 -0.001315                  0.000941
2023-06-02 16:00:00+00:00                  0.000807                 -0.000443
2023-06-02 17:00:00+00:00                  0.003252                 -0.000721
2023-06-02 18:00:00+00:00                  0.000120                  0.001634

                           spx_close_overnight_gap  vix_close_overnight_gap  ₩
Datetime
2023-06-02 14:00:00+00:00                 0.004880                -0.019353
2023-06-02 15:00:00+00:00                -0.000358                -0.010159
2023-06-02 16:00:00+00:00                 0.001978                 0.010159
2023-06-02 17:00:00+00:00                -0.000808                -0.007440
2023-06-02 18:00:00+00:00                 0.000430                -0.002039

                           nvda_close_overnight_gap  btc_close_overnight_gap
Datetime
2023-06-02 14:00:00+00:00                  0.003810                 0.002882
2023-06-02 15:00:00+00:00                 -0.004483                 0.004858
2023-06-02 16:00:00+00:00                 -0.002478                -0.001518
2023-06-02 17:00:00+00:00                 -0.007202                -0.000430
2023-06-02 18:00:00+00:00                  0.002357                 0.004578
0
```

Step 8: Alternative Data Integration

1. Step 8A : Integrate Twitter Sentiment Analysis
2. Step 8B : News Sentiment via NLP
3. Step 8C : Macroeconomic Indicators Integration (FRED)
4. Step 8D : Google Trends Feature Engineering

Step 8A : Integrate Twitter Sentiment Analysis

```
import sys, subprocess, importlib, logging, re, pandas as pd
from datetime import datetime, timedelta, timezone

# lightweight deps
def pip_install(pkg):
    try: importlib.import_module(pkg.split("==")[0].replace("-", "_"))
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install", "-q", pkg])

for lib in ("tweepy", "vaderSentiment"):
    pip_install(lib)

import tweepy
from vaderSentiment.vaderSentiment import SentimentIntensityAnalyzer

logging.getLogger("tweepy.client").setLevel(logging.ERROR)

# config
LOOKBACK_HOURS = 6          # <- change this if needed
MAX_RESULTS    = 50         # tweets per API call   (max 100)
CHUNK_HOURS    = 6          # if look-back is longer than this, window is chunked

DEFAULT_QUERIES = {
    "AAPL": '"Apple Inc" OR AAPL',
    "BTC":  "bitcoin OR BTC",
    "SPX":  '"S&P 500" OR SPX',
}

def _clean(txt: str) -> str:
    txt = re.sub(r"http₩S+|www₩S+", "", txt.lower())
    txt = re.sub(r"[@#]₩w+", "", txt)
    txt = re.sub(r"[^₩w₩s]", " ", txt)
    return re.sub(r"₩s+", " ", txt).strip()

def add_twitter_sentiment_safe(df_model: pd.DataFrame,
                               bearer_token: str,
                               search_queries: dict[str, str] | None = None,
                               lookback_hours: int = LOOKBACK_HOURS,
                               chunk_hours: int = CHUNK_HOURS,
                               max_results: int = MAX_RESULTS) -> pd.DataFrame:
    """
    Adds <TICKER>_sent_1h columns.
    • Uses short look-back (default 6 h) to avoid rate-limits.
    • If Tweepy error ⇒ neutral 0.0 column so pipeline never breaks.
    """
    # ensure DatetimeIndex UTC
    if not isinstance(df_model.index, pd.DatetimeIndex):
        if "datetime" in df_model.columns:
            df_model = df_model.copy()
            df_model["datetime"] = pd.to_datetime(df_model["datetime"], utc=True)
            df_model = df_model.set_index("datetime")
        else:
            raise ValueError("df_model needs DatetimeIndex or 'datetime' column.")

    search_queries = search_queries or DEFAULT_QUERIES
    analyzer       = SentimentIntensityAnalyzer()
```

```
    client        = tweepy.Client(bearer_token=bearer_token, wait_on_rate_limit=False)

    end_time   = datetime.utcnow().replace(tzinfo=timezone.utc)
    start_time = end_time - timedelta(hours=lookback_hours)

    out = df_model.copy()

    for tk, query in search_queries.items():
        col = f"{tk}_sent_1h"
        try:
            # chunk long ranges (rarely needed because default = 6 h)
            ranges = []
            cur_end = end_time
            while cur_end > start_time:
                cur_start = max(start_time, cur_end - timedelta(hours=chunk_hours))
                ranges.append((cur_start, cur_end))
                cur_end = cur_start

            all_rows = []
            for st, et in ranges:
                resp = client.search_recent_tweets(
                    query=f"{query} -is:retweet lang:en",
                    tweet_fields=["created_at", "text"],
                    start_time=st, end_time=et,
                    max_results=max_results,
                )
                tweets = resp.data or []
                all_rows.extend(
                    [(t.created_at.astimezone(timezone.utc), t.text) for t in tweets]
                )

            if not all_rows:
                raise RuntimeError("no tweets")

            df_t = pd.DataFrame(all_rows, columns=["datetime", "text"])
            df_t["sent"]  = df_t["text"].map(
                lambda x: analyzer.polarity_scores(_clean(x))["compound"]
            )
            df_t["dt_hr"] = df_t["datetime"].dt.floor("1h")
            hourly = df_t.groupby("dt_hr")["sent"].mean()

            out[col] = out.index.map(hourly).astype(float)
            print(f"✓ {tk}: real sentiment added ({len(all_rows)} tweets).")

        except Exception as e:
            out[col] = 0.0
            print(f"[neutral] {tk}: {str(e).splitlines()[0]}")

    # cosmetic gap-fill
    out.update(out.filter(like="_sent_1h").ffill(limit=6))
    out.update(out.filter(like="_sent_1h").bfill(limit=1))

    print("8A finished – sentiment columns ready.")
    return out

# example invocation (comment in production)
if __name__ == "__main__":
    BEARER_TOKEN = "AAAAAAAAAAAAAAAAAAAAADqo1AEAAAAABB4EMJg6BeahMCrtU3ueVv0Wx%2Fg%3D0YWhSShJHoFiP600CLrAAhTy4lZispGbB620JG0jnuTedLhlEl"  # leave empty to demo neutral
    df_model_ready = add_twitter_sentiment_safe(
        df_model_ready,           # from Step 7C (+7C-2)
        bearer_token=BEARER_TOKEN,
        lookback_hours=LOOKBACK_HOURS
    )
df_model_ready = add_twitter_sentiment_safe(
    df_model_ready,               # ← from Step 7 C
    bearer_token="AAAAAAAAAAAAAAAAAAAAADqo1AEAAAAABB4EMJg6BeahMCrtU3ueVv0Wx%2Fg%3D0YWhSShJHoFiP600CLrAAhTy4lZispGbB620JG0jnuTedLhlEl",
    lookback_hours=6              # keep at 6 h (or shorter) to stay safe
)
```

```
[neutral] AAPL: 429 Too Many Requests
[neutral] BTC: 429 Too Many Requests
[neutral] SPX: 429 Too Many Requests
8A finished – sentiment columns ready.
[neutral] AAPL: 429 Too Many Requests
[neutral] BTC: 429 Too Many Requests
[neutral] SPX: 429 Too Many Requests
8A finished – sentiment columns ready.
```

Step 8B : News Sentiment via NLP

```
# NewsAPI → Google-News RSS → neutral fallback

import sys, subprocess, importlib, logging, re, pandas as pd
from datetime import datetime, timedelta, timezone

# light deps (works outside Colab)
def pip_install(pkg):
    try: importlib.import_module(pkg.split("==")[0].replace("-", "_"))
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install", "-q", pkg])

for lib in ("requests", "feedparser", "vaderSentiment"):
    pip_install(lib)

import requests, feedparser
from vaderSentiment.vaderSentiment import SentimentIntensityAnalyzer

# CONFIG
NEWSAPI_KEY   = "23e55b5d88d2421c8642ce0d8d35e1fb"   # "" to rely on RSS only
LOOKBACK_DAYS = 3
TICKERS       = {
    "AAPL": "Apple Inc",
    "BTC":  "Bitcoin",
    "SPX":  '"S&P 500"',
}
SIDER = SentimentIntensityAnalyzer()

logging.basicConfig(level=logging.INFO, force=True)

# helpers
def _clean(txt: str) -> str:
    txt = re.sub(r"http₩S+|www₩S+", "", txt.lower())
    txt = re.sub(r"[^₩w₩s]", " ", txt)
    return re.sub(r"₩s+", " ", txt).strip()

def _newsapi_pull(keyword: str, start_iso: str):
    url = "https://newsapi.org/v2/everything"
    params = dict(q=keyword, from_=start_iso, sortBy="publishedAt",
                  language="en", pageSize=100, apiKey=NEWSAPI_KEY)
    r = requests.get(url, params=params, timeout=10)
    r.raise_for_status()
    arts = r.json().get("articles", [])
    return [(datetime.fromisoformat(a["publishedAt"])
             .replace(tzinfo=timezone.utc), a["title"]) for a in arts]

def _rss_pull(keyword: str, hours: int):
    url   = ("https://news.google.com/rss/search?q=" +
```

```
            requests.utils.quote(keyword) + "&hl=en-US&gl=US&ceid=US:en")
    feed  = feedparser.parse(url)
    cutoff = datetime.utcnow().replace(tzinfo=timezone.utc) - timedelta(hours=hours)
    return [(datetime(*e.published_parsed[:6], tzinfo=timezone.utc), e.title)
            for e in feed.entries
            if datetime(*e.published_parsed[:6], tzinfo=timezone.utc) >= cutoff]

# main entry
def add_news_sentiment(df_model: pd.DataFrame,
                       tickers: dict[str, str] = TICKERS,
                       lookback_days: int = LOOKBACK_DAYS) -> pd.DataFrame:
    """Adds / overwrites daily `avg_vader_sent` column."""

    # ensure DatetimeIndex UTC
    if not isinstance(df_model.index, pd.DatetimeIndex):
        if "datetime" in df_model.columns:
            df_model = df_model.set_index(
                pd.to_datetime(df_model["datetime"], utc=True))
        else:
            raise ValueError("df_model needs DatetimeIndex or 'datetime' col.")

    end   = datetime.utcnow().replace(tzinfo=timezone.utc)
    start = end - timedelta(days=lookback_days)
    rows  = []

    for tk, keyword in tickers.items():
        try:
            if NEWSAPI_KEY:
                arts = _newsapi_pull(keyword, start.date().isoformat())
                logging.info(f"{tk}: {len(arts)} headlines via NewsAPI")
            else:
                raise RuntimeError("NEWSAPI key missing")
        except Exception as e:
            logging.warning(f"{tk}: NewsAPI failed ({e}); falling back to RSS.")
            try:
                arts = _rss_pull(keyword, hours=24*lookback_days)
                logging.info(f"{tk}: {len(arts)} headlines via RSS")
            except Exception as e2:
                logging.warning(f"{tk}: RSS failed ({e2}).")
                arts = []

        rows.extend([(dt.date(), _clean(ttl)) for dt, ttl in arts])

    # build daily sentiment table
    if rows:
        news = pd.DataFrame(rows, columns=["date", "text"])
        news["vader"] = news["text"].map(lambda t: SIDER.polarity_scores(t)["compound"])
        daily = (news.groupby("date")["vader"]
                 .mean().rename("avg_vader_sent").to_frame())
    else:
        logging.warning("All sources empty - neutral sentiment column used.")
        rng = pd.date_range(df_model.index.min().floor("D"),
                            df_model.index.max().floor("D"),
                            freq="D", tz="UTC").date
        daily = pd.DataFrame({"avg_vader_sent": 0.0}, index=rng)

    daily.index = pd.to_datetime(daily.index, utc=True)

    # merge into model frame
    out = df_model.copy()
    out["avg_vader_sent"] = out.index.map(daily["avg_vader_sent"]).astype(float)
    out["avg_vader_sent"] = out["avg_vader_sent"].ffill().bfill()

    print("8B finished - avg_vader_sent column ready.")
    return out


# example usage (remove or comment in production)
if __name__ == "__main__":
    # df_model_ready must exist from Steps 7C (+7C-2) and 8A
    df_model_ready = add_news_sentiment(df_model_ready)
```

```
INFO:root:AAPL: 100 headlines via NewsAPI
INFO:root:BTC: 99 headlines via NewsAPI
INFO:root:SPX: 96 headlines via NewsAPI
8B finished - avg_vader_sent column ready.
```

Step 8C : Macroeconomic Indicators Integration (Fred)

```
# CPI & Unemployment → FRED
# PMI → Quandl (ISM/MAN_PMI)

import sys, subprocess, importlib, logging, pandas as pd
from datetime import datetime, timedelta, timezone

# tiny  "smart pip"  (no %pip)
def pip_install(pkg):
    try: importlib.import_module(pkg.split("==")[0].replace("-", "_"))
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install", "-q", pkg])

for lib in ("fredapi", "quandl"):
    pip_install(lib)

from fredapi import Fred
import quandl

# PUT YOUR API KEYS HERE
FRED_API_KEY   = "5f39b23d049c9a2b761b40ca32431a7d"   # "" → API Keys
QUANDL_API_KEY = "v3NWjN2z99FLFsj4VyPs"                    # "" → fallback neutral

# parameters you may tweak
LOOKBACK_YEARS = 10
FRED_SERIES    = {
    "cpi_yoy":      "CPIAUCSL",
    "unemployment": "UNRATE",
}

PMI_QUANDL_CODE = "ISM/MAN_PMI"   # ISM Manufacturing PMI (%)

logging.basicConfig(level=logging.INFO, force=True)

# helper
def add_macro_indicators(df_model: pd.DataFrame,
                         fred_key   : str = FRED_API_KEY,
                         quandl_key : str = QUANDL_API_KEY,
                         lookback_years: int = LOOKBACK_YEARS) -> pd.DataFrame:

    # ensure DatetimeIndex UTC
    if not isinstance(df_model.index, pd.DatetimeIndex):
        if "datetime" in df_model.columns:
            df_model = df_model.set_index(
                pd.to_datetime(df_model["datetime"], utc=True))
        else:
            raise ValueError("df_model needs DatetimeIndex or 'datetime' col.")

    start = (datetime.utcnow() -
```

```
            timedelta(days=365 * lookback_years)).date()

    frames = []

    # FRED pulls (CPI, Unemployment)
    fred = Fred(api_key=fred_key or None)
    for label, sid in FRED_SERIES.items():
        try:
            logging.info(f"{label}: pulling {sid} via FRED")
            ser = fred.get_series(sid, observation_start=start).dropna()
            ser.index = pd.to_datetime(ser.index, utc=True)
            ser.name  = label
            frames.append(ser)
        except Exception as e:
            logging.warning(f"{label}: FRED failed ({e}); neutral 0.0 used.")
            rng = pd.date_range(df_model.index.min().floor("D"),
                                df_model.index.max().floor("D"),
                                freq="ME", tz="UTC")
            frames.append(pd.Series(0.0, index=rng, name=label))

    # Quandl pull (PMI)
    try:
        if not quandl_key:
            raise RuntimeError("Quandl key missing")
        quandl.ApiConfig.api_key = quandl_key
        logging.info(f"pmi: pulling {PMI_QUANDL_CODE} via Quandl")
        pmi = quandl.get(PMI_QUANDL_CODE, start_date=start).dropna()
        # Quandl returns DataFrame with one column
        if isinstance(pmi, pd.DataFrame):
            pmi = pmi.iloc[:, 0]
        pmi.index = pd.to_datetime(pmi.index, utc=True)
        pmi.name  = "pmi"
        frames.append(pmi)
    except Exception as e:
        logging.warning(f"pmi: Quandl failed ({e}); neutral 0.0 used.")
        rng = pd.date_range(df_model.index.min().floor("D"),
                            df_model.index.max().floor("D"),
                            freq="ME", tz="UTC")
        frames.append(pd.Series(0.0, index=rng, name="pmi"))

    # combine, forward-fill to daily, align to df_model
    df_macro = (pd.concat(frames, axis=1)
                  .resample("D").ffill()
                  .reindex(df_model.index)
                  .ffill())

    # merge into main frame
    out = df_model.copy()
    for col in df_macro.columns:
        out[col] = df_macro[col].astype(float)

    print("8C finished – macro columns added/updated.")
    return out

# example usage (delete or comment in production)
if __name__ == "__main__":
    # df_model_ready must exist from Steps 7 C (+7C-2) and 8 B
    df_model_ready = add_macro_indicators(df_model_ready)
```

```
INFO:root:cpi_yoy: pulling CPIAUCSL via FRED
INFO:root:unemployment: pulling UNRATE via FRED
INFO:root:pmi: pulling ISM/MAN_PMI via Quandl
WARNING:root:pmi: Quandl failed ((Status 403) Something went wrong. Please try again. If you continue to have problems, please contact us at connect@quandl.com.); neutral 0.0 used.
8C finished – macro columns added/updated.
```

Step 8D : Google Trends Feature Engineering

```
# Google-Trends Features  (v2)
#   - per-keyword back-off
#   - tiny JSON cache (quota-friendly)
#   - optional variance filter

import sys, subprocess, importlib, logging, re, time, json, pathlib, pandas as pd
from datetime import datetime, timedelta, timezone

# auto-install
def _pip(pkg):
    try: importlib.import_module(pkg.split("==")[0].replace("-", "_"))
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install", "-q", pkg])

_pip("pytrends")
from pytrends.request import TrendReq
from pytrends import exceptions as ptexc

logging.basicConfig(level=logging.INFO, force=True)

# CONFIG
KEYWORDS      = [
    "Apple stock", "Bitcoin", "S&P 500",
    "interest rates", "inflation", "unemployment",
    "recession", "stock market crash", "VIX",
    "buy stocks", "crypto trading"
]
LOOKBACK_DAYS = 90           # history window
MA_WINDOW     = 3            # moving-average length
INCLUDE_DELTA = True         # add first difference feature
BATCH_SIZE    = 1            # ≤5; smaller → fewer 429s
DROP_CONST    = True         # drop zero-variance cols right after merge
CACHE_DAYS    = 7            # re-use pulls <= N days old
CACHE_DIR     = pathlib.Path("./trends_cache")

def _sanitize(k): return re.sub(r"₩s+", "_", k.lower())

def _days_to_tf(d):
    return f"now {d}-d" if d < 30 else f"today {round(d/30)}-m" if d < 365 else f"today {round(d/365)}-y"

def _cached_path(key):
    CACHE_DIR.mkdir(exist_ok=True)
    return CACHE_DIR / f"{_sanitize(key)}.json"

def _load_cache(key):
    p = _cached_path(key)
    if not p.exists():                return None
    if (datetime.utcnow() - datetime.utcfromtimestamp(p.stat().st_mtime)).days > CACHE_DAYS:
        p.unlink(missing_ok=True);    return None
    return pd.read_json(p, typ="series").tz_localize("UTC")

def _save_cache(key, series):
    series.to_json(_cached_path(key), date_unit="s")

def _pull_one_keyword(pytrends, kw, tf):
    cached = _load_cache(kw)
    if cached is not None:
        logging.info("Cache hit · %s", kw)
        return cached
```

```

    wait = 60           # start 1 min → 2 min → 4 min
    for n in range(1, 4):
        try:
            pytrends.build_payload([kw], timeframe=tf, geo="")
            s = pytrends.interest_over_time()[kw]
            s.index = s.index.tz_localize("UTC")
            _save_cache(kw, s)
            logging.info("Pulled · %s (%d points)", kw, len(s))
            return s
        except (ptexc.ResponseError, ptexc.TooManyRequestsError) as e:
            if n == 3:
                logging.warning("Google rejected '%s' - neutral 0.", kw)
                return pd.Series(dtype=float)  # will be made neutral later
            logging.warning("429/400 for '%s' (try %d/3) - sleeping %ds", kw, n, wait)
            time.sleep(wait); wait *= 2

def add_google_trends(df_model: pd.DataFrame,
                      keywords      = KEYWORDS,
                      lookback_days = LOOKBACK_DAYS,
                      ma_window     = MA_WINDOW,
                      include_delta = INCLUDE_DELTA,
                      drop_const    = DROP_CONST,
                      batch         = BATCH_SIZE) -> pd.DataFrame:

    # ensure DatetimeIndex UTC
    if not isinstance(df_model.index, pd.DatetimeIndex):
        if "datetime" in df_model:
            df_model = df_model.set_index(pd.to_datetime(df_model["datetime"], utc=True))
        else:
            raise ValueError("df_model needs DatetimeIndex or 'datetime' col")

    tf  = _days_to_tf(lookback_days)
    end = datetime.utcnow().replace(tzinfo=timezone.utc)
    start = end - timedelta(days=lookback_days)
    full_range = pd.date_range(start, end, freq="D", tz="UTC")

    pytrends = TrendReq(hl="en-US", tz=360)

    # pull & cache keyword series
    series_dict = {}
    for kw in keywords:
        series_dict[kw] = _pull_one_keyword(pytrends, kw, tf)

    # assemble into one DataFrame; neutral zeros where empty
    df_trends = pd.DataFrame(
        { _sanitize(k): (s.reindex(full_range).astype(float) if not s.empty else 0.0)
          for k, s in series_dict.items() },
        index=full_range
    )

    # feature engineering
    feats = {}
    for col in df_trends:
        s = df_trends[col]
        feats[f"{col}_ma{ma_window}"] = s.rolling(ma_window).mean()
        if include_delta:
            feats[f"{col}_delta"] = s.diff()
    df_feat = pd.DataFrame(feats).dropna()

    # merge into modelling frame
    out = df_model.copy()
    for c in df_feat:
        out[c] = out.index.map(df_feat[c])
    out.update(out.filter(like=f"_ma{ma_window}").ffill())
    if include_delta:
        out.update(out.filter(like="_delta").fillna(0))

    # optional variance filter
    if drop_const:
        var0 = [c for c in out.columns if out[c].nunique() <= 1]
        if var0:
            logging.info("Dropped %d zero-variance cols.", len(var0))
            out = out.drop(columns=var0)

    logging.info("Google-Trends done - %d features total.", len(df_feat.columns))
    return out

# EXAMPLE (comment-out in production)
if __name__ == "__main__":
    # df_model_ready must come from Steps 7 C → 8 C
    df_model_ready = add_google_trends(df_model_ready)
    print("8 D pipeline finished; df_model_ready shape →", df_model_ready.shape)
```

```
INFO:root:Pulled · Apple stock (93 points)
INFO:root:Pulled · Bitcoin (93 points)
INFO:root:Pulled · S&P 500 (93 points)
INFO:root:Pulled · interest rates (93 points)
INFO:root:Pulled · inflation (93 points)
INFO:root:Pulled · unemployment (93 points)
INFO:root:Pulled · recession (93 points)
INFO:root:Pulled · stock market crash (93 points)
INFO:root:Pulled · VIX (93 points)
INFO:root:Pulled · buy stocks (93 points)
INFO:root:Pulled · crypto trading (93 points)
INFO:root:Dropped 29 zero-variance cols.
INFO:root:Google-Trends done - 22 features total.
8 D pipeline finished; df_model_ready shape → (4474, 101)
```

Step 9 : Advanced Validation – Walk-Forward Testing

1. Step 9A : Implement Walk-Forward Validation
2. Step 9B : Rolling-Window Retraining & Hyperparameter Optimization

Step 9A : Implement Walk-Forward Validation

```
# WALK-FORWARD VALIDATION (XGBoost ≥ 1.6, incl. 2.1)
import warnings, logging, inspect, numpy as np, pandas as pd, matplotlib.pyplot as plt
from tqdm.auto            import tqdm
from sklearn.preprocessing import StandardScaler
from sklearn.metrics       import mean_squared_error, mean_absolute_error
try:
    from sklearn.metrics import mean_absolute_percentage_error
except ImportError:
    def mean_absolute_percentage_error(y, p):
        return np.mean(np.abs((y - p) / (y + 1e-9)))

import xgboost as xgb
from   xgboost import XGBRegressor

# USER SETTINGS
PRICE_COL   = "spx_close"
TARGET_LAG  = 1
TARGET_NAME = "target_return"

```

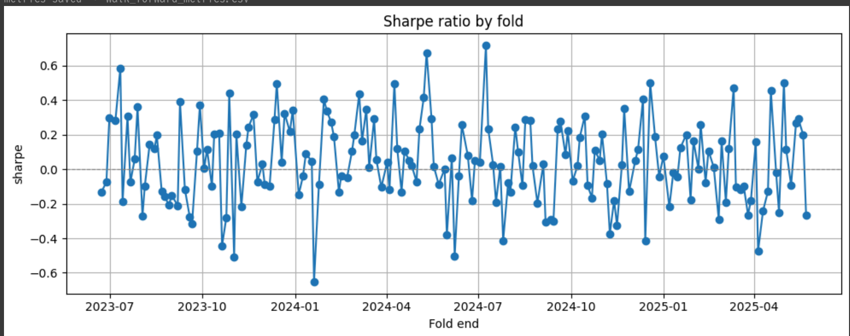
```
WINDOW, TEST, STEP = 120, 24, 24
EARLY_ROUNDS       = 50
GPU_PARAMS         = {"tree_method": "gpu_hist"}      # {} → CPU
RISK_FREE          = 0.02 / 252                       # daily RF

warnings.filterwarnings("ignore", category=UserWarning)
logging.basicConfig(level=logging.INFO, force=True)

# INPUT & TARGET PREP
if 'df_model_ready' not in globals():
    raise RuntimeError("Run Steps 7-8 first so that df_model_ready exists.")

df_model_ready = df_model_ready.copy()

if TARGET_NAME not in df_model_ready:
    if PRICE_COL not in df_model_ready:
        raise KeyError(f"Column '{PRICE_COL}' not found – pick an existing price column.")
    df_model_ready[TARGET_NAME] = (
        df_model_ready[PRICE_COL].pct_change(TARGET_LAG).shift(-TARGET_LAG)
    )
    df_model_ready.dropna(subset=[TARGET_NAME], inplace=True)
    logging.info("Created %s from %s pct-change (lag=%d).",
                 TARGET_NAME, PRICE_COL, TARGET_LAG)

# XGBoost-version flags
VER = tuple(int(v) for v in xgb.__version__.split(".")[:2])
HAS_ES_PARAM    = (1, 6) <= VER < (2, 0)                # early_stopping_rounds arg
CALLBACK_IN_FIT = 'callbacks' in inspect.signature(XGBRegressor.fit).parameters
logging.info("XGBoost %s  ·  ES-param: %s  ·  callbacks-in-fit: %s",
             xgb.__version__, HAS_ES_PARAM, CALLBACK_IN_FIT)

# helpers
def _rmse(y, p):
    try:
        return mean_squared_error(y, p, squared=False)
    except TypeError:                                  # old sklearn
        return np.sqrt(mean_squared_error(y, p))

def _train_xgb(Xtr, ytr, Xval, yval, rounds):
    """Fit an XGBRegressor with version-appropriate early stopping."""
    scaler = StandardScaler().fit(Xtr)
    Xtr_s  = scaler.transform(Xtr)
    Xval_s = scaler.transform(Xval)

    model = XGBRegressor(
        n_estimators=1000, learning_rate=0.05, max_depth=4,
        subsample=0.8, colsample_bytree=0.8, random_state=42,
        **GPU_PARAMS
    )

    if HAS_ES_PARAM:                                   # 1.6 – 1.7
        model.fit(
            Xtr_s, ytr, eval_set=[(Xval_s, yval)],
            early_stopping_rounds=rounds, verbose=False
        )
    elif CALLBACK_IN_FIT:                              # 2.0.x
        cb = xgb.callback.EarlyStopping(rounds=rounds, save_best=True)
        model.fit(
            Xtr_s, ytr,
            eval_set=[(Xval_s, yval)],
            callbacks=[cb], verbose=False
        )
    else:                                              # ≥ 2.1
        cb = xgb.callback.EarlyStopping(rounds=rounds, save_best=True)
        model.set_params(callbacks=[cb])
        model.fit(
            Xtr_s, ytr,
            eval_set=[(Xval_s, yval)],
            verbose=False
        )
    return scaler, model

# main walk-forward
def walk_forward(df: pd.DataFrame,
                 features: list[str] | None = None,
                 win=WINDOW, test=TEST, step=STEP):

    # ensure DatetimeIndex
    if not isinstance(df.index, pd.DatetimeIndex):
        if "datetime" in df:
            df = df.set_index(pd.to_datetime(df["datetime"], utc=True))
        else:
            raise ValueError("Need DatetimeIndex or a 'datetime' column.")

    if features is None:
        features = [c for c in df.columns if c not in {TARGET_NAME, "datetime"}]

    # PATCH: missing-data handling
    # Drop any feature that is > 90 % NaN
    features = [c for c in features if df[c].isna().mean() < 0.90]

    # Forward / back-fill remaining NaNs
    df[features] = df[features].ffill().bfill()

    logging.info("Using %d features after cleaning.", len(features))

    # Drop rows only if TARGET is NaN
    df = df.dropna(subset=[TARGET_NAME])


    if len(df) < win + test:
        raise RuntimeError(f"Need ≥{win+test} rows; have {len(df)}.")

    rows, bar = [], tqdm(
        range(0, len(df) - win - test + 1, step),
        desc="Walk-forward", unit="fold"
    )
    for s in bar:
        tr, te = df.iloc[s:s+win], df.iloc[s+win:s+win+test]
        Xtr, ytr = tr[features], tr[TARGET_NAME]
        Xte, yte = te[features], te[TARGET_NAME]

        scaler, model = _train_xgb(Xtr, ytr, Xte, yte, EARLY_ROUNDS)
        p = model.predict(scaler.transform(Xte))

        strat = np.sign(p) * yte.values
        rows.append({
            "start": tr.index[0],
            "end":   te.index[-1],
            "rmse":     _rmse(yte, p),
            "mae":      mean_absolute_error(yte, p),
            "mape":     mean_absolute_percentage_error(yte, p),
            "sharpe":   (strat.mean() - RISK_FREE) / (strat.std(ddof=0) + 1e-9),
            "dir_acc":  (np.sign(p) == np.sign(yte)).mean(),
            "cum_pnl":  strat.sum(),
            "best_trees": getattr(model, "best_ntree_limit", np.nan)
        })

    res = pd.DataFrame(rows)
```

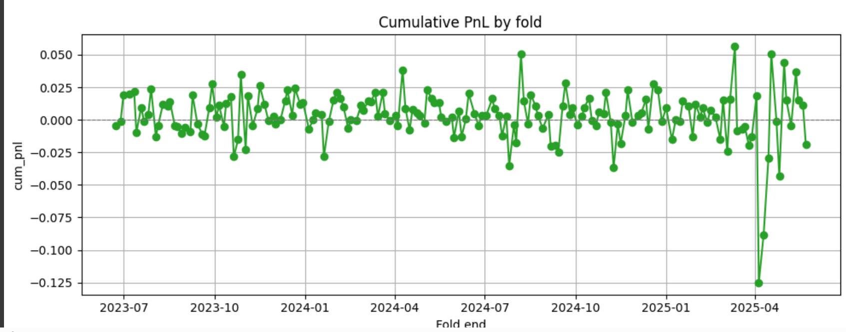
```python
    logging.info("Completed %d folds.", len(res))
    return res

# run & plot
metrics = walk_forward(df_model_ready)
display(metrics.head())

metrics.to_csv("walk_forward_metrics.csv", index=False)
print("metrics saved → walk_forward_metrics.csv")

def _plot(d, col, ttl, clr):
    plt.figure(figsize=(10, 4))
    plt.plot(d["end"], d[col], marker="o", color=clr)
    plt.axhline(0, ls="--", lw=.8, c="grey")
    plt.title(ttl); plt.xlabel("Fold end"); plt.ylabel(col)
    plt.grid(True); plt.tight_layout(); plt.show()

_plot(metrics, "sharpe",  "Sharpe ratio by fold",   "tab:blue")
_plot(metrics, "cum_pnl", "Cumulative PnL by fold", "tab:green")
```

```
INFO:root:XGBoost 2.1.4 · ES-param: False · callbacks-in-fit: False
INFO:root:Using 98 features after cleaning.
Walk-forward: 100% 180/180 [00:47<00:00,  5.27fold/s]
INFO:root:Completed 180 folds.
```

	start	end	rmse	mae	mape	sharpe	dir_acc	cum_pnl	best_trees
0	2023-05-31 13:00:00+00:00	2023-06-22 21:00:00+00:00	0.002221	0.001579	3.585986e+11	-0.131600	0.250000	-0.004748	NaN
1	2023-06-02 19:00:00+00:00	2023-06-27 18:00:00+00:00	0.001725	0.001372	3.700027e+11	-0.072942	0.458333	-0.001279	NaN
2	2023-06-07 16:00:00+00:00	2023-06-30 15:00:00+00:00	0.002455	0.001280	2.905812e+11	0.295675	0.541667	0.018795	NaN
3	2023-06-12 13:00:00+00:00	2023-07-06 16:00:00+00:00	0.002608	0.001275	4.713207e+11	0.283037	0.500000	0.019468	NaN
4	2023-06-14 19:00:00+00:00	2023-07-11 13:00:00+00:00	0.001530	0.001225	6.248947e+11	0.584802	0.541667	0.021584	NaN

```
metrics saved → walk_forward_metrics.csv
```





Step 9B : Rolling-Window Retraining & Hyperparameter Optimization

```python
# Rolling-Window Retraining + Optuna Hyper-Tuning

import pandas as pd, numpy as np, warnings, logging, importlib, subprocess, sys
from tqdm.auto import tqdm
from sklearn.metrics import mean_squared_error, mean_absolute_error

# tiny helper
def _ensure(pkg):
    try:
        importlib.import_module(pkg)
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install", "-q", pkg])

for _p in ("optuna", "xgboost"):      # scikit-learn already present in Colab
    _ensure(_p)

import optuna
from  xgboost import XGBRegressor

warnings.filterwarnings("ignore", category=UserWarning)
logging.basicConfig(level=logging.INFO, format="%(levelname)s: %(message)s")

# version-safe RMSE (works for ALL sklearn versions)
def _rmse(y_true, y_pred):
    """Root-MSE with backward-compatible call signature."""
    return np.sqrt(mean_squared_error(y_true, y_pred))

# utilities
def _prepare_df(df, dt_col="datetime"):
    if dt_col not in df.columns and isinstance(df.index, pd.DatetimeIndex):
        df = df.reset_index().rename(columns={"index": dt_col})
        logging.info(f"Promoted DatetimeIndex → column `{dt_col}`.")
    if dt_col not in df.columns:
        raise ValueError("No datetime column or DatetimeIndex found.")
    df[dt_col] = pd.to_datetime(df[dt_col], errors="coerce")
    return df.dropna(subset=[dt_col]).reset_index(drop=True)

# main routine
def run_walkforward_step_9b_optuna(
        df_model     : pd.DataFrame,
        feature_cols : list | None,
        target_col   : str,
        datetime_col : str = "datetime",
        window_size  : int  = 60,
        test_size    : int  = 5,
        step_size    : int  = 5,
        n_trials     : int  = 20,
```

```
        random_state : int  = 42,
        gpu          : bool = False,
    ) -> pd.DataFrame:

    df = _prepare_df(df_model, datetime_col)

    # feature selection
    if not feature_cols:
        feature_cols = []
    avail = [c for c in feature_cols if c in df.columns]
    if not avail:
        avail = [c for c in df.select_dtypes(include=[np.number]).columns
                 if c != target_col]

    if target_col not in df.columns:
        raise ValueError(f"`{target_col}` missing from df_model_ready.")

    # keep rows with valid datetime & target; fill feature NaNs with 0
    df = (df[avail + [target_col, datetime_col]]
          .dropna(subset=[target_col, datetime_col])
          .reset_index(drop=True))
    df[avail] = df[avail].fillna(0)

    # guardrail for short history
    if len(df) < window_size + test_size:
        logging.warning(f"Only {len(df)} rows after cleaning; shrinking windows.")
        window_size = max(5, len(df) // 3)
        test_size   = max(1, window_size // 5)
        step_size   = max(1, test_size)
    if len(df) < window_size + test_size:
        logging.error("Still too few rows. Add more history.")
        return pd.DataFrame()

    iterator = range(0, len(df) - window_size - test_size + 1, step_size)
    logging.info(f"Walk-forward: {len(iterator)} fold(s) "
                 f"({window_size} train, {test_size} test, step {step_size})")

    results = []
    for start in tqdm(iterator, desc="Walk-forward", unit="fold"):
        tr = df.iloc[start:start+window_size]
        te = df.iloc[start+window_size:start+window_size+test_size]
        X_tr, y_tr = tr[avail], tr[target_col]
        X_te, y_te = te[avail], te[target_col]

        # Optuna objective
        def _objective(t):
            p = {
                "n_estimators"     : t.suggest_int(  "n_estimators",     50, 300),
                "max_depth"        : t.suggest_int(  "max_depth",         3,   8),
                "learning_rate"    : t.suggest_float("learning_rate", 1e-2, .3, log=True),
                "subsample"        : t.suggest_float("subsample",       .5, 1.0),
                "colsample_bytree" : t.suggest_float("colsample_bytree",.5, 1.0),
                "gamma"            : t.suggest_float("gamma",            0,   5),
                "random_state"     : random_state,
                "objective"        : "reg:squarederror",
                "verbosity"        : 0
            }
            if gpu:
                p |= {"tree_method":"gpu_hist", "predictor":"gpu_predictor"}
            model  = XGBRegressor(**p).fit(X_tr, y_tr)
            preds  = model.predict(X_te)
            return _rmse(y_te, preds)

        study = optuna.create_study(direction="minimize")
        study.optimize(_objective, n_trials=n_trials, show_progress_bar=False)

        best = study.best_params | {"random_state": random_state}
        if gpu:
            best |= {"tree_method":"gpu_hist", "predictor":"gpu_predictor"}

        model  = XGBRegressor(**best).fit(X_tr, y_tr)
        preds  = model.predict(X_te)
        strat  = np.sign(preds) * y_te.values

        results.append({
            "start"               : tr[datetime_col].iloc[0],
            "end"                 : te[datetime_col].iloc[-1],
            "rmse"                : _rmse(y_te, preds),
            "mae"                 : mean_absolute_error(y_te, preds),
            "sharpe"              : np.mean(strat) / (np.std(strat) + 1e-9),
            "directional_accuracy": (np.sign(preds) == np.sign(y_te)).mean(),
            "avg_pnl"             : strat.mean(),
            "best_params"         : best
        })

    return pd.DataFrame(results)

# RUN
feature_cols, target_col = [], "target_return"

df_metrics_optuna = run_walkforward_step_9b_optuna(
    df_model     = df_model_ready,
    feature_cols = feature_cols,
    target_col   = target_col,
    window_size  = 60,
    test_size    = 5,
    step_size    = 5,
    n_trials     = 20,       # consider 10-15 if runtime is long
    gpu          = False,
)

print("Rows in df_metrics_optuna:", len(df_metrics_optuna))
if not df_metrics_optuna.empty:
    display(df_metrics_optuna.head())
```

```
INFO:root:Walk-forward: 879 fold(s) (60 train, 5 test, step 5)
Walk-forward: 100%                                                  879/879 [47:05<00:00,  3.41s/fold]
스트리밍 출력 내용이 길어서 마지막 5000줄이 삭제되었습니다.
[I 2025-05-31 02:36:30,856] Trial 18 finished with value: 0.00136487210857359 and parameters: {'n_estimators': 217, 'max_depth': 7, 'learning_rate': 0.1645881951949726, 'subsample': 0.800637550923414, 'colsample_bytree': 0.93879148
[I 2025-05-31 02:36:31,021] Trial 19 finished with value: 0.001425240363766766 and parameters: {'n_estimators': 280, 'max_depth': 5, 'learning_rate': 0.09494846565162779, 'subsample': 0.5795163259215439, 'colsample_bytree': 0.9910
[I 2025-05-31 02:36:31,178] A new study created in memory with name: no-name-34ef5c06-cd0e-4034-a0a6-b6ed6a5a5c4a
[I 2025-05-31 02:36:31,304] Trial 0 finished with value: 0.0011598331031812507 and parameters: {'n_estimators': 138, 'max_depth': 3, 'learning_rate': 0.1690518241479651, 'subsample': 0.9718646406572924, 'colsample_bytree': 0.992774
[I 2025-05-31 02:36:31,409] Trial 1 finished with value: 0.001118373591533767 and parameters: {'n_estimators': 188, 'max_depth': 4, 'learning_rate': 0.012171975908814588, 'subsample': 0.6691593072069075, 'colsample_bytree': 0.78703
[I 2025-05-31 02:36:31,500] Trial 2 finished with value: 0.0011635491256226842 and parameters: {'n_estimators': 149, 'max_depth': 5, 'learning_rate': 0.27648544514574075, 'subsample': 0.78142812067034, 'colsample_bytree': 0.6976510
[I 2025-05-31 02:36:31,594] Trial 3 finished with value: 0.0011106518697033805 and parameters: {'n_estimators': 158, 'max_depth': 4, 'learning_rate': 0.01993514148937617, 'subsample': 0.6246222990804517, 'colsample_bytree': 0.52460
[I 2025-05-31 02:36:31,756] Trial 4 finished with value: 0.0011547838068298912 and parameters: {'n_estimators': 237, 'max_depth': 3, 'learning_rate': 0.07804050591696998, 'subsample': 0.7186230796746486, 'colsample_bytree': 0.94166
[I 2025-05-31 02:36:31,837] Trial 5 finished with value: 0.0010382318551584676 and parameters: {'n_estimators': 110, 'max_depth': 8, 'learning_rate': 0.05528590213561829, 'subsample': 0.5211065980020451, 'colsample_bytree': 0.88494
[I 2025-05-31 02:36:31,956] Trial 6 finished with value: 0.0011804242285239413 and parameters: {'n_estimators': 220, 'max_depth': 8, 'learning_rate': 0.061583224921001586, 'subsample': 0.9232045451929287, 'colsample_bytree': 0.9078
[I 2025-05-31 02:36:32,063] Trial 7 finished with value: 0.0012075125985583422 and parameters: {'n_estimators': 195, 'max_depth': 6, 'learning_rate': 0.24874251140550424, 'subsample': 0.6360624235237358, 'colsample_bytree': 0.58431
[I 2025-05-31 02:36:32,204] Trial 8 finished with value: 0.0011618521926617057 and parameters: {'n_estimators': 300, 'max_depth': 8, 'learning_rate': 0.07344020976161475, 'subsample': 0.9336937274923103, 'colsample_bytree': 0.97342
[I 2025-05-31 02:36:32,318] Trial 9 finished with value: 0.00115168866741182 and parameters: {'n_estimators': 201, 'max_depth': 3, 'learning_rate': 0.17965446011412875, 'subsample': 0.9789036215380033, 'colsample_bytree': 0.9812112
[I 2025-05-31 02:36:32,401] Trial 10 finished with value: 0.0010824586985528205 and parameters: {'n_estimators': 60, 'max_depth': 7, 'learning_rate': 0.03148084316019519, 'subsample': 0.5065458428312457, 'colsample_bytree': 0.82757
[I 2025-05-31 02:36:32,484] Trial 11 finished with value: 0.0010834873116276407 and parameters: {'n_estimators': 58, 'max_depth': 7, 'learning_rate': 0.03089024309076983, 'subsample': 0.513971092478512, 'colsample_bytree': 0.821635
[I 2025-05-31 02:36:32,569] Trial 12 finished with value: 0.0010828632575498607 and parameters: {'n_estimators': 62, 'max_depth': 7, 'learning_rate': 0.03766625163075562, 'subsample': 0.5099649480517215, 'colsample_bytree': 0.84449
[I 2025-05-31 02:36:32,672] Trial 13 finished with value: 0.0011158407647684511 and parameters: {'n_estimators': 100, 'max_depth': 7, 'learning_rate': 0.032698780002406246, 'subsample': 0.5687993111447289, 'colsample_bytree': 0.872
[I 2025-05-31 02:36:32,791] Trial 14 finished with value: 0.0011534186035985937 and parameters: {'n_estimators': 103, 'max_depth': 8, 'learning_rate': 0.11442178897516789, 'subsample': 0.7920002569212785, 'colsample_bytree': 0.7056
[I 2025-05-31 02:36:32,894] Trial 15 finished with value: 0.0011059336688476523 and parameters: {'n_estimators': 102, 'max_depth': 6, 'learning_rate': 0.021080933053679165, 'subsample': 0.5694953953767856, 'colsample_bytree': 0.746
[I 2025-05-31 02:36:32,984] Trial 16 finished with value: 0.0011113759033502132 and parameters: {'n_estimators': 78, 'max_depth': 7, 'learning_rate': 0.04879521825847629, 'subsample': 0.5768770450152646, 'colsample_bytree': 0.89282
[I 2025-05-31 02:36:33,094] Trial 17 finished with value: 0.0011629902243123307 and parameters: {'n_estimators': 128, 'max_depth': 6, 'learning_rate': 0.012849995376720649, 'subsample': 0.8420519929584803, 'colsample_bytree': 0.645
[I 2025-05-31 02:36:33,188] Trial 18 finished with value: 0.0011376605582256972 and parameters: {'n_estimators': 81, 'max_depth': 8, 'learning_rate': 0.021490970798601135, 'subsample': 0.7048474855604248, 'colsample_bytree': 0.7879
[I 2025-05-31 02:36:33,292] Trial 19 finished with value: 0.0011051076860848373 and parameters: {'n_estimators': 118, 'max_depth': 7, 'learning_rate': 0.10747508616534873, 'subsample': 0.5001549406160555, 'colsample_bytree': 0.8308
[I 2025-05-31 02:36:33,388] A new study created in memory with name: no-name-cbeb1f33-ef1c-47bf-9ed0-2eff37392550
[I 2025-05-31 02:36:33,536] Trial 0 finished with value: 0.0012832808754339848 and parameters: {'n_estimators': 193, 'max_depth': 3, 'learning_rate': 0.04190201377167322, 'subsample': 0.6950019364738413, 'colsample_bytree': 0.87167
[I 2025-05-31 02:36:33,638] Trial 1 finished with value: 0.0012668432559214142 and parameters: {'n_estimators': 161, 'max_depth': 5, 'learning_rate': 0.10318193270643586, 'subsample': 0.784936627855275, 'colsample_bytree': 0.998692
[I 2025-05-31 02:36:33,814] Trial 2 finished with value: 0.0012090268466966731 and parameters: {'n_estimators': 288, 'max_depth': 5, 'learning_rate': 0.23204205981231987, 'subsample': 0.8400885423461217, 'colsample_bytree': 0.981395
[I 2025-05-31 02:36:33,962] Trial 3 finished with value: 0.0012312066170488767 and parameters: {'n_estimators': 291, 'max_depth': 8, 'learning_rate': 0.27591954762146337, 'subsample': 0.8525290616316825, 'colsample_bytree': 0.79557
[I 2025-05-31 02:36:34,054] Trial 4 finished with value: 0.001279011779856109 and parameters: {'n_estimators': 136, 'max_depth': 6, 'learning_rate': 0.018589336132270127, 'subsample': 0.7378420094791496, 'colsample_bytree': 0.62085
[I 2025-05-31 02:36:34,173] Trial 5 finished with value: 0.001390270343346671 and parameters: {'n_estimators': 213, 'max_depth': 5, 'learning_rate': 0.18571272133598782, 'subsample': 0.6359640644955028, 'colsample_bytree': 0.754314
[I 2025-05-31 02:36:34,276] Trial 6 finished with value: 0.0013403291241833783 and parameters: {'n_estimators': 171, 'max_depth': 6, 'learning_rate': 0.13093480818139927, 'subsample': 0.9199668829283116, 'colsample_bytree': 0.95466
[I 2025-05-31 02:36:34,375] Trial 7 finished with value: 0.0012401496632303034 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': 0.20436529556699476, 'subsample': 0.6966001497675969, 'colsample_bytree': 0.80752
[I 2025-05-31 02:36:34,467] Trial 8 finished with value: 0.0012853454871079423 and parameters: {'n_estimators': 139, 'max_depth': 3, 'learning_rate': 0.037438007423395855, 'subsample': 0.9357609254297361, 'colsample_bytree': 0.9572
[I 2025-05-31 02:36:34,593] Trial 9 finished with value: 0.0012030262246106927 and parameters: {'n_estimators': 244, 'max_depth': 6, 'learning_rate': 0.04866933202290359, 'subsample': 0.5828630131348518, 'colsample_bytree': 0.62933
[I 2025-05-31 02:36:34,677] Trial 10 finished with value: 0.0012942532911386605 and parameters: {'n_estimators': 57, 'max_depth': 7, 'learning_rate': 0.012938258160877382, 'subsample': 0.5055513572992297, 'colsample_bytree': 0.5008
[I 2025-05-31 02:36:34,876] Trial 11 finished with value: 0.0011906125313377977 and parameters: {'n_estimators': 299, 'max_depth': 4, 'learning_rate': 0.07087521824654211, 'subsample': 0.5492728337426263, 'colsample_bytree': 0.6441
[I 2025-05-31 02:36:35,019] Trial 12 finished with value: 0.0012100635671567826 and parameters: {'n_estimators': 234, 'max_depth': 4, 'learning_rate': 0.07188879313953626, 'subsample': 0.5341320692621199, 'colsample_bytree': 0.6526
[I 2025-05-31 02:36:35,169] Trial 13 finished with value: 0.0012336399821768365 and parameters: {'n_estimators': 257, 'max_depth': 4, 'learning_rate': 0.025161739361363355, 'subsample': 0.5858708572018377, 'colsample_bytree': 0.637
[I 2025-05-31 02:36:35,316] Trial 14 finished with value: 0.0011918457905615552 and parameters: {'n_estimators': 247, 'max_depth': 4, 'learning_rate': 0.06178980890120488, 'subsample': 0.6025903867427824, 'colsample_bytree': 0.5440
[I 2025-05-31 02:36:35,486] Trial 15 finished with value: 0.0012022855276080473 and parameters: {'n_estimators': 299, 'max_depth': 4, 'learning_rate': 0.07513744546314473, 'subsample': 0.626660215072188, 'colsample_bytree': 0.51516
[I 2025-05-31 02:36:35,636] Trial 16 finished with value: 0.0013289906442452745 and parameters: {'n_estimators': 267, 'max_depth': 3, 'learning_rate': 0.11477303173300218, 'subsample': 0.5654194590101133, 'colsample_bytree': 0.5783
[I 2025-05-31 02:36:35,778] Trial 17 finished with value: 0.0013028535237523153 and parameters: {'n_estimators': 214, 'max_depth': 4, 'learning_rate': 0.02772112147079569, 'subsample': 0.6510727013856534, 'colsample_bytree': 0.7107
[I 2025-05-31 02:36:35,953] Trial 18 finished with value: 0.0013579868850103337 and parameters: {'n_estimators': 268, 'max_depth': 4, 'learning_rate': 0.06817489193593365, 'subsample': 0.5023478898612586, 'colsample_bytree': 0.5548
[I 2025-05-31 02:36:36,053] Trial 19 finished with value: 0.0013047848357106337 and parameters: {'n_estimators': 92, 'max_depth': 3, 'learning_rate': 0.15114869682195875, 'subsample': 0.9852832792983306, 'colsample_bytree': 0.69427
[I 2025-05-31 02:36:36,202] A new study created in memory with name: no-name-5d301829-5ed5-4284-a16c-aa52984cb164
[I 2025-05-31 02:36:36,306] Trial 0 finished with value: 0.0014821890842784111 and parameters: {'n_estimators': 96, 'max_depth': 7, 'learning_rate': 0.013054695405872115, 'subsample': 0.9508445491017847, 'colsample_bytree': 0.98520
[I 2025-05-31 02:36:36,426] Trial 1 finished with value: 0.00153489104331684 and parameters: {'n_estimators': 210, 'max_depth': 8, 'learning_rate': 0.03744756783955671, 'subsample': 0.8078335860047339, 'colsample_bytree': 0.8989905
[I 2025-05-31 02:36:36,494] Trial 2 finished with value: 0.0014954821654165928 and parameters: {'n_estimators': 51, 'max_depth': 6, 'learning_rate': 0.026153485562234357, 'subsample': 0.840809200224673, 'colsample_bytree': 0.730768
[I 2025-05-31 02:36:36,566] Trial 3 finished with value: 0.0015033886414548892 and parameters: {'n_estimators': 78, 'max_depth': 6, 'learning_rate': 0.018599853435419582, 'subsample': 0.7217839963394549, 'colsample_bytree': 0.80914
[I 2025-05-31 02:36:36,688] Trial 4 finished with value: 0.0014903774327122742 and parameters: {'n_estimators': 215, 'max_depth': 4, 'learning_rate': 0.01506939031917235, 'subsample': 0.9732992121993307, 'colsample_bytree': 0.99463
[I 2025-05-31 02:36:36,828] Trial 5 finished with value: 0.0015023590909273533 and parameters: {'n_estimators': 297, 'max_depth': 8, 'learning_rate': 0.02830965659231153, 'subsample': 0.7941250904172223, 'colsample_bytree': 0.54489
[I 2025-05-31 02:36:36,929] Trial 6 finished with value: 0.0014719971445901646 and parameters: {'n_estimators': 77, 'max_depth': 3, 'learning_rate': 0.09326378512943657, 'subsample': 0.9650027847066266, 'colsample_bytree': 0.875911
[I 2025-05-31 02:36:37,059] Trial 7 finished with value: 0.0015945551540416539 and parameters: {'n_estimators': 251, 'max_depth': 8, 'learning_rate': 0.06415419025160625, 'subsample': 0.5468314761511489, 'colsample_bytree': 0.64660
[I 2025-05-31 02:36:37,197] Trial 8 finished with value: 0.001438757470917062 and parameters: {'n_estimators': 290, 'max_depth': 6, 'learning_rate': 0.1211485560243811, 'subsample': 0.6752477485585398, 'colsample_bytree': 0.7413446
[I 2025-05-31 02:36:37,314] Trial 9 finished with value: 0.0015827374062378247 and parameters: {'n_estimators': 214, 'max_depth': 4, 'learning_rate': 0.012322634776098627, 'subsample': 0.6022631173865203, 'colsample_bytree': 0.6913
[I 2025-05-31 02:36:37,430] Trial 10 finished with value: 0.0015512849666797588 and parameters: {'n_estimators': 151, 'max_depth': 5, 'learning_rate': 0.26963551196181684, 'subsample': 0.6690951707927401, 'colsample_bytree': 0.5765
[I 2025-05-31 02:36:37,541] Trial 11 finished with value: 0.0014913652574030014 and parameters: {'n_estimators': 135, 'max_depth': 3, 'learning_rate': 0.10517491409340825, 'subsample': 0.882213309917208, 'colsample_bytree': 0.83060
[I 2025-05-31 02:36:37,697] Trial 12 finished with value: 0.0015702667797915745 and parameters: {'n_estimators': 273, 'max_depth': 3, 'learning_rate': 0.13442345158245103, 'subsample': 0.6501381692411033, 'colsample_bytree': 0.8388
[I 2025-05-31 02:36:37,808] Trial 13 finished with value: 0.0016983423103515865 and parameters: {'n_estimators': 116, 'max_depth': 5, 'learning_rate': 0.16877833130690245, 'subsample': 0.5009803643432063, 'colsample_bytree': 0.9042
[I 2025-05-31 02:36:37,975] Trial 14 finished with value: 0.0015678930651116861 and parameters: {'n_estimators': 177, 'max_depth': 7, 'learning_rate': 0.05325545527584146, 'subsample': 0.7203685984941228, 'colsample_bytree': 0.7766
[I 2025-05-31 02:36:38,098] Trial 15 finished with value: 0.0015568343147785945 and parameters: {'n_estimators': 177, 'max_depth': 4, 'learning_rate': 0.08169410822838093, 'subsample': 0.8647841069132953, 'colsample_bytree': 0.6384
[I 2025-05-31 02:36:38,248] Trial 16 finished with value: 0.001511202781103593 and parameters: {'n_estimators': 250, 'max_depth': 6, 'learning_rate': 0.1987814440622146, 'subsample': 0.9034504361121404, 'colsample_bytree': 0.909309
[I 2025-05-31 02:36:38,419] Trial 17 finished with value: 0.001489120088792849 and parameters: {'n_estimators': 300, 'max_depth': 5, 'learning_rate': 0.09364478138500176, 'subsample': 0.7645915487730328, 'colsample_bytree': 0.72951
[I 2025-05-31 02:36:38,504] Trial 18 finished with value: 0.0014894489538249157 and parameters: {'n_estimators': 56, 'max_depth': 7, 'learning_rate': 0.04738698196524752, 'subsample': 0.659531385060468, 'colsample_bytree': 0.504509
[I 2025-05-31 02:36:38,619] Trial 19 finished with value: 0.0014808679909548194 and parameters: {'n_estimators': 149, 'max_depth': 3, 'learning_rate': 0.13190378801110866, 'subsample': 0.9941937115609233, 'colsample_bytree': 0.8656
[I 2025-05-31 02:36:38,766] A new study created in memory with name: no-name-de40d746-9b25-4dcd-ac8d-2553040762f5
[I 2025-05-31 02:36:38,931] Trial 0 finished with value: 0.0021086092926833723 and parameters: {'n_estimators': 250, 'max_depth': 8, 'learning_rate': 0.0995231923646766, 'subsample': 0.7669299603463955, 'colsample_bytree': 0.644782
[I 2025-05-31 02:36:39,047] Trial 1 finished with value: 0.0020892176756284924 and parameters: {'n_estimators': 101, 'max_depth': 8, 'learning_rate': 0.19245164269146806, 'subsample': 0.6388946235754476, 'colsample_bytree': 0.58208
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[I 2025-05-31 02:36:51,521] Trial 5 finished with value: 0.0012559606049765064 and parameters: {'n_estimators': 223, 'max_depth': 8, 'learning_rate': 0.06510944637550366, 'subsample': 0.7438284774428512, 'colsample_bytree': 0.63114
[I 2025-05-31 02:36:51,653] Trial 6 finished with value: 0.0011568248048078882 and parameters: {'n_estimators': 274, 'max_depth': 6, 'learning_rate': 0.2540295660411333, 'subsample': 0.508979444253918, 'colsample_bytree': 0.5983228
[I 2025-05-31 02:36:51,754] Trial 7 finished with value: 0.0012788650715462658 and parameters: {'n_estimators': 158, 'max_depth': 6, 'learning_rate': 0.010685514408674886, 'subsample': 0.931960987195068, 'colsample_bytree': 0.91378
[I 2025-05-31 02:36:51,896] Trial 8 finished with value: 0.0012792316869636156 and parameters: {'n_estimators': 295, 'max_depth': 6, 'learning_rate': 0.023870497027994975, 'subsample': 0.8946139419431975, 'colsample_bytree': 0.5626
[I 2025-05-31 02:36:51,988] Trial 9 finished with value: 0.0012496017639865029 and parameters: {'n_estimators': 144, 'max_depth': 6, 'learning_rate': 0.010216542822441353, 'subsample': 0.6056826546397658, 'colsample_bytree': 0.7245
[I 2025-05-31 02:36:52,089] Trial 10 finished with value: 0.0010544491923123274 and parameters: {'n_estimators': 57, 'max_depth': 3, 'learning_rate': 0.2928527421434159, 'subsample': 0.646164502274061, 'colsample_bytree': 0.6505230
[I 2025-05-31 02:36:52,200] Trial 11 finished with value: 0.0012567234715012224 and parameters: {'n_estimators': 51, 'max_depth': 3, 'learning_rate': 0.2758596517315392, 'subsample': 0.6102094240185598, 'colsample_bytree': 0.668416
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[I 2025-05-31 02:36:53,664] Trial 15 finished with value: 0.0012708680751715316 and parameters: {'n_estimators': 86, 'max_depth': 5, 'learning_rate': 0.15500895117934754, 'subsample': 0.5644053211429341, 'colsample_bytree': 0.81090
[I 2025-05-31 02:36:54,190] Trial 16 finished with value: 0.0012518093898110003 and parameters: {'n_estimators': 191, 'max_depth': 7, 'learning_rate': 0.10590100605639348, 'subsample': 0.5802424569169387, 'colsample_bytree': 0.6099
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[I 2025-05-31 02:36:54,996] Trial 19 finished with value: 0.0012568949084282761 and parameters: {'n_estimators': 216, 'max_depth': 3, 'learning_rate': 0.09279258988414744, 'subsample': 0.7090617667224484, 'colsample_bytree': 0.5637
[I 2025-05-31 02:36:55,068] A new study created in memory with name: no-name-f087f0ae-3ba5-4f19-8e04-771fb5d59daa
[I 2025-05-31 02:36:55,224] Trial 0 finished with value: 0.005565477921971474 and parameters: {'n_estimators': 255, 'max_depth': 8, 'learning_rate': 0.23981147109194315, 'subsample': 0.5933950062578914, 'colsample_bytree': 0.993347
[I 2025-05-31 02:36:55,287] Trial 1 finished with value: 0.005481505962727009 and parameters: {'n_estimators': 52, 'max_depth': 8, 'learning_rate': 0.03527224445661746, 'subsample': 0.8481838875651577, 'colsample_bytree': 0.8180244
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[I 2025-05-31 02:36:55,947] Trial 7 finished with value: 0.005503946686153232 and parameters: {'n_estimators': 70, 'max_depth': 4, 'learning_rate': 0.18313391446293997, 'subsample': 0.8741621580140002, 'colsample_bytree': 0.9185614
[I 2025-05-31 02:36:56,024] Trial 8 finished with value: 0.005521328612659454 and parameters: {'n_estimators': 86, 'max_depth': 8, 'learning_rate': 0.10948604783004248, 'subsample': 0.517389391554971, 'colsample_bytree': 0.92518812
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[I 2025-05-31 02:36:56,472] Trial 12 finished with value: 0.0054834278776449774 and parameters: {'n_estimators': 54, 'max_depth': 5, 'learning_rate': 0.010427129378693209, 'subsample': 0.9926615854266727, 'colsample_bytree': 0.7602
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[I 2025-05-31 02:36:56,724] Trial 14 finished with value: 0.005485001643075066 and parameters: {'n_estimators': 204, 'max_depth': 7, 'learning_rate': 0.033137724424623115, 'subsample': 0.7438203817233918, 'colsample_bytree': 0.8345
[I 2025-05-31 02:36:56,826] Trial 15 finished with value: 0.005487065818955481 and parameters: {'n_estimators': 97, 'max_depth': 5, 'learning_rate': 0.016799828820865104, 'subsample': 0.9302022448171399, 'colsample_bytree': 0.65107
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[I 2025-05-31 02:36:57,447] A new study created in memory with name: no-name-75fd53cb-285a-4ce0-83ad-20f649aa8062
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[I 2025-05-31 02:36:57,734] Trial 1 finished with value: 0.0017807686323972444 and parameters: {'n_estimators': 170, 'max_depth': 4, 'learning_rate': 0.2527547723098834, 'subsample': 0.8049087194989226, 'colsample_bytree': 0.766768
[I 2025-05-31 02:36:57,826] Trial 2 finished with value: 0.0017820201719864065 and parameters: {'n_estimators': 138, 'max_depth': 4, 'learning_rate': 0.06876245657552263, 'subsample': 0.7436266650743315, 'colsample_bytree': 0.77508
[I 2025-05-31 02:36:57,963] Trial 3 finished with value: 0.0018240701757270706 and parameters: {'n_estimators': 271, 'max_depth': 6, 'learning_rate': 0.07506554557434672, 'subsample': 0.677702891551117, 'colsample_bytree': 0.575016
[I 2025-05-31 02:36:58,116] Trial 4 finished with value: 0.0018217221182624456 and parameters: {'n_estimators': 295, 'max_depth': 5, 'learning_rate': 0.24122910010292611, 'subsample': 0.6120144155678509, 'colsample_bytree': 0.88243
[I 2025-05-31 02:36:58,236] Trial 5 finished with value: 0.0017850652684709507 and parameters: {'n_estimators': 219, 'max_depth': 5, 'learning_rate': 0.08916288502612772, 'subsample': 0.8786522872440026, 'colsample_bytree': 0.84097
[I 2025-05-31 02:36:58,369] Trial 6 finished with value: 0.0017732038447331882 and parameters: {'n_estimators': 267, 'max_depth': 8, 'learning_rate': 0.01158935657788451, 'subsample': 0.5946614058109773, 'colsample_bytree': 0.61351
[I 2025-05-31 02:36:58,490] Trial 7 finished with value: 0.0017879012795088156 and parameters: {'n_estimators': 227, 'max_depth': 4, 'learning_rate': 0.011412699570316444, 'subsample': 0.8053870274540708, 'colsample_bytree': 0.9893
[I 2025-05-31 02:36:58,626] Trial 8 finished with value: 0.0018266417806412462 and parameters: {'n_estimators': 266, 'max_depth': 7, 'learning_rate': 0.21309135052696865, 'subsample': 0.973640900305436, 'colsample_bytree': 0.856529
[I 2025-05-31 02:36:58,797] Trial 9 finished with value: 0.001777539339820381 and parameters: {'n_estimators': 270, 'max_depth': 6, 'learning_rate': 0.01267337679688047, 'subsample': 0.6653125436133337, 'colsample_bytree': 0.969771
[I 2025-05-31 02:36:58,893] Trial 10 finished with value: 0.0017836439839783503 and parameters: {'n_estimators': 63, 'max_depth': 3, 'learning_rate': 0.028194185290369093, 'subsample': 0.5057588292459242, 'colsample_bytree': 0.6666
[I 2025-05-31 02:36:59,029] Trial 11 finished with value: 0.0017547457123430186 and parameters: {'n_estimators': 208, 'max_depth': 8, 'learning_rate': 0.0238570785044701, 'subsample': 0.5325251231207624, 'colsample_bytree': 0.51174
[I 2025-05-31 02:36:59,158] Trial 12 finished with value: 0.0017589847901763125 and parameters: {'n_estimators': 208, 'max_depth': 8, 'learning_rate': 0.0271056409225305, 'subsample': 0.5381489902256699, 'colsample_bytree': 0.51632
[I 2025-05-31 02:36:59,290] Trial 13 finished with value: 0.0017574711437581027 and parameters: {'n_estimators': 194, 'max_depth': 8, 'learning_rate': 0.030324731641793647, 'subsample': 0.5198314145166618, 'colsample_bytree': 0.506
[I 2025-05-31 02:36:59,407] Trial 14 finished with value: 0.0017528460666620376 and parameters: {'n_estimators': 158, 'max_depth': 7, 'learning_rate': 0.036275615145547724, 'subsample': 0.5657918609036694, 'colsample_bytree': 0.670
[I 2025-05-31 02:36:59,515] Trial 15 finished with value: 0.0018032071674104234 and parameters: {'n_estimators': 130, 'max_depth': 7, 'learning_rate': 0.04597939231530547, 'subsample': 0.580298702014183, 'colsample_bytree': 0.68625
[I 2025-05-31 02:36:59,639] Trial 16 finished with value: 0.00178040934465159 6 and parameters: {'n_estimators': 160, 'max_depth': 7, 'learning_rate': 0.046951924965649386, 'subsample': 0.7238885952885359, 'colsample_bytree': 0.6918
[I 2025-05-31 02:36:59,757] Trial 17 finished with value: 0.0017635622471276172 and parameters: {'n_estimators': 97, 'max_depth': 7, 'learning_rate': 0.13180605165453937, 'subsample': 0.5694558601928653, 'colsample_bytree': 0.63162
[I 2025-05-31 02:36:59,860] Trial 18 finished with value: 0.0017650159606200926 and parameters: {'n_estimators': 112, 'max_depth': 8, 'learning_rate': 0.02103458588696558, 'subsample': 0.6319679347196178, 'colsample_bytree': 0.5746
[I 2025-05-31 02:36:59,988] Trial 19 finished with value: 0.00175202462404620 2 and parameters: {'n_estimators': 186, 'max_depth': 6, 'learning_rate': 0.018207394071511382, 'subsample': 0.5578848308300126, 'colsample_bytree': 0.5682
[I 2025-05-31 02:37:00,102] A new study created in memory with name: no-name-eb0b99a4-5674-4e59-b8c6-62d686429e18
[I 2025-05-31 02:37:00,195] Trial 0 finished with value: 0.0015725258697761072 and parameters: {'n_estimators': 51, 'max_depth': 5, 'learning_rate': 0.05223527815997326, 'subsample': 0.549851979693361, 'colsample_bytree': 0.7859319
[I 2025-05-31 02:37:00,274] Trial 1 finished with value: 0.0015769448581155969 and parameters: {'n_estimators': 88, 'max_depth': 8, 'learning_rate': 0.05105586991284825, 'subsample': 0.8197276544779741, 'colsample_bytree': 0.768603
[I 2025-05-31 02:37:00,406] Trial 2 finished with value: 0.0015718751411215556 and parameters: {'n_estimators': 260, 'max_depth': 4, 'learning_rate': 0.020283820252110576, 'subsample': 0.8442238012331768, 'colsample_bytree': 0.9933
[I 2025-05-31 02:37:00,518] Trial 3 finished with value: 0.001572151646934307 and parameters: {'n_estimators': 193, 'max_depth': 7, 'learning_rate': 0.014625438098147113, 'subsample': 0.801756016262020 8, 'colsample_bytree': 0.95279
[I 2025-05-31 02:37:00,646] Trial 4 finished with value: 0.0015834217106061527 and parameters: {'n_estimators': 241, 'max_depth': 6, 'learning_rate': 0.1359643904300782, 'subsample': 0.9084641552226858, 'colsample_bytree': 0.730253
[I 2025-05-31 02:37:00,715] Trial 5 finished with value: 0.0015725228206092943 and parameters: {'n_estimators': 63, 'max_depth': 8, 'learning_rate': 0.01631373066734949, 'subsample': 0.7699165017927821, 'colsample_bytree': 0.954411
[I 2025-05-31 02:37:00,867] Trial 6 finished with value: 0.0015774259609678408 and parameters: {'n_estimators': 230, 'max_depth': 7, 'learning_rate': 0.048676037119446874, 'subsample': 0.9193611793187518, 'colsample_bytree': 0.6039
[I 2025-05-31 02:37:00,958] Trial 7 finished with value: 0.0015722819858670373 and parameters: {'n_estimators': 112, 'max_depth': 8, 'learning_rate': 0.05903815594278138, 'subsample': 0.8750630780437763, 'colsample_bytree': 0.68291
[I 2025-05-31 02:37:01,083] Trial 8 finished with value: 0.0015808112197008603 and parameters: {'n_estimators': 218, 'max_depth': 7, 'learning_rate': 0.11781279846524426, 'subsample': 0.9619775929059635, 'colsample_bytree': 0.95102
[I 2025-05-31 02:37:01,229] Trial 9 finished with value: 0.0015734170052568567 and parameters: {'n_estimators': 299, 'max_depth': 4, 'learning_rate': 0.11133789591623384, 'subsample': 0.5962805586050568, 'colsample_bytree': 0.92524
[I 2025-05-31 02:37:01,386] Trial 10 finished with value: 0.0015779281549023001 and parameters: {'n_estimators': 281, 'max_depth': 3, 'learning_rate': 0.026105384374130035, 'subsample': 0.6521214335250174, 'colsample_bytree': 0.847
[I 2025-05-31 02:37:01,508] Trial 11 finished with value: 0.0015626546843690128 and parameters: {'n_estimators': 163, 'max_depth': 5, 'learning_rate': 0.010817833275112385, 'subsample': 0.6808316875700845, 'colsample_bytree': 0.981
[I 2025-05-31 02:37:01,625] Trial 12 finished with value: 0.0015621728096500223 and parameters: {'n_estimators': 144, 'max_depth': 4, 'learning_rate': 0.01204151116159036, 'subsample': 0.680710854700834, 'colsample_bytree': 0.86361
[I 2025-05-31 02:37:01,741] Trial 13 finished with value: 0.0015630966634473718 and parameters: {'n_estimators': 143, 'max_depth': 5, 'learning_rate': 0.010827821102852056, 'subsample': 0.6799512186490905, 'colsample_bytree': 0.863
[I 2025-05-31 02:37:01,895] Trial 14 finished with value: 0.0015644927865 00796 and parameters: {'n_estimators': 154, 'max_depth': 3, 'learning_rate': 0.010276609904723368, 'subsample': 0.7180542291234056, 'colsample_bytree': 0.8652
[I 2025-05-31 02:37:02,023] Trial 15 finished with value: 0.0015710014492020168 and parameters: {'n_estimators': 179, 'max_depth': 4, 'learning_rate': 0.029290135951544425, 'subsample': 0.6170682192114079, 'colsample_bytree': 0.557
[I 2025-05-31 02:37:02,136] Trial 16 finished with value: 0.0015571394138091707 and parameters: {'n_estimators': 136, 'max_depth': 5, 'learning_rate': 0.20043478904573028, 'subsample': 0.5150823917392107, 'colsample_bytree': 0.8881
[I 2025-05-31 02:37:02,242] Trial 17 finished with value: 0.001540891002886465 and parameters: {'n_estimators': 119, 'max_depth': 6, 'learning_rate': 0.2771317805516932, 'subsample': 0.5364034443376509, 'colsample_bytree': 0.815078
[I 2025-05-31 02:37:02,350] Trial 18 finished with value: 0.0015547820199274167 and parameters: {'n_estimators': 116, 'max_depth': 6, 'learning_rate': 0.29614582892634184, 'subsample': 0.5014730544744881, 'colsample_bytree': 0.6854
[I 2025-05-31 02:37:02,451] Trial 19 finished with value: 0.0015481670428594836 and parameters: {'n_estimators': 98, 'max_depth': 6, 'learning_rate': 0.2988426414800953, 'subsample': 0.5193586708373773, 'colsample_bytree': 0.654557
[I 2025-05-31 02:37:02,554] A new study created in memory with name: no-name-6eef00a2-2c76-4813-9c1d-2be323e4d178
[I 2025-05-31 02:37:02,675] Trial 0 finished with value: 0.0023010072691589376 and parameters: {'n_estimators': 136, 'max_depth': 4, 'learning_rate': 0.07767413853368431, 'subsample': 0.600167174834171, 'colsample_bytree': 0.650751
[I 2025-05-31 02:37:02,763] Trial 1 finished with value: 0.0023044663993015456 and parameters: {'n_estimators': 124, 'max_depth': 5, 'learning_rate': 0.018676973381108082, 'subsample': 0.67724228062722, 'colsample_bytree': 0.579240
[I 2025-05-31 02:37:02,920] Trial 2 finished with value: 0.0023095907036415507 and parameters: {'n_estimators': 235, 'max_depth': 3, 'learning_rate': 0.17018462897982597, 'subsample': 0.7245050076810875, 'colsample_bytree': 0.64495
[I 2025-05-31 02:37:03,020] Trial 3 finished with value: 0.00230742258268895 7 and parameters: {'n_estimators': 163, 'max_depth': 8, 'learning_rate': 0.03515309835400101, 'subsample': 0.8673918944563956, 'colsample_bytree': 0.947199
[I 2025-05-31 02:37:03,109] Trial 4 finished with value: 0.0023042152948489682 and parameters: {'n_estimators': 145, 'max_depth': 7, 'learning_rate': 0.01392943776355719, 'subsample': 0.7385347162955456, 'colsample_bytree': 0.51338
[I 2025-05-31 02:37:03,172] Trial 5 finished with value: 0.002310794574784725 and parameters: {'n_estimators': 60, 'max_depth': 8, 'learning_rate': 0.11390706233307353, 'subsample': 0.9611356204161581, 'colsample_bytree': 0.7049243
[I 2025-05-31 02:37:03,268] Trial 6 finished with value: 0.0023064956918826 and parameters: {'n_estimators': 160, 'max_depth': 4, 'learning_rate': 0.2560323590977009, 'subsample': 0.82845123508335 6, 'colsample_bytree': 0.5494658278
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[I 2025-05-31 02:37:27,197] Trial 12 finished with value: 0.001928306668732140 34 and parameters: {'n_estimators': 209, 'max_depth': 6, 'learning_rate': 0.28861689690242004, 'subsample': 0.5076487176965525, 'colsample_bytree': 0.9884
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[I 2025-05-31 02:37:27,460] Trial 14 finished with value: 0.0019061074976000857 and parameters: {'n_estimators': 200, 'max_depth': 4, 'learning_rate': 0.2946515104106616, 'subsample': 0.5603301455658793, 'colsample_bytree': 0.926001
[I 2025-05-31 02:37:27,620] Trial 15 finished with value: 0.001993147826090667 and parameters: {'n_estimators': 286, 'max_depth': 4, 'learning_rate': 0.08070053495742174, 'subsample': 0.5736547838772652, 'colsample_bytree': 0.90929
[I 2025-05-31 02:37:27,751] Trial 16 finished with value: 0.001960449669498085 and parameters: {'n_estimators': 181, 'max_depth': 4, 'learning_rate': 0.20137235680340873, 'subsample': 0.8017273880143413, 'colsample_bytree': 0.9293
[I 2025-05-31 02:37:27,898] Trial 17 finished with value: 0.0019728269815724757 and parameters: {'n_estimators': 240, 'max_depth': 4, 'learning_rate': 0.028379954883241174, 'subsample': 0.5780809270512399, 'colsample_bytree': 0.663
[I 2025-05-31 02:37:28,026] Trial 18 finished with value: 0.0019465075765472565 and parameters: {'n_estimators': 177, 'max_depth': 5, 'learning_rate': 0.10567013704102465, 'subsample': 0.7655351986471489, 'colsample_bytree': 0.9406
[I 2025-05-31 02:37:28,170] Trial 19 finished with value: 0.0019788463957019 42 and parameters: {'n_estimators': 231, 'max_depth': 7, 'learning_rate': 0.19773620116785445, 'subsample': 0.6656335265887602, 'colsample_bytree': 0.85697
[I 2025-05-31 02:37:28,301] A new study created in memory with name: no-name-8f77cb00-10bf-4019-a8bc-c411da0e599c
[I 2025-05-31 02:37:28,420] Trial 0 finished with value: 0.0010681298620657104 and parameters: {'n_estimators': 145, 'max_depth': 7, 'learning_rate': 0.11580365788018439, 'subsample': 0.9009938696843541, 'colsample_bytree': 0.74735
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[I 2025-05-31 02:37:28,725] Trial 3 finished with value: 0.0010665005480667092 and parameters: {'n_estimators': 237, 'max_depth': 8, 'learning_rate': 0.01853102384292869, 'subsample': 0.8915936436445765, 'colsample_bytree': 0.8282991
[I 2025-05-31 02:37:28,852] Trial 4 finished with value: 0.0010736985475956772 and parameters: {'n_estimators': 152, 'max_depth': 6, 'learning_rate': 0.14113066098330498, 'subsample': 0.8585442265540627, 'colsample_bytree': 0.63506
[I 2025-05-31 02:37:28,996] Trial 5 finished with value: 0.0011201257980358744 and parameters: {'n_estimators': 294, 'max_depth': 7, 'learning_rate': 0.025100582255890142, 'subsample': 0.5773006855938314, 'colsample_bytree': 0.7869
[I 2025-05-31 02:37:29,110] Trial 6 finished with value: 0.0011684982855346933 and parameters: {'n_estimators': 196, 'max_depth': 6, 'learning_rate': 0.026839992163848466, 'subsample': 0.5262362809261606, 'colsample_bytree': 0.9374
[I 2025-05-31 02:37:29,179] Trial 7 finished with value: 0.0010575060191334348 and parameters: {'n_estimators': 69, 'max_depth': 7, 'learning_rate': 0.019127754141381452, 'subsample': 0.9381991756646226, 'colsample_bytree': 0.74262
[I 2025-05-31 02:37:29,285] Trial 8 finished with value: 0.0010450866332846 87 and parameters: {'n_estimators': 176, 'max_depth': 3, 'learning_rate': 0.20774504880037528, 'subsample': 0.9499738104180414, 'colsample_bytree': 0.546032
[I 2025-05-31 02:37:29,374] Trial 9 finished with value: 0.0010914259503950045 and parameters: {'n_estimators': 112, 'max_depth': 3, 'learning_rate': 0.0660197531155391, 'subsample': 0.8727153717390332, 'colsample_bytree': 0.974332
[I 2025-05-31 02:37:29,511] Trial 10 finished with value: 0.0010894719564229413 and parameters: {'n_estimators': 217, 'max_depth': 4, 'learning_rate': 0.2683469501227589, 'subsample': 0.7289347876388961, 'colsample_bytree': 0.50027
[I 2025-05-31 02:37:29,596] Trial 11 finished with value: 0.0010558699907023 03 and parameters: {'n_estimators': 55, 'max_depth': 5, 'learning_rate': 0.04127804398471451, 'subsample': 0.7804623912015876, 'colsample_bytree': 0.513255
[I 2025-05-31 02:37:29,681] Trial 12 finished with value: 0.0010689243628092344 and parameters: {'n_estimators': 53, 'max_depth': 3, 'learning_rate': 0.042205168323122995, 'subsample': 0.7567667119078151, 'colsample_bytree': 0.5009
[I 2025-05-31 02:37:29,834] Trial 13 finished with value: 0.0010254193665340256 and parameters: {'n_estimators': 254, 'max_depth': 5, 'learning_rate': 0.2592566975707844, 'subsample': 0.7654077820746106, 'colsample_bytree': 0.59431
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[I 2025-05-31 02:37:30,138] Trial 15 finished with value: 0.0010522202356094655 and parameters: {'n_estimators': 246, 'max_depth': 5, 'learning_rate': 0.16454044240930896, 'subsample': 0.995252706839 5007, 'colsample_bytree': 0.5845
[I 2025-05-31 02:37:30,274] Trial 16 finished with value: 0.0010766840898485561 and parameters: {'n_estimators': 195, 'max_depth': 3, 'learning_rate': 0.01055929982454032, 'subsample': 0.8001587734894899, 'colsample_bytree': 0.68147
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[I 2025-05-31 02:37:30,751] Trial 19 finished with value: 0.0010677098222019866 and parameters: {'n_estimators': 266, 'max_depth': 6, 'learning_rate': 0.19583836528108353, 'subsample': 0.6421074210525826, 'colsample_bytree': 0.6816
[I 2025-05-31 02:37:30,925] A new study created in memory with name: no-name-cfbc458a-b4ec-40be-b273-ecda46dc332a
[I 2025-05-31 02:37:31,093] Trial 0 finished with value: 0.0006621342250839926 and parameters: {'n_estimators': 285, 'max_depth': 5, 'learning_rate': 0.037356209017992345, 'subsample': 0.5662387375445505, 'colsample_bytree': 0.7070
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[I 2025-05-31 02:37:31,538] Trial 3 finished with value: 0.0006586345160139022 and parameters: {'n_estimators': 156, 'max_depth': 4, 'learning_rate': 0.07973966274125077, 'subsample': 0.5459856566709186, 'colsample_bytree': 0.58895
[I 2025-05-31 02:37:32,331] Trial 4 finished with value: 0.0006586449668596026 and parameters: {'n_estimators': 214, 'max_depth': 5, 'learning_rate': 0.035822053015816466, 'subsample': 0.5233458733299278, 'colsample_bytree': 0.8408
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[I 2025-05-31 02:37:32,721] Trial 6 finished with value: 0.0006592620859817436 and parameters: {'n_estimators': 187, 'max_depth': 3, 'learning_rate': 0.01372893921358442, 'subsample': 0.6191051722594937, 'colsample_bytree': 0.89788
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[I 2025-05-31 02:37:33,968] Trial 9 finished with value: 0.0006591032545270374 and parameters: {'n_estimators': 174, 'max_depth': 3, 'learning_rate': 0.14617104992677712, 'subsample': 0.9528125526493938, 'colsample_bytree': 0.71253
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[I 2025-05-31 02:37:34,353] Trial 11 finished with value: 0.0006586468222815838 and parameters: {'n_estimators': 131, 'max_depth': 7, 'learning_rate': 0.023211343424494737, 'subsample': 0.5120422013514943, 'colsample_bytree': 0.833
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[I 2025-05-31 02:37:34,579] Trial 13 finished with value: 0.0006625293330835 4 and parameters: {'n_estimators': 82, 'max_depth': 4, 'learning_rate': 0.05531337296651582, 'subsample': 0.5037871131908217, 'colsample_bytree': 0.8151640
[I 2025-05-31 02:37:34,727] Trial 14 finished with value: 0.0006603720445744576 and parameters: {'n_estimators': 232, 'max_depth': 4, 'learning_rate': 0.16691217594402707, 'subsample': 0.6575854498786177, 'colsample_bytree': 0.6380
[I 2025-05-31 02:37:34,867] Trial 15 finished with value: 0.0006598430603456884 and parameters: {'n_estimators': 171, 'max_depth': 6, 'learning_rate': 0.0218135519497615, 'subsample': 0.774657833724743, 'colsample_bytree': 0.810141
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[I 2025-05-31 02:37:35,245] Trial 18 finished with value: 0.0006598927825228378 and parameters: {'n_estimators': 152, 'max_depth': 5, 'learning_rate': 0.11424782334005779, 'subsample': 0.6958548705856411, 'colsample_bytree': 0.7717
[I 2025-05-31 02:37:35,401] Trial 19 finished with value: 0.0006588495430005454 and parameters: {'n_estimators': 258, 'max_depth': 4, 'learning_rate': 0.21064405898602603, 'subsample': 0.6400189933487019, 'colsample_bytree': 0.9937
[I 2025-05-31 02:37:35,505] A new study created in memory with name: no-name-2e809a95-1508-44b9-a373-48b1504baa4f
[I 2025-05-31 02:37:35,647] Trial 0 finished with value: 0.0016482531373673533 and parameters: {'n_estimators': 200, 'max_depth': 6, 'learning_rate': 0.11623979461375812, 'subsample': 0.504860340675352, 'colsample_bytree': 0.723834
[I 2025-05-31 02:37:35,782] Trial 1 finished with value: 0.0016626788713219821 and parameters: {'n_estimators': 224, 'max_depth': 6, 'learning_rate': 0.03505587759511874, 'subsample': 0.7399567511937468, 'colsample_bytree': 0.99360
[I 2025-05-31 02:37:35,855] Trial 2 finished with value: 0.001652886184024865 and parameters: {'n_estimators': 63, 'max_depth': 7, 'learning_rate': 0.014361383363057771, 'subsample': 0.834317422196733, 'colsample_bytree': 0.5752378
[I 2025-05-31 02:37:35,961] Trial 3 finished with value: 0.0016436396950917263 and parameters: {'n_estimators': 184, 'max_depth': 5, 'learning_rate': 0.01835100281702722, 'subsample': 0.6684794295865647, 'colsample_bytree': 0.70370
[I 2025-05-31 02:37:36,100] Trial 4 finished with value: 0.0016533494106519518 and parameters: {'n_estimators': 184, 'max_depth': 6, 'learning_rate': 0.015555905143604535, 'subsample': 0.7948791974589645, 'colsample_bytree': 0.5129
[I 2025-05-31 02:37:36,172] Trial 5 finished with value: 0.0016343503802213927 and parameters: {'n_estimators': 70, 'max_depth': 5, 'learning_rate': 0.09342734473059953, 'subsample': 0.6687424364809018, 'colsample_bytree': 0.850606
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[I 2025-05-31 02:37:36,693] Trial 9 finished with value: 0.0016446650599358762 and parameters: {'n_estimators': 300, 'max_depth': 6, 'learning_rate': 0.010620478469243862, 'subsample': 0.8010754934927551, 'colsample_bytree': 0.6675
[I 2025-05-31 02:37:36,801] Trial 10 finished with value: 0.0016266009535723853 and parameters: {'n_estimators': 135, 'max_depth': 3, 'learning_rate': 0.229032767097287, 'subsample': 0.9598680293134763, 'colsample_bytree': 0.609827
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[I 2025-05-31 02:37:37,012] Trial 12 finished with value: 0.0016673402154485516 and parameters: {'n_estimators': 118, 'max_depth': 4, 'learning_rate': 0.2994114251906341, 'subsample': 0.9690561315295524, 'colsample_bytree': 0.62260
[I 2025-05-31 02:37:37,167] Trial 13 finished with value: 0.0016153924508765986 and parameters: {'n_estimators': 131, 'max_depth': 4, 'learning_rate': 0.15839561269900176, 'subsample': 0.9159418956790295, 'colsample_bytree': 0.5056
[I 2025-05-31 02:37:37,336] Trial 14 finished with value: 0.0016061946739170416 and parameters: {'n_estimators': 298, 'max_depth': 4, 'learning_rate': 0.1453556648208685, 'subsample': 0.8848376674259302, 'colsample_bytree': 0.50099
[I 2025-05-31 02:37:37,499] Trial 15 finished with value: 0.0015959454622992153 and parameters: {'n_estimators': 296, 'max_depth': 4, 'learning_rate': 0.0720071925923137, 'subsample': 0.6748296645726146, 'colsample_bytree': 0.79033
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[I 2025-05-31 02:37:37,814] Trial 17 finished with value: 0.0016297248161991 51 and parameters: {'n_estimators': 264, 'max_depth': 4, 'learning_rate': 0.04968170092718188, 'subsample': 0.7333487354201078, 'colsample_bytree': 0.79962
[I 2025-05-31 02:37:37,956] Trial 18 finished with value: 0.0016679412566813743 and parameters: {'n_estimators': 232, 'max_depth': 3, 'learning_rate': 0.07710898279647718, 'subsample': 0.5972032003660225, 'colsample_bytree': 0.7600
[I 2025-05-31 02:37:38,115] Trial 19 finished with value: 0.0016372900406530129 and parameters: {'n_estimators': 281, 'max_depth': 5, 'learning_rate': 0.026982852993324896, 'subsample': 0.7069890521782005, 'colsample_bytree': 0.668
[I 2025-05-31 02:37:38,270] A new study created in memory with name: no-name-3c25baa4-7ab6-4429-8c7a-1939e44b586b
[I 2025-05-31 02:37:38,400] Trial 0 finished with value: 0.0002492656838915834 and parameters: {'n_estimators': 115, 'max_depth': 6, 'learning_rate': 0.02867816850892968, 'subsample': 0.9121337880511813, 'colsample_bytree': 0.78976
[I 2025-05-31 02:37:38,529] Trial 1 finished with value: 0.0002575043982101288 and parameters: {'n_estimators': 271, 'max_depth': 3, 'learning_rate': 0.1446381292434982, 'subsample': 0.6588394368065015, 'colsample_bytree': 0.547021
[I 2025-05-31 02:37:38,612] Trial 2 finished with value: 0.0002510417403610932 6 and parameters: {'n_estimators': 106, 'max_depth': 5, 'learning_rate': 0.03361863524595195, 'subsample': 0.9738135125186689, 'colsample_bytree': 0.9829
[I 2025-05-31 02:37:38,717] Trial 3 finished with value: 0.0002364034933782283 2 and parameters: {'n_estimators': 176, 'max_depth': 6, 'learning_rate': 0.22165310967102628, 'subsample': 0.5526223980403565, 'colsample_bytree': 0.5457
[I 2025-05-31 02:37:38,805] Trial 4 finished with value: 0.0002458700022368735 and parameters: {'n_estimators': 125, 'max_depth': 4, 'learning_rate': 0.21394413652902483, 'subsample': 0.9689970461311748, 'colsample_bytree': 0.58561
[I 2025-05-31 02:37:38,909] Trial 5 finished with value: 0.0002493109075148525 and parameters: {'n_estimators': 182, 'max_depth': 6, 'learning_rate': 0.18849545826156652, 'subsample': 0.880348194520 5451, 'colsample_bytree': 0.88748
[I 2025-05-31 02:37:39,029] Trial 6 finished with value: 0.0002431653653588 1847 and parameters: {'n_estimators': 221, 'max_depth': 4, 'learning_rate': 0.18979539950454408, 'subsample': 0.8564970593383594, 'colsample_bytree': 0.8746
[I 2025-05-31 02:37:39,093] Trial 7 finished with value: 0.0002433915650577498 3 and parameters: {'n_estimators': 59, 'max_depth': 7, 'learning_rate': 0.02121679080695215, 'subsample': 0.715129661130 2245, 'colsample_bytree': 0.60192
[I 2025-05-31 02:37:39,269] Trial 8 finished with value: 0.0002607762852774157 3 and parameters: {'n_estimators': 297, 'max_depth': 6, 'learning_rate': 0.06571869034411804, 'subsample': 0.6465807407445254, 'colsample_bytree': 0.9503
[I 2025-05-31 02:37:39,402] Trial 9 finished with value: 0.0002507004786380169 and parameters: {'n_estimators': 263, 'max_depth': 8, 'learning_rate': 0.013598732809097043, 'subsample': 0.9091616357847134, 'colsample_bytree': 0.9381
[I 2025-05-31 02:37:39,524] Trial 10 finished with value: 0.00023077265757471643 and parameters: {'n_estimators': 175, 'max_depth': 8, 'learning_rate': 0.08296291403503522, 'subsample': 0.5042453147472081, 'colsample_bytree': 0.686
[I 2025-05-31 02:37:39,646] Trial 11 finished with value: 0.00022833452492423585 and parameters: {'n_estimators': 179, 'max_depth': 8, 'learning_rate': 0.08527267924671289, 'subsample': 0.5107897452063678, 'colsample_bytree': 0.683
[I 2025-05-31 02:37:39,785] Trial 12 finished with value: 0.0002559965039799139 and parameters: {'n_estimators': 218, 'max_depth': 8, 'learning_rate': 0.07920848099146478, 'subsample': 0.5107879063206213, 'colsample_bytree': 0.6978
[I 2025-05-31 02:37:39,902] Trial 13 finished with value: 0.00028292049391265685 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': 0.10857740551027728, 'subsample': 0.5839092611220252, 'colsample_bytree': 0.696
[I 2025-05-31 02:37:40,036] Trial 14 finished with value: 0.00024897740227215314 and parameters: {'n_estimators': 207, 'max_depth': 7, 'learning_rate': 0.04196599773010216, 'subsample': 0.5101730686715639, 'colsample_bytree': 0.761
[I 2025-05-31 02:37:40,156] Trial 15 finished with value: 0.00026722218439338534 and parameters: {'n_estimators': 161, 'max_depth': 7, 'learning_rate': 0.102116536891567, 'subsample': 0.806375194901397, 'colsample_bytree': 0.662182
[I 2025-05-31 02:37:40,274] Trial 16 finished with value: 0.00023314439005142764 and parameters: {'n_estimators': 76, 'max_depth': 8, 'learning_rate': 0.05498789039510651, 'subsample': 0.6067158586569747, 'colsample_bytree': 0.7979
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[I 2025-05-31 02:38:07,090] Trial 1 finished with value: 0.0016915777845563018 and parameters: {'n_estimators': 191, 'max_depth': 5, 'learning_rate': 0.04367593858156099, 'subsample': 0.9454859475786516, 'colsample_bytree': 0.915902
[I 2025-05-31 02:38:07,209] Trial 2 finished with value: 0.0016900808608163668 and parameters: {'n_estimators': 182, 'max_depth': 8, 'learning_rate': 0.02463505834206084, 'subsample': 0.5172200459631688, 'colsample_bytree': 0.74555
[I 2025-05-31 02:38:07,350] Trial 3 finished with value: 0.0016918678673366004 and parameters: {'n_estimators': 299, 'max_depth': 3, 'learning_rate': 0.011232360491264783, 'subsample': 0.7724844031200071, 'colsample_bytree': 0.6705
[I 2025-05-31 02:38:07,449] Trial 4 finished with value: 0.0016910160002471988 and parameters: {'n_estimators': 152, 'max_depth': 3, 'learning_rate': 0.16616709246533773, 'subsample': 0.8178675725311562, 'colsample_bytree': 0.99656
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[I 2025-05-31 02:38:07,829] Trial 7 finished with value: 0.0016927189032360084 and parameters: {'n_estimators': 282, 'max_depth': 4, 'learning_rate': 0.06597823522001763, 'subsample': 0.6781354525947779, 'colsample_bytree': 0.655683
[I 2025-05-31 02:38:07,947] Trial 8 finished with value: 0.0016927687882119684 and parameters: {'n_estimators': 227, 'max_depth': 3, 'learning_rate': 0.112446507391143, 'subsample': 0.9734690754021174, 'colsample_bytree': 0.9500543
[I 2025-05-31 02:38:08,041] Trial 9 finished with value: 0.0016909587477777786 and parameters: {'n_estimators': 142, 'max_depth': 3, 'learning_rate': 0.061461308142977414, 'subsample': 0.7028457885081505, 'colsample_bytree': 0.62260
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[I 2025-05-31 02:38:09,169] Trial 18 finished with value: 0.0016921259274245105 and parameters: {'n_estimators': 247, 'max_depth': 5, 'learning_rate': 0.04248288825335898, 'subsample': 0.6269988524004546, 'colsample_bytree': 0.5855
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[I 2025-05-31 02:38:09,438] A new study created in memory with name: no-name-c71113f7-79e7-4e36-889c-9fb55be9eb71
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[I 2025-05-31 02:38:09,726] Trial 2 finished with value: 0.0008357189469662471 and parameters: {'n_estimators': 136, 'max_depth': 5, 'learning_rate': 0.1676155359149007, 'subsample': 0.9389235708862776, 'colsample_bytree': 0.8922584
[I 2025-05-31 02:38:09,821] Trial 3 finished with value: 0.0008280570823343464 and parameters: {'n_estimators': 147, 'max_depth': 7, 'learning_rate': 0.013361403639107356, 'subsample': 0.6048103682208295, 'colsample_bytree': 0.6651
[I 2025-05-31 02:38:09,913] Trial 4 finished with value: 0.0008309979246170984 and parameters: {'n_estimators': 105, 'max_depth': 5, 'learning_rate': 0.05137556215154196, 'subsample': 0.8086633508191592, 'colsample_bytree': 0.75288
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[I 2025-05-31 02:38:10,383] Trial 8 finished with value: 0.0008303791078087887 and parameters: {'n_estimators': 160, 'max_depth': 6, 'learning_rate': 0.15708986331805935, 'subsample': 0.7283291937694547, 'colsample_bytree': 0.94079
[I 2025-05-31 02:38:10,531] Trial 9 finished with value: 0.0008317775159799259 and parameters: {'n_estimators': 292, 'max_depth': 8, 'learning_rate': 0.01953499037921752, 'subsample': 0.8330871311168475, 'colsample_bytree': 0.56645
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[I 2025-05-31 02:38:10,981] Trial 13 finished with value: 0.0008356973441861048 and parameters: {'n_estimators': 224, 'max_depth': 7, 'learning_rate': 0.023383497910718185, 'subsample': 0.6071829467075285, 'colsample_bytree': 0.783
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[I 2025-05-31 02:38:12,082] Trial 16 finished with value: 0.0008307348264944011 and parameters: {'n_estimators': 264, 'max_depth': 6, 'learning_rate': 0.016654288725333467, 'subsample': 0.5602618195319816, 'colsample_bytree': 0.681
[I 2025-05-31 02:38:13,014] Trial 17 finished with value: 0.000832804075738236 and parameters: {'n_estimators': 182, 'max_depth': 7, 'learning_rate': 0.03370329955156914, 'subsample': 0.6588788160894474, 'colsample_bytree': 0.65280
[I 2025-05-31 02:38:13,150] Trial 18 finished with value: 0.0008282503942045064 and parameters: {'n_estimators': 81, 'max_depth': 8, 'learning_rate': 0.0631150899896605, 'subsample': 0.6615843227579804, 'colsample_bytree': 0.813993
[I 2025-05-31 02:38:13,313] Trial 19 finished with value: 0.0008293618113226684 and parameters: {'n_estimators': 128, 'max_depth': 6, 'learning_rate': 0.07304964636091803, 'subsample': 0.6635179617401612, 'colsample_bytree': 0.8371
[I 2025-05-31 02:38:13,507] A new study created in memory with name: no-name-9d4575fa-f238-4ab2-9eb8-86c3048822f3
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[I 2025-05-31 02:38:13,955] Trial 2 finished with value: 0.001438660709345553 and parameters: {'n_estimators': 71, 'max_depth': 3, 'learning_rate': 0.016730771174501172, 'subsample': 0.9247860683292157, 'colsample_bytree': 0.919402
[I 2025-05-31 02:38:14,035] Trial 3 finished with value: 0.001448673549750379 and parameters: {'n_estimators': 107, 'max_depth': 7, 'learning_rate': 0.04826264668154591, 'subsample': 0.7323323699070854, 'colsample_bytree': 0.948622
[I 2025-05-31 02:38:14,153] Trial 4 finished with value: 0.0014069802857788526 and parameters: {'n_estimators': 222, 'max_depth': 7, 'learning_rate': 0.04016841040831818, 'subsample': 0.50418114422641, 'colsample_bytree': 0.975454
[I 2025-05-31 02:38:14,247] Trial 5 finished with value: 0.0014323209064192562 and parameters: {'n_estimators': 150, 'max_depth': 8, 'learning_rate': 0.08686005728135655, 'subsample': 0.6649753642823784, 'colsample_bytree': 0.65259
[I 2025-05-31 02:38:14,329] Trial 6 finished with value: 0.0014397807576421375 and parameters: {'n_estimators': 112, 'max_depth': 4, 'learning_rate': 0.01531576809830243, 'subsample': 0.803831540045673, 'colsample_bytree': 0.927398
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[I 2025-05-31 02:38:14,712] Trial 9 finished with value: 0.00143775458245622 and parameters: {'n_estimators': 188, 'max_depth': 8, 'learning_rate': 0.1731126165353474, 'subsample': 0.771853747444315, 'colsample_bytree': 0.764948469
[I 2025-05-31 02:38:14,873] Trial 10 finished with value: 0.0014848266992594401 and parameters: {'n_estimators': 293, 'max_depth': 5, 'learning_rate': 0.27874560430984097, 'subsample': 0.5357130206869742, 'colsample_bytree': 0.5336
[I 2025-05-31 02:38:15,015] Trial 11 finished with value: 0.0014395213133313696 and parameters: {'n_estimators': 238, 'max_depth': 6, 'learning_rate': 0.05686878736367268, 'subsample': 0.9814438330400975, 'colsample_bytree': 0.5742
[I 2025-05-31 02:38:15,158] Trial 12 finished with value: 0.0014126165195948736 and parameters: {'n_estimators': 240, 'max_depth': 6, 'learning_rate': 0.032657266118477135, 'subsample': 0.5225270116565076, 'colsample_bytree': 0.844
[I 2025-05-31 02:38:15,293] Trial 13 finished with value: 0.001441711821846593 and parameters: {'n_estimators': 197, 'max_depth': 5, 'learning_rate': 0.0306788217306393, 'subsample': 0.5015211357671453, 'colsample_bytree': 0.847572
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[I 2025-05-31 02:38:15,631] Trial 15 finished with value: 0.0014290835857595405 and parameters: {'n_estimators': 223, 'max_depth': 7, 'learning_rate': 0.032679507177284885, 'subsample': 0.5765125803784905, 'colsample_bytree': 0.979
[I 2025-05-31 02:38:15,752] Trial 16 finished with value: 0.001407434705596087 and parameters: {'n_estimators': 148, 'max_depth': 5, 'learning_rate': 0.1254254890082348, 'subsample': 0.510106234574591, 'colsample_bytree': 0.8634105
[I 2025-05-31 02:38:15,873] Trial 17 finished with value: 0.0014537049770830877 and parameters: {'n_estimators': 154, 'max_depth': 4, 'learning_rate': 0.12234756451367217, 'subsample': 0.6133443106336567, 'colsample_bytree': 0.8870
[I 2025-05-31 02:38:15,990] Trial 18 finished with value: 0.001419070670478224 and parameters: {'n_estimators': 141, 'max_depth': 4, 'learning_rate': 0.14876387591515838, 'subsample': 0.6909394229164796, 'colsample_bytree': 0.98897
[I 2025-05-31 02:38:16,126] Trial 19 finished with value: 0.0014305579568785125 and parameters: {'n_estimators': 205, 'max_depth': 5, 'learning_rate': 0.2593125184547318, 'subsample': 0.5774742491807018, 'colsample_bytree': 0.80840
[I 2025-05-31 02:38:16,257] A new study created in memory with name: no-name-a26e4c79-8f2d-44b2-8b2a-9f70ae8c09a1
[I 2025-05-31 02:38:16,384] Trial 0 finished with value: 0.0008511249213775307 and parameters: {'n_estimators': 138, 'max_depth': 7, 'learning_rate': 0.06724737050127143, 'subsample': 0.99710626642545, 'colsample_bytree': 0.7992015
[I 2025-05-31 02:38:16,527] Trial 1 finished with value: 0.00085080212568256 and parameters: {'n_estimators': 294, 'max_depth': 5, 'learning_rate': 0.0430718892700062, 'subsample': 0.9955280473959542, 'colsample_bytree': 0.95009432
[I 2025-05-31 02:38:16,676] Trial 2 finished with value: 0.0008382709059173736 and parameters: {'n_estimators': 253, 'max_depth': 3, 'learning_rate': 0.08855043086920501, 'subsample': 0.7868322301588193, 'colsample_bytree': 0.83046
[I 2025-05-31 02:38:16,796] Trial 3 finished with value: 0.0008710664506846751 and parameters: {'n_estimators': 210, 'max_depth': 8, 'learning_rate': 0.25011572922865744, 'subsample': 0.7586594634783628, 'colsample_bytree': 0.56648
[I 2025-05-31 02:38:16,917] Trial 4 finished with value: 0.0008468979404875917 and parameters: {'n_estimators': 235, 'max_depth': 4, 'learning_rate': 0.03723611676377913, 'subsample': 0.9687423063608365, 'colsample_bytree': 0.61183
[I 2025-05-31 02:38:17,008] Trial 5 finished with value: 0.0008568425927131119 and parameters: {'n_estimators': 139, 'max_depth': 4, 'learning_rate': 0.014110396184377485, 'subsample': 0.7013002690710775, 'colsample_bytree': 0.6362
[I 2025-05-31 02:38:17,078] Trial 6 finished with value: 0.0008499135459489179 and parameters: {'n_estimators': 63, 'max_depth': 8, 'learning_rate': 0.041707230125610874, 'subsample': 0.9873498968246066, 'colsample_bytree': 0.65583
[I 2025-05-31 02:38:17,187] Trial 7 finished with value: 0.0008703139493005186 and parameters: {'n_estimators': 195, 'max_depth': 5, 'learning_rate': 0.05867645082396751, 'subsample': 0.7232879471727133, 'colsample_bytree': 0.72209
[I 2025-05-31 02:38:17,265] Trial 8 finished with value: 0.0008553671274517899 and parameters: {'n_estimators': 104, 'max_depth': 6, 'learning_rate': 0.11406370888155659, 'subsample': 0.9471878916842593, 'colsample_bytree': 0.78618
[I 2025-05-31 02:38:17,357] Trial 9 finished with value: 0.0008604716674831799 and parameters: {'n_estimators': 142, 'max_depth': 5, 'learning_rate': 0.019081680009562833, 'subsample': 0.692450431746422, 'colsample_bytree': 0.69948
[I 2025-05-31 02:38:17,520] Trial 10 finished with value: 0.0009094357296865054 and parameters: {'n_estimators': 285, 'max_depth': 3, 'learning_rate': 0.16908541264799554, 'subsample': 0.5071019066881144, 'colsample_bytree': 0.9211
[I 2025-05-31 02:38:17,698] Trial 11 finished with value: 0.0008492865831643819 and parameters: {'n_estimators': 242, 'max_depth': 3, 'learning_rate': 0.0258114855717563, 'subsample': 0.8518535341489487, 'colsample_bytree': 0.53135
[I 2025-05-31 02:38:17,849] Trial 12 finished with value: 0.0008438792274078116 and parameters: {'n_estimators': 251, 'max_depth': 4, 'learning_rate': 0.10147741830435593, 'subsample': 0.8778921904670343, 'colsample_bytree': 0.8635
[I 2025-05-31 02:38:17,999] Trial 13 finished with value: 0.0008435983929094602 and parameters: {'n_estimators': 251, 'max_depth': 4, 'learning_rate': 0.10283910358589043, 'subsample': 0.8357952630920336, 'colsample_bytree': 0.8922
[I 2025-05-31 02:38:18,153] Trial 14 finished with value: 0.0008684852441525997 and parameters: {'n_estimators': 270, 'max_depth': 3, 'learning_rate': 0.10222775779626934, 'subsample': 0.7979309627957885, 'colsample_bytree': 0.8624
[I 2025-05-31 02:38:18,290] Trial 15 finished with value: 0.0008992745657709686 and parameters: {'n_estimators': 210, 'max_depth': 4, 'learning_rate': 0.2832739815307547, 'subsample': 0.5862366323086101, 'colsample_bytree': 0.86174
[I 2025-05-31 02:38:18,415] Trial 16 finished with value: 0.0008696739843042071 and parameters: {'n_estimators': 180, 'max_depth': 3, 'learning_rate': 0.176626762779659, 'subsample': 0.8693132357148613, 'colsample_bytree': 0.991233
[I 2025-05-31 02:38:18,650] Trial 17 finished with value: 0.0008678126388115972 and parameters: {'n_estimators': 262, 'max_depth': 6, 'learning_rate': 0.07599479830263008, 'subsample': 0.6451610364775888, 'colsample_bytree': 0.7914
[I 2025-05-31 02:38:18,797] Trial 18 finished with value: 0.0008527842552746246 and parameters: {'n_estimators': 226, 'max_depth': 4, 'learning_rate': 0.15042211565887392, 'subsample': 0.7979828890792959, 'colsample_bytree': 0.9325
[I 2025-05-31 02:38:18,921] Trial 19 finished with value: 0.0008453797240332122 and parameters: {'n_estimators': 164, 'max_depth': 3, 'learning_rate': 0.07968883947453141, 'subsample': 0.916948840110182, 'colsample_bytree': 0.83453
[I 2025-05-31 02:38:19,058] A new study created in memory with name: no-name-ec39574e-a4b4-4907-a2b5-52118726264c
[I 2025-05-31 02:38:19,145] Trial 0 finished with value: 0.0006724576957691631 and parameters: {'n_estimators': 54, 'max_depth': 7, 'learning_rate': 0.10885360076373987, 'subsample': 0.8510938851810957, 'colsample_bytree': 0.664672
[I 2025-05-31 02:38:19,254] Trial 1 finished with value: 0.0006901858500078251 and parameters: {'n_estimators': 207, 'max_depth': 8, 'learning_rate': 0.09812095153220053, 'subsample': 0.682095188409594, 'colsample_bytree': 0.536071
[I 2025-05-31 02:38:19,388] Trial 2 finished with value: 0.0007080752064675658 and parameters: {'n_estimators': 240, 'max_depth': 6, 'learning_rate': 0.03977203339028034, 'subsample': 0.5187052309361906, 'colsample_bytree': 0.85260
[I 2025-05-31 02:38:19,541] Trial 3 finished with value: 0.0006756069123891021 and parameters: {'n_estimators': 285, 'max_depth': 6, 'learning_rate': 0.012534319356013965, 'subsample': 0.7862356298539603, 'colsample_bytree': 0.9673
[I 2025-05-31 02:38:19,613] Trial 4 finished with value: 0.0006652940027834093 and parameters: {'n_estimators': 81, 'max_depth': 8, 'learning_rate': 0.011624926121113686, 'subsample': 0.8790331716745499, 'colsample_bytree': 0.63534
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[I 2025-05-31 02:38:43,816] Trial 11 finished with value: 0.0007108300156279165 and parameters: {'n_estimators': 155, 'max_depth': 6, 'learning_rate': 0.038619513632448144, 'subsample': 0.6503253373947881, 'colsample_bytree': 0.509
[I 2025-05-31 02:38:43,964] Trial 12 finished with value: 0.0007010563647252917 and parameters: {'n_estimators': 238, 'max_depth': 3, 'learning_rate': 0.23774601570106854, 'subsample': 0.6823184883346055, 'colsample_bytree': 0.5057
[I 2025-05-31 02:38:44,111] Trial 13 finished with value: 0.0007154182971105743 and parameters: {'n_estimators': 244, 'max_depth': 6, 'learning_rate': 0.2590657628355057, 'subsample': 0.6743753559277208, 'colsample_bytree': 0.57746
[I 2025-05-31 02:38:44,283] Trial 14 finished with value: 0.0007108264426912942 and parameters: {'n_estimators': 298, 'max_depth': 4, 'learning_rate': 0.010947081040020913, 'subsample': 0.6533707086516314, 'colsample_bytree': 0.787
[I 2025-05-31 02:38:44,426] Trial 15 finished with value: 0.0006836859568893849 and parameters: {'n_estimators': 221, 'max_depth': 7, 'learning_rate': 0.29936865879629887, 'subsample': 0.572910179723724, 'colsample_bytree': 0.56141
[I 2025-05-31 02:38:44,557] Trial 16 finished with value: 0.0007077464904068566 and parameters: {'n_estimators': 207, 'max_depth': 7, 'learning_rate': 0.2634898466696095, 'subsample': 0.5968561293650911, 'colsample_bytree': 0.51397
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[I 2025-05-31 02:38:44,846] Trial 18 finished with value: 0.0006705049480900318 and parameters: {'n_estimators': 250, 'max_depth': 5, 'learning_rate': 0.29363863104016913, 'subsample': 0.6180180740523531, 'colsample_bytree': 0.5604
[I 2025-05-31 02:38:44,999] Trial 19 finished with value: 0.0006996327894245049 and parameters: {'n_estimators': 259, 'max_depth': 5, 'learning_rate': 0.09113804864089362, 'subsample': 0.6066506004499752, 'colsample_bytree': 0.8479
[I 2025-05-31 02:38:45,133] A new study created in memory with name: no-name-fdfd4ade-58b1-49e4-ba0c-5c59a5402a93
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[I 2025-05-31 02:38:45,843] Trial 5 finished with value: 0.0028458949588676466 and parameters: {'n_estimators': 226, 'max_depth': 4, 'learning_rate': 0.11750227026330706, 'subsample': 0.5784450061621089, 'colsample_bytree': 0.52599
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[I 2025-05-31 02:38:46,767] Trial 12 finished with value: 0.0028524071652152695 and parameters: {'n_estimators': 233, 'max_depth': 4, 'learning_rate': 0.014634222570178561, 'subsample': 0.8463838743005433, 'colsample_bytree': 0.615
[I 2025-05-31 02:38:46,890] Trial 13 finished with value: 0.002854492547363312 and parameters: {'n_estimators': 163, 'max_depth': 6, 'learning_rate': 0.06643262596097989, 'subsample': 0.6323378836062543, 'colsample_bytree': 0.60422
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[I 2025-05-31 02:38:47,177] Trial 15 finished with value: 0.0028781533057784785 and parameters: {'n_estimators': 198, 'max_depth': 5, 'learning_rate': 0.267762961034026, 'subsample': 0.6082195642071475, 'colsample_bytree': 0.664625
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[I 2025-05-31 02:38:47,448] Trial 17 finished with value: 0.002857527386968472 and parameters: {'n_estimators': 259, 'max_depth': 5, 'learning_rate': 0.052192517007306795, 'subsample': 0.9930631611226757, 'colsample_bytree': 0.6546
[I 2025-05-31 02:38:47,590] Trial 18 finished with value: 0.0028368449573902446 and parameters: {'n_estimators': 203, 'max_depth': 3, 'learning_rate': 0.17372950906734808, 'subsample': 0.7697648153826882, 'colsample_bytree': 0.5580
[I 2025-05-31 02:38:47,761] Trial 19 finished with value: 0.002854694686023963 and parameters: {'n_estimators': 200, 'max_depth': 3, 'learning_rate': 0.2014029331303003, 'subsample': 0.7951163751065498, 'colsample_bytree': 0.570513
[I 2025-05-31 02:38:47,886] A new study created in memory with name: no-name-74b28d78-c900-4452-9464-c6e526a13120
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[I 2025-05-31 02:38:48,581] Trial 6 finished with value: 0.0013496485109649025 and parameters: {'n_estimators': 178, 'max_depth': 5, 'learning_rate': 0.16168342944432967, 'subsample': 0.8904623214849741, 'colsample_bytree': 0.73826
[I 2025-05-31 02:38:48,679] Trial 7 finished with value: 0.0013874252208376102 and parameters: {'n_estimators': 155, 'max_depth': 6, 'learning_rate': 0.030266843132646604, 'subsample': 0.5279092450265447, 'colsample_bytree': 0.5867
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[I 2025-05-31 02:38:48,922] Trial 9 finished with value: 0.0013639925779898535 and parameters: {'n_estimators': 168, 'max_depth': 6, 'learning_rate': 0.032909672266284724, 'subsample': 0.845428174921516, 'colsample_bytree': 0.81176
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[I 2025-05-31 02:38:49,352] Trial 12 finished with value: 0.0013609815293973585 and parameters: {'n_estimators': 116, 'max_depth': 5, 'learning_rate': 0.14239576249992636, 'subsample': 0.9187983242460869, 'colsample_bytree': 0.9723
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[I 2025-05-31 02:38:49,756] Trial 15 finished with value: 0.0013630983321022167 and parameters: {'n_estimators': 247, 'max_depth': 4, 'learning_rate': 0.2982904262889328, 'subsample': 0.9367991953176424, 'colsample_bytree': 0.64153
[I 2025-05-31 02:38:49,871] Trial 16 finished with value: 0.0013644450780150028 and parameters: {'n_estimators': 120, 'max_depth': 5, 'learning_rate': 0.05908457587925788, 'subsample': 0.9113404154235565, 'colsample_bytree': 0.9072
[I 2025-05-31 02:38:50,043] Trial 17 finished with value: 0.00136843292569956 5 and parameters: {'n_estimators': 207, 'max_depth': 8, 'learning_rate': 0.13278101925768193, 'subsample': 0.6836579622391084, 'colsample_bytree': 0.76370
[I 2025-05-31 02:38:50,923] Trial 18 finished with value: 0.0013715804582902387 and parameters: {'n_estimators': 273, 'max_depth': 7, 'learning_rate': 0.09401106949512629, 'subsample': 0.8149358373924117, 'colsample_bytree': 0.9372
[I 2025-05-31 02:38:51,074] Trial 19 finished with value: 0.00136651943342671 and parameters: {'n_estimators': 92, 'max_depth': 4, 'learning_rate': 0.19495746923099072, 'subsample': 0.9581264471389703, 'colsample_bytree': 0.8189867
[I 2025-05-31 02:38:52,093] A new study created in memory with name: no-name-fe5e55f5-2b82-4dd0-b883-0c0ec50e0417
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[I 2025-05-31 02:38:52,770] Trial 2 finished with value: 0.00646051029029248 and parameters: {'n_estimators': 185, 'max_depth': 4, 'learning_rate': 0.01513540432318896, 'subsample': 0.9911156153919083, 'colsample_bytree': 0.9761355
[I 2025-05-31 02:38:53,021] Trial 3 finished with value: 0.006460678694470028 and parameters: {'n_estimators': 197, 'max_depth': 8, 'learning_rate': 0.1519570631179219, 'subsample': 0.8921497175134476, 'colsample_bytree': 0.9914429
[I 2025-05-31 02:38:53,163] Trial 4 finished with value: 0.006436105734816592 and parameters: {'n_estimators': 297, 'max_depth': 6, 'learning_rate': 0.09296552193829849, 'subsample': 0.6827215326394975, 'colsample_bytree': 0.773517
[I 2025-05-31 02:38:53,268] Trial 5 finished with value: 0.0064396714919726095 and parameters: {'n_estimators': 179, 'max_depth': 8, 'learning_rate': 0.016602927388456923, 'subsample': 0.6860805899217445, 'colsample_bytree': 0.8999
[I 2025-05-31 02:38:53,343] Trial 6 finished with value: 0.006466951275984932 and parameters: {'n_estimators': 90, 'max_depth': 5, 'learning_rate': 0.014342559696477544, 'subsample': 0.7171818363328962, 'colsample_bytree': 0.812759
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[I 2025-05-31 02:38:53,557] Trial 8 finished with value: 0.006416857484357221 and parameters: {'n_estimators': 196, 'max_depth': 4, 'learning_rate': 0.06420096085068885, 'subsample': 0.6963936090490356, 'colsample_bytree': 0.600092
[I 2025-05-31 02:38:53,619] Trial 9 finished with value: 0.006470266752395226 5 and parameters: {'n_estimators': 55, 'max_depth': 3, 'learning_rate': 0.01907469917514288, 'subsample': 0.6221383963095368, 'colsample_bytree': 0.831092
[I 2025-05-31 02:38:53,727] Trial 10 finished with value: 0.006452128057291836 and parameters: {'n_estimators': 124, 'max_depth': 3, 'learning_rate': 0.28468320704914063, 'subsample': 0.7999303373280788, 'colsample_bytree': 0.50174
[I 2025-05-31 02:38:53,872] Trial 11 finished with value: 0.006439287181349239 and parameters: {'n_estimators': 236, 'max_depth': 4, 'learning_rate': 0.044911420083756474, 'subsample': 0.577182410614597, 'colsample_bytree': 0.65394
[I 2025-05-31 02:38:54,024] Trial 12 finished with value: 0.006469510735782719 and parameters: {'n_estimators': 139, 'max_depth': 5, 'learning_rate': 0.07487343956991922, 'subsample': 0.8000037435272871, 'colsample_bytree': 0.66200
[I 2025-05-31 02:38:54,159] Trial 13 finished with value: 0.006436496108530946 and parameters: {'n_estimators': 219, 'max_depth': 4, 'learning_rate': 0.040697124062774745, 'subsample': 0.610004151531643, 'colsample_bytree': 0.52253
[I 2025-05-31 02:38:54,268] Trial 14 finished with value: 0.0064671210799924755 and parameters: {'n_estimators': 134, 'max_depth': 4, 'learning_rate': 0.11641534525406119, 'subsample': 0.7636223948276645, 'colsample_bytree': 0.5852
[I 2025-05-31 02:38:54,405] Trial 15 finished with value: 0.006437096311859632 and parameters: {'n_estimators': 231, 'max_depth': 5, 'learning_rate': 0.06294146801281654, 'subsample': 0.6546590691863519, 'colsample_bytree': 0.71156
[I 2025-05-31 02:38:54,519] Trial 16 finished with value: 0.0064468706821979894 and parameters: {'n_estimators': 143, 'max_depth': 3, 'learning_rate': 0.030336919364027694, 'subsample': 0.5149055619951692, 'colsample_bytree': 0.902
[I 2025-05-31 02:38:54,641] Trial 17 finished with value: 0.006425847742794187 and parameters: {'n_estimators': 165, 'max_depth': 7, 'learning_rate': 0.1792949459614674, 'subsample': 0.7495696005255033, 'colsample_bytree': 0.593490
[I 2025-05-31 02:38:54,747] Trial 18 finished with value: 0.006461777553779991 and parameters: {'n_estimators': 101, 'max_depth': 4, 'learning_rate': 0.0540514773333142, 'subsample': 0.853150132990246 1, 'colsample_bytree': 0.888569
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[I 2025-05-31 02:38:55,010] A new study created in memory with name: no-name-1b096bde-db06-4a49-a190-7dc760b68bd5
[I 2025-05-31 02:38:55,157] Trial 0 finished with value: 0.005630270378341616 and parameters: {'n_estimators': 218, 'max_depth': 5, 'learning_rate': 0.06674899464544057, 'subsample': 0.9513269650459839, 'colsample_bytree': 0.849904
[I 2025-05-31 02:38:55,259] Trial 1 finished with value: 0.005626701248301973 and parameters: {'n_estimators': 157, 'max_depth': 7, 'learning_rate': 0.23836086769281511, 'subsample': 0.5681986550206388, 'colsample_bytree': 0.840391
[I 2025-05-31 02:38:55,381] Trial 2 finished with value: 0.005631995845868697 and parameters: {'n_estimators': 240, 'max_depth': 7, 'learning_rate': 0.014926599077064109, 'subsample': 0.5340350033724568, 'colsample_bytree': 0.51894
[I 2025-05-31 02:38:55,499] Trial 3 finished with value: 0.005631276934718129 and parameters: {'n_estimators': 226, 'max_depth': 6, 'learning_rate': 0.010821803507597092, 'subsample': 0.9756232286975575, 'colsample_bytree': 0.55181
[I 2025-05-31 02:38:55,567] Trial 4 finished with value: 0.005631698939211062 and parameters: {'n_estimators': 67, 'max_depth': 5, 'learning_rate': 0.021099266270853345, 'subsample': 0.6760359469754358, 'colsample_bytree': 0.714052
[I 2025-05-31 02:38:55,690] Trial 5 finished with value: 0.005630959285451671 5 and parameters: {'n_estimators': 246, 'max_depth': 4, 'learning_rate': 0.07489528097541891, 'subsample': 0.7673952338490105, 'colsample_bytree': 0.77247
[I 2025-05-31 02:38:55,755] Trial 6 finished with value: 0.005629772922548377 and parameters: {'n_estimators': 51, 'max_depth': 4, 'learning_rate': 0.20447409861268495, 'subsample': 0.9021485435948638, 'colsample_bytree': 0.8525510
[I 2025-05-31 02:38:55,825] Trial 7 finished with value: 0.005631167976805245 5 and parameters: {'n_estimators': 62, 'max_depth': 3, 'learning_rate': 0.011308607485857072, 'subsample': 0.9519412888085079, 'colsample_bytree': 0.50135
[I 2025-05-31 02:38:55,954] Trial 8 finished with value: 0.005629375503697281 and parameters: {'n_estimators': 240, 'max_depth': 3, 'learning_rate': 0.17558047444015923, 'subsample': 0.9181210434208102, 'colsample_bytree': 0.934543
[I 2025-05-31 02:38:56,088] Trial 9 finished with value: 0.005633009711183109 and parameters: {'n_estimators': 163, 'max_depth': 3, 'learning_rate': 0.100072350834898, 'subsample': 0.6636042348634651, 'colsample_bytree': 0.59857081
[I 2025-05-31 02:38:56,202] Trial 10 finished with value: 0.005624236865741637 and parameters: {'n_estimators': 140, 'max_depth': 8, 'learning_rate': 0.03833845652593205, 'subsample': 0.5002604493687715, 'colsample_bytree': 0.96884
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[I 2025-05-31 02:38:56,424] Trial 12 finished with value: 0.005627220750400073 and parameters: {'n_estimators': 113, 'max_depth': 8, 'learning_rate': 0.038716507468259165, 'subsample': 0.585981925769006 7, 'colsample_bytree': 0.9017
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[I 2025-05-31 02:39:22,708] Trial 1 finished with value: 0.002736021258053635 and parameters: {'n_estimators': 254, 'max_depth': 3, 'learning_rate': 0.09977878217931967, 'subsample': 0.9762742427157755, 'colsample_bytree': 0.880097
[I 2025-05-31 02:39:22,835] Trial 2 finished with value: 0.002767897290396053 and parameters: {'n_estimators': 252, 'max_depth': 8, 'learning_rate': 0.04262639945104939, 'subsample': 0.5486417671343207, 'colsample_bytree': 0.71147
[I 2025-05-31 02:39:22,978] Trial 3 finished with value: 0.0027382862694747033 and parameters: {'n_estimators': 296, 'max_depth': 6, 'learning_rate': 0.017435186164623556, 'subsample': 0.9872755607059581, 'colsample_bytree': 0.5420
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[I 2025-05-31 02:39:23,300] Trial 6 finished with value: 0.00273953819 35419 and parameters: {'n_estimators': 240, 'max_depth': 7, 'learning_rate': 0.0453084572703224, 'subsample': 0.9246265909635691, 'colsample_bytree': 0.750213821
[I 2025-05-31 02:39:23,404] Trial 7 finished with value: 0.002726070776440057 and parameters: {'n_estimators': 174, 'max_depth': 4, 'learning_rate': 0.12874837182429372, 'subsample': 0.7007022712982303, 'colsample_bytree': 0.909783
[I 2025-05-31 02:39:23,509] Trial 8 finished with value: 0.0027226566719243837 and parameters: {'n_estimators': 193, 'max_depth': 5, 'learning_rate': 0.08960871421419533, 'subsample': 0.5475313480287677, 'colsample_bytree': 0.54504
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[I 2025-05-31 02:39:23,986] Trial 12 finished with value: 0.002741652876 76831 23 and parameters: {'n_estimators': 208, 'max_depth': 6, 'learning_rate': 0.024916239216824957, 'subsample': 0.6147366347820025, 'colsample_bytree': 0.589
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[I 2025-05-31 02:39:24,442] Trial 15 finished with value: 0.0027516747682024105 and parameters: {'n_estimators': 295, 'max_depth': 4, 'learning_rate': 0.16028044191543234, 'subsample': 0.8782725214995377, 'colsample_bytree': 0.9992
[I 2025-05-31 02:39:24,583] Trial 16 finished with value: 0.0027572826899061567 and parameters: {'n_estimators': 223, 'max_depth': 6, 'learning_rate': 0.29358285845848925, 'subsample': 0.8346873875836193, 'colsample_bytree': 0.7825
[I 2025-05-31 02:39:24,741] Trial 17 finished with value: 0.0027202456761 74676 and parameters: {'n_estimators': 273, 'max_depth': 4, 'learning_rate': 0.18239164385330242, 'subsample': 0.6928868962362 76, 'colsample_bytree': 0.66738
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[I 2025-05-31 02:39:25,962] Trial 6 finished with value: 0.007846495869140274 and parameters: {'n_estimators': 120, 'max_depth': 7, 'learning_rate': 0.10721298062585162, 'subsample': 0.8413942438192603, 'colsample_bytree': 0.699775
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[I 2025-05-31 02:39:26,746] Trial 14 finished with value: 0.007824556762076197 and parameters: {'n_estimators': 84, 'max_depth': 4, 'learning_rate': 0.06945655249384833, 'subsample': 0.6684228631819098, 'colsample_bytree': 0.650983
[I 2025-05-31 02:39:26,895] Trial 15 finished with value: 0.007853559436615 97 and parameters: {'n_estimators': 234, 'max_depth': 3, 'learning_rate': 0.0600889125174536, 'subsample': 0.6697045940236483, 'colsample_bytree': 0.6042895
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[I 2025-05-31 02:39:27,635] Trial 0 finished with value: 0.002209155789415864 7 and parameters: {'n_estimators': 233, 'max_depth': 6, 'learning_rate': 0.05297262059937274 4, 'subsample': 0.6115149570483626, 'colsample_bytree': 0.7605
[I 2025-05-31 02:39:27,724] Trial 1 finished with value: 0.002261988427100946 6 and parameters: {'n_estimators': 124, 'max_depth': 3, 'learning_rate': 0.2781617158971132, 'subsample': 0.8105619742273933, 'colsample_bytree': 0.764290
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[I 2025-05-31 02:39:28,419] Trial 7 finished with value: 0.002210470809494495 and parameters: {'n_estimators': 116, 'max_depth': 7, 'learning_rate': 0.01974714703541111, 'subsample': 0.9692112946426917, 'colsample_bytree': 0.808929
[I 2025-05-31 02:39:28,531] Trial 8 finished with value: 0.0022020686631649346 and parameters: {'n_estimators': 199, 'max_depth': 8, 'learning_rate': 0.014004150309234265, 'subsample': 0.6999750848777428, 'colsample_bytree': 0.9675
[I 2025-05-31 02:39:28,643] Trial 9 finished with value: 0.002197315040894761 and parameters: {'n_estimators': 189, 'max_depth': 3, 'learning_rate': 0.06540835315352199, 'subsample': 0.6536226487824399, 'colsample_bytree': 0.600514
[I 2025-05-31 02:39:28,725] Trial 10 finished with value: 0.002215468896295598 and parameters: {'n_estimators': 51, 'max_depth': 5, 'learning_rate': 0.10999757270881785, 'subsample': 0.8712053122388159, 'colsample_bytree': 0.516916
[I 2025-05-31 02:39:28,850] Trial 11 finished with value: 0.0021731097719877505 and parameters: {'n_estimators': 174, 'max_depth': 4, 'learning_rate': 0.06708689946996775, 'subsample': 0.5190011847061367, 'colsample_bytree': 0.6121
[I 2025-05-31 02:39:28,939] Trial 12 finished with value: 0.002192810472678967 and parameters: {'n_estimators': 58, 'max_depth': 5, 'learning_rate': 0.05339090438858609, 'subsample': 0.503056112495953 8, 'colsample_bytree': 0.646838
[I 2025-05-31 02:39:29,027] Trial 13 finished with value: 0.002204044731543374 and parameters: {'n_estimators': 53, 'max_depth': 4, 'learning_rate': 0.04204510382155294, 'subsample': 0.5102572867181772, 'colsample_bytree': 0.639078
[I 2025-05-31 02:39:29,150] Trial 14 finished with value: 0.0022329955786235685 and parameters: {'n_estimators': 150, 'max_depth': 4, 'learning_rate': 0.08662583098323622, 'subsample': 0.5043591941663649, 'colsample_bytree': 0.6441
[I 2025-05-31 02:39:29,255] Trial 15 finished with value: 0.002191988861417817 and parameters: {'n_estimators': 92, 'max_depth': 4, 'learning_rate': 0.03509012219208192, 'subsample': 0.577407413892933 8, 'colsample_bytree': 0.505346
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[I 2025-05-31 02:39:30,289] Trial 18 finished with value: 0.0022108791029237756 and parameters: {'n_estimators': 81, 'max_depth': 6, 'learning_rate': 0.01156000869381873, 'subsample': 0.7233552996437838, 'colsample_bytree': 0.56542
[I 2025-05-31 02:39:31,264] Trial 19 finished with value: 0.002192098110204553 8 and parameters: {'n_estimators': 95, 'max_depth': 4, 'learning_rate': 0.08076276553556003, 'subsample': 0.562092106101296 1, 'colsample_bytree': 0.69417
[I 2025-05-31 02:39:31,539] A new study created in memory with name: no-name-03491f0f-16d5-488f-a853-d2f29767ea85
[I 2025-05-31 02:39:31,718] Trial 0 finished with value: 0.002357654888411488 and parameters: {'n_estimators': 148, 'max_depth': 7, 'learning_rate': 0.11402598134369449, 'subsample': 0.9480688187922046, 'colsample_bytree': 0.809682
[I 2025-05-31 02:39:31,878] Trial 1 finished with value: 0.0023126595660045426 and parameters: {'n_estimators': 135, 'max_depth': 5, 'learning_rate': 0.01802448899659791, 'subsample': 0.7110320744351357, 'colsample_bytree': 0.76707
[I 2025-05-31 02:39:31,962] Trial 2 finished with value: 0.0022907319118484646 and parameters: {'n_estimators': 58, 'max_depth': 5, 'learning_rate': 0.25030687280774494, 'subsample': 0.821821281295666 9, 'colsample_bytree': 0.529845
[I 2025-05-31 02:39:32,144] Trial 3 finished with value: 0.002303679021923345 and parameters: {'n_estimators': 62, 'max_depth': 5, 'learning_rate': 0.2185797490298111, 'subsample': 0.9369818744303959, 'colsample_bytree': 0.51886587
[I 2025-05-31 02:39:32,217] Trial 4 finished with value: 0.002309378753571003 and parameters: {'n_estimators': 50, 'max_depth': 3, 'learning_rate': 0.08985989006926783, 'subsample': 0.9172596614674027, 'colsample_bytree': 0.8809076
[I 2025-05-31 02:39:32,284] Trial 5 finished with value: 0.002317153644779015 and parameters: {'n_estimators': 65, 'max_depth': 8, 'learning_rate': 0.01767867285885411, 'subsample': 0.8098309387952234, 'colsample_bytree': 0.7130209
[I 2025-05-31 02:39:32,410] Trial 6 finished with value: 0.002307222601361188 and parameters: {'n_estimators': 197, 'max_depth': 8, 'learning_rate': 0.026571556339873067, 'subsample': 0.764891211225430 6, 'colsample_bytree': 0.70433
[I 2025-05-31 02:39:32,499] Trial 7 finished with value: 0.002306868768616058 and parameters: {'n_estimators': 127, 'max_depth': 5, 'learning_rate': 0.051113411709234606, 'subsample': 0.8108165005766623, 'colsample_bytree': 0.92055
[I 2025-05-31 02:39:32,617] Trial 8 finished with value: 0.002292525778196764 and parameters: {'n_estimators': 207, 'max_depth': 8, 'learning_rate': 0.027476536089134227, 'subsample': 0.7185414122354933, 'colsample_bytree': 0.97132
[I 2025-05-31 02:39:32,721] Trial 9 finished with value: 0.002233393254010938 3 and parameters: {'n_estimators': 182, 'max_depth': 3, 'learning_rate': 0.10022763183307971, 'subsample': 0.5195358549974481, 'colsample_bytree': 0.84587
[I 2025-05-31 02:39:32,880] Trial 10 finished with value: 0.00232140404898893 and parameters: {'n_estimators': 287, 'max_depth': 3, 'learning_rate': 0.05963889735465462, 'subsample': 0.5122317862093704, 'colsample_bytree': 0.650937
[I 2025-05-31 02:39:33,027] Trial 11 finished with value: 0.0022456365899066947 and parameters: {'n_estimators': 240, 'max_depth': 4, 'learning_rate': 0.2920116513209572, 'subsample': 0.5103444784230746, 'colsample_bytree': 0.51385
[I 2025-05-31 02:39:33,180] Trial 12 finished with value: 0.0023012659374704795 and parameters: {'n_estimators': 260, 'max_depth': 4, 'learning_rate': 0.15021641465961016, 'subsample': 0.5151763417285999, 'colsample_bytree': 0.6118
[I 2025-05-31 02:39:33,330] Trial 13 finished with value: 0.0022401352904967576 and parameters: {'n_estimators': 239, 'max_depth': 4, 'learning_rate': 0.29856856378276186, 'subsample': 0.6071496462258911, 'colsample_bytree': 0.8525
[I 2025-05-31 02:39:33,508] Trial 14 finished with value: 0.0022764335851113812 and parameters: {'n_estimators': 216, 'max_depth': 3, 'learning_rate': 0.14544671927464747, 'subsample': 0.6092144127467937, 'colsample_bytree': 0.8372
[I 2025-05-31 02:39:33,637] Trial 15 finished with value: 0.002283349095083964 and parameters: {'n_estimators': 177, 'max_depth': 4, 'learning_rate': 0.07002111673498605, 'subsample': 0.6273340984483979, 'colsample_bytree': 0.98506
[I 2025-05-31 02:39:33,813] Trial 16 finished with value: 0.0023101311101455867 and parameters: {'n_estimators': 296, 'max_depth': 6, 'learning_rate': 0.040140234958495585, 'subsample': 0.6144538066613681, 'colsample_bytree': 0.885
[I 2025-05-31 02:39:33,968] Trial 17 finished with value: 0.0022683563664126763 and parameters: {'n_estimators': 240, 'max_depth': 4, 'learning_rate': 0.18214217226229457, 'subsample': 0.5792608793216758, 'colsample_bytree': 0.8201
[I 2025-05-31 02:39:34,075] Trial 18 finished with value: 0.002268997195648581 and parameters: {'n_estimators': 109, 'max_depth': 3, 'learning_rate': 0.10224730557164413, 'subsample': 0.5686593483260522, 'colsample_bytree': 0.76025
[I 2025-05-31 02:39:34,199] Trial 19 finished with value: 0.002290902413932131 and parameters: {'n_estimators': 161, 'max_depth': 6, 'learning_rate': 0.14659954167058117, 'subsample': 0.6682886951162718, 'colsample_bytree': 0.92773
[I 2025-05-31 02:39:34,317] A new study created in memory with name: no-name-44df8f0b-b02e-429b-b0d0-9f8f1162fa9b
[I 2025-05-31 02:39:34,417] Trial 0 finished with value: 0.002011736621548772 and parameters: {'n_estimators': 84, 'max_depth': 3, 'learning_rate': 0.04575519982556005, 'subsample': 0.7306254672313406, 'colsample_bytree': 0.5162201
[I 2025-05-31 02:39:34,588] Trial 1 finished with value: 0.0020125547283789368 and parameters: {'n_estimators': 277, 'max_depth': 4, 'learning_rate': 0.0384508416360699, 'subsample': 0.735550265344445, 'colsample_bytree': 0.7757159
[I 2025-05-31 02:39:34,687] Trial 2 finished with value: 0.002008763200187165 and parameters: {'n_estimators': 163, 'max_depth': 3, 'learning_rate': 0.037354312790779345, 'subsample': 0.5584675804124769, 'colsample_bytree': 0.60836
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[I 2025-05-31 02:39:48,122] Trial 15 finished with value: 0.0033508142953327233 and parameters: {'n_estimators': 103, 'max_depth': 4, 'learning_rate': 0.1805399313893464, 'subsample': 0.9705420001153405, 'colsample_bytree': 0.81410
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[I 2025-05-31 02:39:49,526] Trial 5 finished with value: 0.005294342854754142 and parameters: {'n_estimators': 229, 'max_depth': 4, 'learning_rate': 0.25005734807308716, 'subsample': 0.7521146412322763, 'colsample_bytree': 0.747690
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[I 2025-05-31 02:39:49,706] Trial 7 finished with value: 0.005316503178811017 and parameters: {'n_estimators': 203, 'max_depth': 4, 'learning_rate': 0.16753555841031698, 'subsample': 0.6536794426412855, 'colsample_bytree': 0.572120
[I 2025-05-31 02:39:49,789] Trial 8 finished with value: 0.005355266031262248 and parameters: {'n_estimators': 111, 'max_depth': 8, 'learning_rate': 0.10827937910726294, 'subsample': 0.7607072082449557, 'colsample_bytree': 0.616994
[I 2025-05-31 02:39:49,921] Trial 9 finished with value: 0.005323756310901682 and parameters: {'n_estimators': 263, 'max_depth': 6, 'learning_rate': 0.2688348204966656, 'subsample': 0.9633283179190537, 'colsample_bytree': 0.6867096
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[I 2025-05-31 02:39:52,648] Trial 8 finished with value: 0.0020382830560263764 and parameters: {'n_estimators': 181, 'max_depth': 6, 'learning_rate': 0.04591451130717645, 'subsample': 0.9106707324736257, 'colsample_bytree': 0.74716
[I 2025-05-31 02:39:52,780] Trial 9 finished with value: 0.0020196172914242225 and parameters: {'n_estimators': 242, 'max_depth': 6, 'learning_rate': 0.07593801707235234, 'subsample': 0.6024817746300516, 'colsample_bytree': 0.87480
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[I 2025-05-31 02:39:53,890] Trial 18 finished with value: 0.0020832866696725077 and parameters: {'n_estimators': 86, 'max_depth': 4, 'learning_rate': 0.29768018304728944, 'subsample': 0.7796388140688588, 'colsample_bytree': 0.57155
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[I 2025-05-31 02:39:57,985] Trial 16 finished with value: 0.0013191799684788678 and parameters: {'n_estimators': 256, 'max_depth': 5, 'learning_rate': 0.04527758836950234, 'subsample': 0.6650762118328881, 'colsample_bytree': 0.8298
[I 2025-05-31 02:39:58,196] Trial 17 finished with value: 0.0012889242432402703 and parameters: {'n_estimators': 188, 'max_depth': 5, 'learning_rate': 0.022768605330537484, 'subsample': 0.5557186272282981, 'colsample_bytree': 0.837
[I 2025-05-31 02:39:58,446] Trial 18 finished with value: 0.0013227031949282037 and parameters: {'n_estimators': 254, 'max_depth': 7, 'learning_rate': 0.05845166887906841, 'subsample': 0.7925671710998246, 'colsample_bytree': 0.9808
[I 2025-05-31 02:39:58,647] Trial 19 finished with value: 0.0012816217645931806 and parameters: {'n_estimators': 125, 'max_depth': 4, 'learning_rate': 0.014315170371300201, 'subsample': 0.6755072628585591, 'colsample_bytree': 0.581
[I 2025-05-31 02:39:58,772] A new study created in memory with name: no-name-645320bf-529c-4931-94ad-90d027344d82
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[I 2025-05-31 02:39:59,118] Trial 2 finished with value: 0.003441854642884348 and parameters: {'n_estimators': 176, 'max_depth': 6, 'learning_rate': 0.12828348614379878, 'subsample': 0.7205310227840247, 'colsample_bytree': 0.906195
[I 2025-05-31 02:39:59,198] Trial 3 finished with value: 0.003401849957215082 and parameters: {'n_estimators': 95, 'max_depth': 5, 'learning_rate': 0.17094109621293258, 'subsample': 0.9812379881162134, 'colsample_bytree': 0.8753470
[I 2025-05-31 02:39:59,281] Trial 4 finished with value: 0.003406752730112938 and parameters: {'n_estimators': 122, 'max_depth': 5, 'learning_rate': 0.012509293148979427, 'subsample': 0.9936466411995477, 'colsample_bytree': 0.52075
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[I 2025-05-31 02:39:59,868] Trial 9 finished with value: 0.0034957171111410336 and parameters: {'n_estimators': 251, 'max_depth': 5, 'learning_rate': 0.22714150383629725, 'subsample': 0.6547991899530343, 'colsample_bytree': 0.94429
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[I 2025-05-31 02:40:00,113] Trial 11 finished with value: 0.0033994965830028 75 and parameters: {'n_estimators': 175, 'max_depth': 3, 'learning_rate': 0.08879225069715321, 'subsample': 0.8796049272002003, 'colsample_bytree': 0.66685
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[I 2025-05-31 02:40:00,526] Trial 14 finished with value: 0.0034271578773235837 and parameters: {'n_estimators': 213, 'max_depth': 4, 'learning_rate': 0.12184689898500838, 'subsample': 0.9155875707066645, 'colsample_bytree': 0.7038
[I 2025-05-31 02:40:00,647] Trial 15 finished with value: 0.0033936889982118072 and parameters: {'n_estimators': 140, 'max_depth': 7, 'learning_rate': 0.29896143712498885, 'subsample': 0.796167323511088, 'colsample_bytree': 0.82914
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[I 2025-05-31 02:40:00,844] Trial 17 finished with value: 0.0033718245782424455 and parameters: {'n_estimators': 52, 'max_depth': 4, 'learning_rate': 0.29773975204621567, 'subsample': 0.7957924139054664, 'colsample_bytree': 0.98022
[I 2025-05-31 02:40:00,936] Trial 18 finished with value: 0.0033634136375311754 and parameters: {'n_estimators': 56, 'max_depth': 4, 'learning_rate': 0.08728021997664782, 'subsample': 0.80112796335592, 'colsample_bytree': 0.9906676
[I 2025-05-31 02:40:01,028] Trial 19 finished with value: 0.0033446449026254582 and parameters: {'n_estimators': 54, 'max_depth': 4, 'learning_rate': 0.2932083102627389, 'subsample': 0.780134770606819, 'colsample_bytree': 0.9965371
[I 2025-05-31 02:40:01,100] A new study created in memory with name: no-name-1f8372ce-3802-4a50-8fca-1f6ee890a2ca
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[I 2025-05-31 02:40:01,384] Trial 1 finished with value: 0.0027309325724429847 and parameters: {'n_estimators': 217, 'max_depth': 4, 'learning_rate': 0.024935834997800894, 'subsample': 0.5104441574817509, 'colsample_bytree': 0.8303
[I 2025-05-31 02:40:01,463] Trial 2 finished with value: 0.002746399796392318 and parameters: {'n_estimators': 97, 'max_depth': 7, 'learning_rate': 0.03602608429220946, 'subsample': 0.8322549280991042, 'colsample_bytree': 0.6157577
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[I 2025-05-31 02:40:02,143] Trial 8 finished with value: 0.0027170257749557247 and parameters: {'n_estimators': 243, 'max_depth': 5, 'learning_rate': 0.05340804432179869, 'subsample': 0.6398642034046754, 'colsample_bytree': 0.50103
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[I 2025-05-31 02:40:25,845] Trial 13 finished with value: 0.007825048163900419 and parameters: {'n_estimators': 257, 'max_depth': 7, 'learning_rate': 0.13312509661413285, 'subsample': 0.5006327545219532, 'colsample_bytree': 0.88442
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[I 2025-05-31 02:40:26,420] Trial 17 finished with value: 0.007875219610629601 and parameters: {'n_estimators': 210, 'max_depth': 7, 'learning_rate': 0.04744706286643534, 'subsample': 0.5590898706782848, 'colsample_bytree': 0.993713
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[I 2025-05-31 02:40:27,528] Trial 5 finished with value: 0.001353922879040471 and parameters: {'n_estimators': 251, 'max_depth': 7, 'learning_rate': 0.010787402055598864, 'subsample': 0.8443084740186033, 'colsample_bytree': 0.7524
[I 2025-05-31 02:40:27,626] Trial 6 finished with value: 0.0013611450961288805 and parameters: {'n_estimators': 146, 'max_depth': 3, 'learning_rate': 0.12599599246957432, 'subsample': 0.9603773101446228, 'colsample_bytree': 0.939670
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[I 2025-05-31 02:40:27,925] Trial 9 finished with value: 0.0013554806581496169 and parameters: {'n_estimators': 248, 'max_depth': 8, 'learning_rate': 0.03373379398272743, 'subsample': 0.8834626642076409, 'colsample_bytree': 0.78122
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[I 2025-05-31 02:40:28,826] Trial 17 finished with value: 0.0013477566684913895 and parameters: {'n_estimators': 81, 'max_depth': 4, 'learning_rate': 0.15942093016079958, 'subsample': 0.5804731841649365, 'colsample_bytree': 0.66466
[I 2025-05-31 02:40:28,938] Trial 18 finished with value: 0.0013397947158289103 and parameters: {'n_estimators': 127, 'max_depth': 4, 'learning_rate': 0.04707868230491115, 'subsample': 0.6931948509646859, 'colsample_bytree': 0.8383
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[I 2025-05-31 02:40:29,174] A new study created in memory with name: no-name-28d98ce5-14d6-43b0-8575-81d5a8802157
[I 2025-05-31 02:40:29,304] Trial 0 finished with value: 0.001054828460498605 and parameters: {'n_estimators': 181, 'max_depth': 8, 'learning_rate': 0.05241893747640057, 'subsample': 0.6735767504659069, 'colsample_bytree': 0.707086
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[I 2025-05-31 02:40:34,740] Trial 4 finished with value: 0.004285761364256375 and parameters: {'n_estimators': 135, 'max_depth': 8, 'learning_rate': 0.025528781332269948, 'subsample': 0.7350849414946496, 'colsample_bytree': 0.65621
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[I 2025-05-31 02:40:36,028] Trial 9 finished with value: 0.004313066700036927 and parameters: {'n_estimators': 141, 'max_depth': 5, 'learning_rate': 0.0354904913906311, 'subsample': 0.5384036892445604, 'colsample_bytree': 0.5236768
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[I 2025-05-31 02:40:37,507] Trial 12 finished with value: 0.004254517354016825 and parameters: {'n_estimators': 261, 'max_depth': 4, 'learning_rate': 0.04705774449118274, 'subsample': 0.8828573567573552, 'colsample_bytree': 0.50895
[I 2025-05-31 02:40:37,693] Trial 13 finished with value: 0.004253740279761545 and parameters: {'n_estimators': 238, 'max_depth': 3, 'learning_rate': 0.2322919142476454, 'subsample': 0.8971701900746437, 'colsample_bytree': 0.624848
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[I 2025-05-31 02:40:38,122] Trial 15 finished with value: 0.004265502508044407 and parameters: {'n_estimators': 215, 'max_depth': 4, 'learning_rate': 0.2142598325069627, 'subsample': 0.9962241965243939, 'colsample_bytree': 0.617071
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[I 2025-05-31 02:40:38,430] Trial 17 finished with value: 0.004274168869658137 and parameters: {'n_estimators': 293, 'max_depth': 4, 'learning_rate': 0.18330046958578378, 'subsample': 0.9357168951989651, 'colsample_bytree': 0.68228
[I 2025-05-31 02:40:38,573] Trial 18 finished with value: 0.004296996332788665 and parameters: {'n_estimators': 194, 'max_depth': 7, 'learning_rate': 0.08032489405865524, 'subsample': 0.8544134536263943, 'colsample_bytree': 0.60186
[I 2025-05-31 02:40:38,717] Trial 19 finished with value: 0.004254006178229417 and parameters: {'n_estimators': 246, 'max_depth': 3, 'learning_rate': 0.15641611823465656, 'subsample': 0.9468791557808905, 'colsample_bytree': 0.68598
[I 2025-05-31 02:40:38,852] A new study created in memory with name: no-name-bec44f95-4131-452e-b8fa-8c2c65ce7236
[I 2025-05-31 02:40:38,998] Trial 0 finished with value: 0.0009688803839629819 and parameters: {'n_estimators': 148, 'max_depth': 6, 'learning_rate': 0.08959161133089034, 'subsample': 0.8900494069058826, 'colsample_bytree': 0.98230
[I 2025-05-31 02:40:39,079] Trial 1 finished with value: 0.0009426761134868688 and parameters: {'n_estimators': 110, 'max_depth': 5, 'learning_rate': 0.05151487484655184, 'subsample': 0.8475185565147476, 'colsample_bytree': 0.86678
[I 2025-05-31 02:40:39,197] Trial 2 finished with value: 0.0009387779643559868 and parameters: {'n_estimators': 223, 'max_depth': 5, 'learning_rate': 0.15438050725574595, 'subsample': 0.9843547883899477, 'colsample_bytree': 0.53372
[I 2025-05-31 02:40:39,285] Trial 3 finished with value: 0.00090073168667 2036 and parameters: {'n_estimators': 127, 'max_depth': 8, 'learning_rate': 0.04379240939209738, 'subsample': 0.9162214098155204, 'colsample_bytree': 0.651768
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[I 2025-05-31 02:40:39,527] Trial 5 finished with value: 0.0009461820623263865 and parameters: {'n_estimators': 212, 'max_depth': 7, 'learning_rate': 0.15552742081096993, 'subsample': 0.7724940604548509, 'colsample_bytree': 0.56788
[I 2025-05-31 02:40:39,667] Trial 6 finished with value: 0.0008375999254672941 and parameters: {'n_estimators': 299, 'max_depth': 4, 'learning_rate': 0.026237222311393745, 'subsample': 0.5316648552217804, 'colsample_bytree': 0.5720
[I 2025-05-31 02:40:39,755] Trial 7 finished with value: 0.0010611767423964968 and parameters: {'n_estimators': 130, 'max_depth': 6, 'learning_rate': 0.26940602762274185, 'subsample': 0.82353292263127, 'colsample_bytree': 0.678821
[I 2025-05-31 02:40:39,858] Trial 8 finished with value: 0.0008984075200289247 and parameters: {'n_estimators': 173, 'max_depth': 6, 'learning_rate': 0.12392101843554881, 'subsample': 0.8776542560728284, 'colsample_bytree': 0.90383
[I 2025-05-31 02:40:40,002] Trial 9 finished with value: 0.0009084020941796969 and parameters: {'n_estimators': 191, 'max_depth': 7, 'learning_rate': 0.06818324203127836, 'subsample': 0.5624165865633965, 'colsample_bytree': 0.53978
[I 2025-05-31 02:40:40,161] Trial 10 finished with value: 0.000911271972138678 and parameters: {'n_estimators': 286, 'max_depth': 3, 'learning_rate': 0.016239940991792632, 'subsample': 0.5005023945879221, 'colsample_bytree': 0.7951
[I 2025-05-31 02:40:40,245] Trial 11 finished with value: 0.0009001380389863972 and parameters: {'n_estimators': 50, 'max_depth': 3, 'learning_rate': 0.01785527356446438, 'subsample': 0.6708624339352347, 'colsample_bytree': 0.92591
[I 2025-05-31 02:40:40,408] Trial 12 finished with value: 0.0008768461173781159 and parameters: {'n_estimators': 299, 'max_depth': 4, 'learning_rate': 0.029102239406407517, 'subsample': 0.6525420454795481, 'colsample_bytree': 0.850
[I 2025-05-31 02:40:40,569] Trial 13 finished with value: 0.0009273618019223955 and parameters: {'n_estimators': 291, 'max_depth': 4, 'learning_rate': 0.02861236568253413, 'subsample': 0.6090801235686418, 'colsample_bytree': 0.8121
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[I 2025-05-31 02:40:40,894] Trial 15 finished with value: 0.0008195283805610673 and parameters: {'n_estimators': 300, 'max_depth': 4, 'learning_rate': 0.03027414479120624, 'subsample': 0.5093090407515084, 'colsample_bytree': 0.7539
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[I 2025-05-31 02:40:41,312] Trial 18 finished with value: 0.0008982830100079629 and parameters: {'n_estimators': 53, 'max_depth': 5, 'learning_rate': 0.03497657855560328, 'subsample': 0.7337608939756147, 'colsample_bytree': 0.74300
[I 2025-05-31 02:40:41,466] Trial 19 finished with value: 0.0009134691295331348 and parameters: {'n_estimators': 262, 'max_depth': 4, 'learning_rate': 0.01060108214542325, 'subsample': 0.5655964313167265, 'colsample_bytree': 0.7920
[I 2025-05-31 02:40:41,619] A new study created in memory with name: no-name-ef55d961-4d5c-4967-8294-145f024b5f74
[I 2025-05-31 02:40:41,725] Trial 0 finished with value: 0.0020588011980339008 and parameters: {'n_estimators': 113, 'max_depth': 5, 'learning_rate': 0.22488841455577935, 'subsample': 0.7324453445590271, 'colsample_bytree': 0.84835
[I 2025-05-31 02:40:41,804] Trial 1 finished with value: 0.0020614820846912526 and parameters: {'n_estimators': 96, 'max_depth': 4, 'learning_rate': 0.10516000101235586, 'subsample': 0.9643951690909331, 'colsample_bytree': 0.980748
[I 2025-05-31 02:40:41,868] Trial 2 finished with value: 0.001985844406736436 and parameters: {'n_estimators': 57, 'max_depth': 4, 'learning_rate': 0.1300476055723461, 'subsample': 0.7986340223611683, 'colsample_bytree': 0.89081800
[I 2025-05-31 02:40:42,006] Trial 3 finished with value: 0.0020191921320838356 and parameters: {'n_estimators': 289, 'max_depth': 4, 'learning_rate': 0.027188861468312044, 'subsample': 0.745678131850847, 'colsample_bytree': 0.66656
[I 2025-05-31 02:40:42,152] Trial 4 finished with value: 0.001956054580831334 and parameters: {'n_estimators': 261, 'max_depth': 3, 'learning_rate': 0.08171018901336365, 'subsample': 0.5028515248124077, 'colsample_bytree': 0.680296
[I 2025-05-31 02:40:42,292] Trial 5 finished with value: 0.0020399744414190358 and parameters: {'n_estimators': 286, 'max_depth': 5, 'learning_rate': 0.025962474189856574, 'subsample': 0.7981892774886439, 'colsample_bytree': 0.79444
[I 2025-05-31 02:40:42,411] Trial 6 finished with value: 0.0020356650422380415 and parameters: {'n_estimators': 242, 'max_depth': 3, 'learning_rate': 0.014611060750647048, 'subsample': 0.968941055503287, 'colsample_bytree': 0.60170
[I 2025-05-31 02:40:42,526] Trial 7 finished with value: 0.0019791048704101 and parameters: {'n_estimators': 229, 'max_depth': 4, 'learning_rate': 0.12293314497179739, 'subsample': 0.7776451571925276, 'colsample_bytree': 0.52917137
[I 2025-05-31 02:40:42,636] Trial 8 finished with value: 0.002063953215465095 and parameters: {'n_estimators': 215, 'max_depth': 8, 'learning_rate': 0.08121741264636902, 'subsample': 0.681928645302281, 'colsample_bytree': 0.5271621
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[I 2025-05-31 02:40:42,722] Trial 9 finished with value: 0.0019954174876552115 and parameters: {'n_estimators': 119, 'max_depth': 5, 'learning_rate': 0.014402898852441559, 'subsample': 0.5738376253159994, 'colsample_bytree': 0.9664
[I 2025-05-31 02:40:42,847] Trial 10 finished with value: 0.0019595588108172603 and parameters: {'n_estimators': 180, 'max_depth': 7, 'learning_rate': 0.04943872660995616, 'subsample': 0.5244291436159061, 'colsample_bytree': 0.6913
[I 2025-05-31 02:40:42,970] Trial 11 finished with value: 0.00196754809099915 and parameters: {'n_estimators': 172, 'max_depth': 7, 'learning_rate': 0.04759961325323318, 'subsample': 0.5169360705811655, 'colsample_bytree': 0.710665
[I 2025-05-31 02:40:43,136] Trial 12 finished with value: 0.0019514919634338848 and parameters: {'n_estimators': 179, 'max_depth': 7, 'learning_rate': 0.04693777383332031, 'subsample': 0.6054716069700165, 'colsample_bytree': 0.6434
[I 2025-05-31 02:40:43,262] Trial 13 finished with value: 0.001992775016340846 and parameters: {'n_estimators': 167, 'max_depth': 7, 'learning_rate': 0.03210165281084384, 'subsample': 0.6146444649898813, 'colsample_bytree': 0.61946
[I 2025-05-31 02:40:43,412] Trial 14 finished with value: 0.0020596199966733354 and parameters: {'n_estimators': 259, 'max_depth': 6, 'learning_rate': 0.27701029652698245, 'subsample': 0.6273891469291332, 'colsample_bytree': 0.7694
[I 2025-05-31 02:40:43,541] Trial 15 finished with value: 0.0019375771861568588 and parameters: {'n_estimators': 201, 'max_depth': 8, 'learning_rate': 0.07049006619554186, 'subsample': 0.504766811170556, 'colsample_bytree': 0.61361
[I 2025-05-31 02:40:43,675] Trial 16 finished with value: 0.0019401281579268775 and parameters: {'n_estimators': 202, 'max_depth': 8, 'learning_rate': 0.041026461314819844, 'subsample': 0.5859590597147111, 'colsample_bytree': 0.601
[I 2025-05-31 02:40:43,819] Trial 17 finished with value: 0.0020254303131185965 and parameters: {'n_estimators': 211, 'max_depth': 8, 'learning_rate': 0.07293824503161464, 'subsample': 0.6790706608086505, 'colsample_bytree': 0.5614
[I 2025-05-31 02:40:43,932] Trial 18 finished with value: 0.0020813317325195043 and parameters: {'n_estimators': 135, 'max_depth': 8, 'learning_rate': 0.16990201629876492, 'subsample': 0.8705572953508594, 'colsample_bytree': 0.5909
[I 2025-05-31 02:40:44,064] Trial 19 finished with value: 0.001986187699260725 and parameters: {'n_estimators': 196, 'max_depth': 6, 'learning_rate': 0.0104067014818423, 'subsample': 0.5519822330803995, 'colsample_bytree': 0.500799
[I 2025-05-31 02:40:44,212] A new study created in memory with name: no-name-ec94ffb1-62bb-4759-b5e3-6b7fda564c0b
[I 2025-05-31 02:40:44,359] Trial 0 finished with value: 0.00280531894868911 and parameters: {'n_estimators': 232, 'max_depth': 5, 'learning_rate': 0.16612530090692956, 'subsample': 0.9952083896182913, 'colsample_bytree': 0.6443248
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[I 2025-05-31 02:40:44,568] Trial 2 finished with value: 0.0028076921853245574 and parameters: {'n_estimators': 131, 'max_depth': 3, 'learning_rate': 0.0976391638940382, 'subsample': 0.5850127918149888, 'colsample_bytree': 0.806415
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MIDDLE_A
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[I 2025-05-31 02:40:53,998] A new study created in memory with name: no-name-f88a048b-c097-49c6-8bb2-a1d4a21c2715
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[I 2025-05-31 02:40:54,660] Trial 5 finished with value: 0.001234764858528784 and parameters: {'n_estimators': 222, 'max_depth': 4, 'learning_rate': 0.2651474631963093, 'subsample': 0.5108034326517066, 'colsample_bytree': 0.8350313
[I 2025-05-31 02:40:54,747] Trial 6 finished with value: 0.0012128317371828284 and parameters: {'n_estimators': 133, 'max_depth': 4, 'learning_rate': 0.022843740551286868, 'subsample': 0.6244670955339879, 'colsample_bytree': 0.5361
[I 2025-05-31 02:40:54,829] Trial 7 finished with value: 0.0012138734504418911 and parameters: {'n_estimators': 123, 'max_depth': 6, 'learning_rate': 0.08751117597995296, 'subsample': 0.5583080279303408, 'colsample_bytree': 0.53897
[I 2025-05-31 02:40:54,963] Trial 8 finished with value: 0.0012155334158413433 and parameters: {'n_estimators': 286, 'max_depth': 6, 'learning_rate': 0.14797264885955594, 'subsample': 0.7318715994994681, 'colsample_bytree': 0.55643
[I 2025-05-31 02:40:55,069] Trial 9 finished with value: 0.0012126954501285427 and parameters: {'n_estimators': 178, 'max_depth': 8, 'learning_rate': 0.17535947036248747, 'subsample': 0.5862374677692375, 'colsample_bytree': 0.95347
[I 2025-05-31 02:40:55,159] Trial 10 finished with value: 0.0012130451340726872 and parameters: {'n_estimators': 50, 'max_depth': 8, 'learning_rate': 0.044435162451438685, 'subsample': 0.9927019396719129, 'colsample_bytree': 0.6803
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[I 2025-05-31 02:40:55,615] Trial 15 finished with value: 0.0012158816625571435 and parameters: {'n_estimators': 73, 'max_depth': 7, 'learning_rate': 0.1268091938981934, 'subsample': 0.8212464143986246, 'colsample_bytree': 0.996028
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[I 2025-05-31 02:40:55,863] Trial 17 finished with value: 0.0012136114276070967 and parameters: {'n_estimators': 115, 'max_depth': 8, 'learning_rate': 0.027640394675386357, 'subsample': 0.9713806301298493, 'colsample_bytree': 0.845
[I 2025-05-31 02:40:55,982] Trial 18 finished with value: 0.0012157744270759312 and parameters: {'n_estimators': 155, 'max_depth': 7, 'learning_rate': 0.06958671707876438, 'subsample': 0.7647848575064744, 'colsample_bytree': 0.6261
[I 2025-05-31 02:40:56,075] Trial 19 finished with value: 0.0012128023426413229 and parameters: {'n_estimators': 71, 'max_depth': 5, 'learning_rate': 0.03560232485815082, 'subsample': 0.8964460425919117, 'colsample_bytree': 0.93974
[I 2025-05-31 02:40:56,150] A new study created in memory with name: no-name-bf909eaa-cd88-4bdf-92b0-13889c9151f6
[I 2025-05-31 02:40:56,248] Trial 0 finished with value: 0.0010376387071055686 and parameters: {'n_estimators': 75, 'max_depth': 3, 'learning_rate': 0.09924936382781456, 'subsample': 0.9320741311098194, 'colsample_bytree': 0.544480
[I 2025-05-31 02:40:56,352] Trial 1 finished with value: 0.0010644975000068252 and parameters: {'n_estimators': 184, 'max_depth': 5, 'learning_rate': 0.15574719774696616, 'subsample': 0.9706981809092063, 'colsample_bytree': 0.73453
[I 2025-05-31 02:40:56,466] Trial 2 finished with value: 0.0009926956532134792 and parameters: {'n_estimators': 193, 'max_depth': 6, 'learning_rate': 0.04692930324688102, 'subsample': 0.6437719997221516, 'colsample_bytree': 0.69164
[I 2025-05-31 02:40:56,558] Trial 3 finished with value: 0.0010585068964116904 and parameters: {'n_estimators': 138, 'max_depth': 4, 'learning_rate': 0.07840062407353829, 'subsample': 0.7424733598310612, 'colsample_bytree': 0.86255
[I 2025-05-31 02:40:56,685] Trial 4 finished with value: 0.0010132669641704783 and parameters: {'n_estimators': 178, 'max_depth': 3, 'learning_rate': 0.08823187817909486, 'subsample': 0.5037120423799231, 'colsample_bytree': 0.61041
[I 2025-05-31 02:40:56,819] Trial 5 finished with value: 0.001052739619758047 and parameters: {'n_estimators': 261, 'max_depth': 5, 'learning_rate': 0.01966412640489841, 'subsample': 0.9131745447908661, 'colsample_bytree': 0.671032
[I 2025-05-31 02:40:56,927] Trial 6 finished with value: 0.000917955799522448 and parameters: {'n_estimators': 203, 'max_depth': 6, 'learning_rate': 0.27563732654622414, 'subsample': 0.5654386994999125, 'colsample_bytree': 0.597433
[I 2025-05-31 02:40:57,032] Trial 7 finished with value: 0.000996735545580794 and parameters: {'n_estimators': 177, 'max_depth': 8, 'learning_rate': 0.014938520470599506, 'subsample': 0.5993319528397081, 'colsample_bytree': 0.88354
[I 2025-05-31 02:40:57,131] Trial 8 finished with value: 0.0010837563047860605 and parameters: {'n_estimators': 154, 'max_depth': 8, 'learning_rate': 0.09201481745555946, 'subsample': 0.8163841840685477, 'colsample_bytree': 0.86274
[I 2025-05-31 02:40:57,223] Trial 9 finished with value: 0.001012294692186741 and parameters: {'n_estimators': 145, 'max_depth': 6, 'learning_rate': 0.17702811009071845, 'subsample': 0.6516394951557052, 'colsample_bytree': 0.900216
[I 2025-05-31 02:40:57,383] Trial 10 finished with value: 0.0010049305007912518 and parameters: {'n_estimators': 299, 'max_depth': 7, 'learning_rate': 0.2894186234598207, 'subsample': 0.5138668632320238, 'colsample_bytree': 0.51681
[I 2025-05-31 02:40:57,524] Trial 11 finished with value: 0.0009897099556742974 and parameters: {'n_estimators': 231, 'max_depth': 6, 'learning_rate': 0.0313767795352947, 'subsample': 0.6367635863774247, 'colsample_bytree': 0.74220
[I 2025-05-31 02:40:57,708] Trial 12 finished with value: 0.0010363722166115402 and parameters: {'n_estimators': 232, 'max_depth': 7, 'learning_rate': 0.03375541595047653, 'subsample': 0.7250021607718371, 'colsample_bytree': 0.9939
[I 2025-05-31 02:40:57,860] Trial 13 finished with value: 0.0009937031966713928 and parameters: {'n_estimators': 260, 'max_depth': 6, 'learning_rate': 0.025378377416751786, 'subsample': 0.5916697673947247, 'colsample_bytree': 0.793
[I 2025-05-31 02:40:58,002] Trial 14 finished with value: 0.0009524623158205776 and parameters: {'n_estimators': 223, 'max_depth': 7, 'learning_rate': 0.045590443293347584, 'subsample': 0.5838339085038745, 'colsample_bytree': 0.604
[I 2025-05-31 02:40:58,104] Trial 15 finished with value: 0.0010022152068613396 and parameters: {'n_estimators': 109, 'max_depth': 7, 'learning_rate': 0.010990245563519187, 'subsample': 0.5445088969296575, 'colsample_bytree': 0.587
MIDDLE_B
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[I 2025-05-31 02:41:01,064] Trial 17 finished with value: 0.0017775135703165454 and parameters: {'n_estimators': 233, 'max_depth': 6, 'learning_rate': 0.03390782744726724, 'subsample': 0.6786384679329271, 'colsample_bytree': 0.8771
[I 2025-05-31 02:41:01,185] Trial 18 finished with value: 0.0017849323896872453 and parameters: {'n_estimators': 52, 'max_depth': 4, 'learning_rate': 0.023651266124574875, 'subsample': 0.5630734446897521, 'colsample_bytree': 0.5372
[I 2025-05-31 02:41:01,372] Trial 19 finished with value: 0.001785827365956246 and parameters: {'n_estimators': 138, 'max_depth': 8, 'learning_rate': 0.08223202628611372, 'subsample': 0.6821326785701666, 'colsample_bytree': 0.77116
[I 2025-05-31 02:41:02,046] A new study created in memory with name: no-name-9b071a6d-734c-4702-b093-569a770dd483
[I 2025-05-31 02:41:02,272] Trial 0 finished with value: 0.007346481311452576 and parameters: {'n_estimators': 225, 'max_depth': 8, 'learning_rate': 0.0231031825842261, 'subsample': 0.8979351072030299, 'colsample_bytree': 0.537454
[I 2025-05-31 02:41:03,214] Trial 1 finished with value: 0.007334551462909022 and parameters: {'n_estimators': 170, 'max_depth': 8, 'learning_rate': 0.023151488566742005, 'subsample': 0.909658450866387, 'colsample_bytree': 0.790157
[I 2025-05-31 02:41:03,429] Trial 2 finished with value: 0.007347596393863918 and parameters: {'n_estimators': 299, 'max_depth': 7, 'learning_rate': 0.1397455125083823, 'subsample': 0.6821687393429766, 'colsample_bytree': 0.9061675
[I 2025-05-31 02:41:03,607] Trial 3 finished with value: 0.007338686224820774 and parameters: {'n_estimators': 187, 'max_depth': 6, 'learning_rate': 0.11332753473035756, 'subsample': 0.9809693115628552, 'colsample_bytree': 0.563684
[I 2025-05-31 02:41:03,794] Trial 4 finished with value: 0.007338727392466688 and parameters: {'n_estimators': 204, 'max_depth': 4, 'learning_rate': 0.028796413889102028, 'subsample': 0.9542218494316811, 'colsample_bytree': 0.89355
[I 2025-05-31 02:41:04,041] Trial 5 finished with value: 0.007323611203180196 5 and parameters: {'n_estimators': 249, 'max_depth': 5, 'learning_rate': 0.2295485191173976, 'subsample': 0.973195376516091, 'colsample_bytree': 0.7277289
[I 2025-05-31 02:41:04,262] Trial 6 finished with value: 0.007338092296630286 and parameters: {'n_estimators': 115, 'max_depth': 6, 'learning_rate': 0.04113687655363338, 'subsample': 0.9570540393616536, 'colsample_bytree': 0.619537
[I 2025-05-31 02:41:04,357] Trial 7 finished with value: 0.007340631559964074 and parameters: {'n_estimators': 139, 'max_depth': 6, 'learning_rate': 0.054341608881903064, 'subsample': 0.7201544050852289, 'colsample_bytree': 0.87623
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[I 2025-05-31 02:41:04,723] Trial 11 finished with value: 0.007311462496572382 5 and parameters: {'n_estimators': 52, 'max_depth': 4, 'learning_rate': 0.26819489296092125, 'subsample': 0.5050888931593024, 'colsample_bytree': 0.72943
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[I 2025-05-31 02:41:05,670] Trial 0 finished with value: 0.002850661710544 1465 and parameters: {'n_estimators': 126, 'max_depth': 5, 'learning_rate': 0.020970928454815876, 'subsample': 0.779945964625 1871, 'colsample_bytree': 0.7123
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[I 2025-05-31 02:41:05,943] Trial 3 finished with value: 0.002836473091814351 and parameters: {'n_estimators': 173, 'max_depth': 4, 'learning_rate': 0.014265644810288892, 'subsample': 0.5665230732174049, 'colsample_bytree': 0.99444
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[I 2025-05-31 02:41:06,746] Trial 11 finished with value: 0.002836709513604 4127 and parameters: {'n_estimators': 176, 'max_depth': 3, 'learning_rate': 0.011327353513579561, 'subsample': 0.5793300301383726, 'colsample_bytree': 0.982
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[I 2025-05-31 02:41:07,779] Trial 19 finished with value: 0.002801471115084 4977 and parameters: {'n_estimators': 158, 'max_depth': 5, 'learning_rate': 0.12727872328167486, 'subsample': 0.5200908794636789, 'colsample_bytree': 0.6675
[I 2025-05-31 02:41:07,881] A new study created in memory with name: no-name-8e71e05b-6ae8-41df-abde-53d15d18672a
[I 2025-05-31 02:41:08,038] Trial 0 finished with value: 0.003031917683835012 and parameters: {'n_estimators': 224, 'max_depth': 3, 'learning_rate': 0.08598415624449475, 'subsample': 0.5953503589407009, 'colsample_bytree': 0.762081
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[I 2025-05-31 02:41:08,345] Trial 3 finished with value: 0.003014043514738 2786 and parameters: {'n_estimators': 208, 'max_depth': 3, 'learning_rate': 0.11191128975654172, 'subsample': 0.6203175198019999, 'colsample_bytree': 0.94921
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[I 2025-05-31 02:41:09,356] Trial 11 finished with value: 0.003032497014871 9655 and parameters: {'n_estimators': 139, 'max_depth': 7, 'learning_rate': 0.06395923197234672, 'subsample': 0.504323698647087, 'colsample_bytree': 0.98796
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[I 2025-05-31 02:41:10,120] Trial 17 finished with value: 0.003044659561172 8212 and parameters: {'n_estimators': 162, 'max_depth': 5, 'learning_rate': 0.06955549825245678, 'subsample': 0.7368228974075675, 'colsample_bytree': 0.7686
[I 2025-05-31 02:41:10,220] Trial 18 finished with value: 0.003070972712672 1482 and parameters: {'n_estimators': 99, 'max_depth': 7, 'learning_rate': 0.12147322224341423, 'subsample': 0.7343419824268742, 'colsample_bytree': 0.70717
[I 2025-05-31 02:41:10,342] Trial 19 finished with value: 0.003055543423144911 and parameters: {'n_estimators': 167, 'max_depth': 3, 'learning_rate': 0.011037163968836984, 'subsample': 0.8462494114829757, 'colsample_bytree': 0.5026
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[I 2025-05-31 02:41:10,785] Trial 2 finished with value: 0.001555635842782 1807 and parameters: {'n_estimators': 178, 'max_depth': 5, 'learning_rate': 0.2849291639172699, 'subsample': 0.717054999575067, 'colsample_bytree': 0.6488860
[I 2025-05-31 02:41:10,882] Trial 3 finished with value: 0.0015994891030950075 and parameters: {'n_estimators': 159, 'max_depth': 8, 'learning_rate': 0.010428423406799716, 'subsample': 0.8737339302195694, 'colsample_bytree': 0.9734
[I 2025-05-31 02:41:10,945] Trial 4 finished with value: 0.0015919302715972767 and parameters: {'n_estimators': 52, 'max_depth': 7, 'learning_rate': 0.012107403157029354, 'subsample': 0.9053199408727959, 'colsample_bytree': 0.99023
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[I 2025-05-31 02:41:11,344] Trial 7 finished with value: 0.0015824806153060655 and parameters: {'n_estimators': 151, 'max_depth': 8, 'learning_rate': 0.2440460248691369, 'subsample': 0.8966323531602762, 'colsample_bytree': 0.878516
[I 2025-05-31 02:41:11,485] Trial 8 finished with value: 0.0016049080581428074 and parameters: {'n_estimators': 280, 'max_depth': 5, 'learning_rate': 0.08677442902888201, 'subsample': 0.8846640977841498, 'colsample_bytree': 0.95191
[I 2025-05-31 02:41:11,575] Trial 9 finished with value: 0.0016037939933418563 and parameters: {'n_estimators': 130, 'max_depth': 4, 'learning_rate': 0.010107634314743087, 'subsample': 0.8003965057895777, 'colsample_bytree': 0.5395
[I 2025-05-31 02:41:11,709] Trial 10 finished with value: 0.001634601114259627 and parameters: {'n_estimators': 207, 'max_depth': 6, 'learning_rate': 0.029681994941803076, 'subsample': 0.6381266844551324, 'colsample_bytree': 0.6628
[I 2025-05-31 02:41:11,811] Trial 11 finished with value: 0.001624759156735293 and parameters: {'n_estimators': 93, 'max_depth': 4, 'learning_rate': 0.2969077194191027, 'subsample': 0.685698019047014, 'colsample_bytree': 0.74298548
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[I 2025-05-31 02:41:12,038] Trial 13 finished with value: 0.0016043913164216575 and parameters: {'n_estimators': 194, 'max_depth': 3, 'learning_rate': 0.15595949337553128, 'subsample': 0.7020175479282698, 'colsample_bytree': 0.6589
[I 2025-05-31 02:41:12,148] Trial 14 finished with value: 0.001640988582472928 and parameters: {'n_estimators': 122, 'max_depth': 6, 'learning_rate': 0.0456191450182737, 'subsample': 0.5999909137454296, 'colsample_bytree': 0.817000
[I 2025-05-31 02:41:12,298] Trial 15 finished with value: 0.0015893070335758525 and parameters: {'n_estimators': 234, 'max_depth': 3, 'learning_rate': 0.15419464017129564, 'subsample': 0.9917521592138665, 'colsample_bytree': 0.6434
[I 2025-05-31 02:41:12,388] Trial 16 finished with value: 0.00158301520993007 and parameters: {'n_estimators': 67, 'max_depth': 5, 'learning_rate': 0.21686043965965368, 'subsample': 0.7452924465893804, 'colsample_bytree': 0.8105741
[I 2025-05-31 02:41:12,515] Trial 17 finished with value: 0.001595136223949277 and parameters: {'n_estimators': 177, 'max_depth': 4, 'learning_rate': 0.05622907566336317, 'subsample': 0.987285571284556, 'colsample_bytree': 0.606082
[I 2025-05-31 02:41:12,622] Trial 18 finished with value: 0.001621762111383193 and parameters: {'n_estimators': 124, 'max_depth': 6, 'learning_rate': 0.12558541440933824, 'subsample': 0.746630810195010 4, 'colsample_bytree': 0.69985
[I 2025-05-31 02:41:12,779] Trial 19 finished with value: 0.0016387903637635616 and parameters: {'n_estimators': 242, 'max_depth': 3, 'learning_rate': 0.04924051002409225, 'subsample': 0.573550330927994 1, 'colsample_bytree': 0.8022
[I 2025-05-31 02:41:12,889] A new study created in memory with name: no-name-7fd12081-2b52-4115-b916-0ba67e07f27a
[I 2025-05-31 02:41:13,031] Trial 0 finished with value: 0.003751198689390739 and parameters: {'n_estimators': 158, 'max_depth': 6, 'learning_rate': 0.02991936421972919, 'subsample': 0.8794544150873216, 'colsample_bytree': 0.888078
[I 2025-05-31 02:41:13,143] Trial 1 finished with value: 0.003751298911216 3005 and parameters: {'n_estimators': 208, 'max_depth': 5, 'learning_rate': 0.23707124871343635, 'subsample': 0.5543640737558484, 'colsample_bytree': 0.60673
[I 2025-05-31 02:41:13,311] Trial 2 finished with value: 0.003751112618551 2866 and parameters: {'n_estimators': 266, 'max_depth': 5, 'learning_rate': 0.022250651983994583, 'subsample': 0.6479059480329907, 'colsample_bytree': 0.9755
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[I 2025-05-31 02:41:13,657] Trial 5 finished with value: 0.003751108458989877 and parameters: {'n_estimators': 296, 'max_depth': 6, 'learning_rate': 0.17925584878020542, 'subsample': 0.9897051276704716, 'colsample_bytree': 0.527902
[I 2025-05-31 02:41:13,746] Trial 6 finished with value: 0.003751198391590 1946 and parameters: {'n_estimators': 140, 'max_depth': 8, 'learning_rate': 0.2236685315507177, 'subsample': 0.8285060410960711, 'colsample_bytree': 0.688897
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[I 2025-05-31 02:41:38,305] Trial 4 finished with value: 0.0010622902256595538 and parameters: {'n_estimators': 178, 'max_depth': 3, 'learning_rate': 0.03589100452885773, 'subsample': 0.8793249621499268, 'colsample_bytree': 0.68791
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[I 2025-05-31 02:41:39,739] Trial 15 finished with value: 0.001047301264574941 and parameters: {'n_estimators': 217, 'max_depth': 7, 'learning_rate': 0.07994546349069556, 'subsample': 0.597199708117073, 'colsample_bytree': 0.880238
[I 2025-05-31 02:41:39,897] Trial 16 finished with value: 0.0010578472442001846 and parameters: {'n_estimators': 261, 'max_depth': 5, 'learning_rate': 0.15177188580407697, 'subsample': 0.5633454818171972, 'colsample_bytree': 0.8672
[I 2025-05-31 02:41:40,050] Trial 17 finished with value: 0.0010557657290360524 and parameters: {'n_estimators': 269, 'max_depth': 7, 'learning_rate': 0.13693331080002322, 'subsample': 0.633010845067354, 'colsample_bytree': 0.71330
[I 2025-05-31 02:41:40,183] Trial 18 finished with value: 0.0010396005907004039 and parameters: {'n_estimators': 196, 'max_depth': 8, 'learning_rate': 0.07233816327197497, 'subsample': 0.501896980505214, 'colsample_bytree': 0.9554
[I 2025-05-31 02:41:40,345] Trial 19 finished with value: 0.0010440420610476895 and parameters: {'n_estimators': 236, 'max_depth': 6, 'learning_rate': 0.024254311799408297, 'subsample': 0.65463404029387, 'colsample_bytree': 0.8137
[I 2025-05-31 02:41:40,494] A new study created in memory with name: no-name-8f26535d-af03-42d9-aa29-36a67fc3b9d1
[I 2025-05-31 02:41:40,634] Trial 0 finished with value: 0.0011881861143805009 and parameters: {'n_estimators': 71, 'max_depth': 8, 'learning_rate': 0.2748968918190025, 'subsample': 0.920808970892651, 'colsample_bytree': 0.60542966
[I 2025-05-31 02:41:40,753] Trial 1 finished with value: 0.0011348041765082864 and parameters: {'n_estimators': 185, 'max_depth': 4, 'learning_rate': 0.029363747052017074, 'subsample': 0.5615037958190472, 'colsample_bytree': 0.8629
[I 2025-05-31 02:41:40,983] Trial 2 finished with value: 0.0011346086622564672 and parameters: {'n_estimators': 239, 'max_depth': 5, 'learning_rate': 0.05305549748190922, 'subsample': 0.5685888921044928, 'colsample_bytree': 0.87857
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[I 2025-05-31 02:41:41,887] Trial 4 finished with value: 0.001130307750543133 and parameters: {'n_estimators': 238, 'max_depth': 8, 'learning_rate': 0.014063674159342144, 'subsample': 0.794301609134815, 'colsample_bytree': 0.540819
[I 2025-05-31 02:41:42,836] Trial 5 finished with value: 0.0011187300586904382 and parameters: {'n_estimators': 194, 'max_depth': 3, 'learning_rate': 0.02729870372699134, 'subsample': 0.9643821419935785, 'colsample_bytree': 0.80768
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[I 2025-05-31 02:41:43,485] Trial 8 finished with value: 0.0011314981780719314 and parameters: {'n_estimators': 211, 'max_depth': 7, 'learning_rate': 0.010212267814516165, 'subsample': 0.8202684298304603, 'colsample_bytree': 0.8120
[I 2025-05-31 02:41:43,609] Trial 9 finished with value: 0.0011263681024358903 and parameters: {'n_estimators': 130, 'max_depth': 4, 'learning_rate': 0.17353836217555896, 'subsample': 0.6723547120724549, 'colsample_bytree': 0.73230
[I 2025-05-31 02:41:43,920] Trial 10 finished with value: 0.0010872538702086788 and parameters: {'n_estimators': 300, 'max_depth': 6, 'learning_rate': 0.09170784033525727, 'subsample': 0.8693696144042228, 'colsample_bytree': 0.6833
[I 2025-05-31 02:41:44,085] Trial 11 finished with value: 0.0010932992081254258 and parameters: {'n_estimators': 296, 'max_depth': 6, 'learning_rate': 0.08682454063322971, 'subsample': 0.8734033235949185, 'colsample_bytree': 0.6724
[I 2025-05-31 02:41:44,240] Trial 12 finished with value: 0.0011051698479163563 and parameters: {'n_estimators': 282, 'max_depth': 6, 'learning_rate': 0.07523983495624358, 'subsample': 0.8837418644629036, 'colsample_bytree': 0.6714
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[I 2025-05-31 02:41:44,570] Trial 14 finished with value: 0.0011252749803626612 and parameters: {'n_estimators': 260, 'max_depth': 5, 'learning_rate': 0.038622690475595606, 'subsample': 0.9968005021120161, 'colsample_bytree': 0.599
[I 2025-05-31 02:41:44,671] Trial 15 finished with value: 0.001157251587790568 and parameters: {'n_estimators': 99, 'max_depth': 6, 'learning_rate': 0.05693547897623614, 'subsample': 0.7148864851720502, 'colsample_bytree': 0.744658
[I 2025-05-31 02:41:44,835] Trial 16 finished with value: 0.0010737365734458481 and parameters: {'n_estimators': 299, 'max_depth': 7, 'learning_rate': 0.2597941382329733, 'subsample': 0.8808663860436935, 'colsample_bytree': 0.61103
[I 2025-05-31 02:41:44,986] Trial 17 finished with value: 0.001082473660846154 and parameters: {'n_estimators': 259, 'max_depth': 7, 'learning_rate': 0.2651227801220123, 'subsample': 0.9320429573861295, 'colsample_bytree': 0.557039
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[I 2025-05-31 02:41:45,292] Trial 19 finished with value: 0.0011975033002641223 and parameters: {'n_estimators': 266, 'max_depth': 7, 'learning_rate': 0.17568578438057242, 'subsample': 0.818604691661418l, 'colsample_bytree': 0.9842
[I 2025-05-31 02:41:45,451] A new study created in memory with name: no-name-7470dec0-bb71-4a19-844d-196a8956dcf0
[I 2025-05-31 02:41:45,570] Trial 0 finished with value: 0.0007060286295713747 and parameters: {'n_estimators': 152, 'max_depth': 4, 'learning_rate': 0.01296608003371252, 'subsample': 0.8848795954314419, 'colsample_bytree': 0.98092
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[I 2025-05-31 02:41:45,774] Trial 2 finished with value: 0.0006900327132537331 and parameters: {'n_estimators': 110, 'max_depth': 5, 'learning_rate': 0.024681729347196483, 'subsample': 0.6946601631945879, 'colsample_bytree': 0.9490
[I 2025-05-31 02:41:45,842] Trial 3 finished with value: 0.0007077196690531126 and parameters: {'n_estimators': 60, 'max_depth': 5, 'learning_rate': 0.01845094755252696, 'subsample': 0.787825613754924, 'colsample_bytree': 0.9303164
[I 2025-05-31 02:41:45,947] Trial 4 finished with value: 0.0007046879423185732 and parameters: {'n_estimators': 188, 'max_depth': 6, 'learning_rate': 0.016032189968126196, 'subsample': 0.649494496356984, 'colsample_bytree': 0.7160
[I 2025-05-31 02:41:46,043] Trial 5 finished with value: 0.000684198267950874 and parameters: {'n_estimators': 118, 'max_depth': 8, 'learning_rate': 0.0904800402538317, 'subsample': 0.6375410912977422, 'colsample_bytree': 0.5714260
[I 2025-05-31 02:41:46,172] Trial 6 finished with value: 0.0006890004173592638 and parameters: {'n_estimators': 251, 'max_depth': 5, 'learning_rate': 0.039780192337766127, 'subsample': 0.816957363251693, 'colsample_bytree': 0.9817
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[I 2025-05-31 02:41:46,397] Trial 8 finished with value: 0.0007058901381662752 and parameters: {'n_estimators': 177, 'max_depth': 7, 'learning_rate': 0.010112503348628019, 'subsample': 0.859432099219092, 'colsample_bytree': 0.9160
[I 2025-05-31 02:41:46,460] Trial 9 finished with value: 0.0007439244925292694 and parameters: {'n_estimators': 54, 'max_depth': 3, 'learning_rate': 0.1480613212310151, 'subsample': 0.7803437627983489, 'colsample_bytree': 0.9265034
[I 2025-05-31 02:41:46,619] Trial 10 finished with value: 0.000809642715652205 and parameters: {'n_estimators': 294, 'max_depth': 8, 'learning_rate': 0.28167096008142783, 'subsample': 0.5124651247782639, 'colsample_bytree': 0.50211
[I 2025-05-31 02:41:46,782] Trial 11 finished with value: 0.0006939140522298914 and parameters: {'n_estimators': 285, 'max_depth': 8, 'learning_rate': 0.05531654170216761, 'subsample': 0.5627322069040421, 'colsample_bytree': 0.5902
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[I 2025-05-31 02:41:47,047] Trial 13 finished with value: 0.0007235484044013298 and parameters: {'n_estimators': 255, 'max_depth': 6, 'learning_rate': 0.08518110602410321, 'subsample': 0.8534448393256089, 'colsample_bytree': 0.6645
[I 2025-05-31 02:41:47,159] Trial 14 finished with value: 0.000682475093128629 and parameters: {'n_estimators': 119, 'max_depth': 7, 'learning_rate': 0.04257015175194171, 'subsample': 0.613396778685888, 'colsample_bytree': 0.805886
[I 2025-05-31 02:41:47,269] Trial 15 finished with value: 0.0006203825923681434 and parameters: {'n_estimators': 105, 'max_depth': 7, 'learning_rate': 0.0839737895628876, 'subsample': 0.5835115393186043, 'colsample_bytree': 0.82197
[I 2025-05-31 02:41:47,367] Trial 16 finished with value: 0.0006863267673982691 and parameters: {'n_estimators': 90, 'max_depth': 7, 'learning_rate': 0.15999025166847355, 'subsample': 0.5604668183019401, 'colsample_bytree': 0.82877
[I 2025-05-31 02:41:47,494] Trial 17 finished with value: 0.0006841046173004236 and parameters: {'n_estimators': 144, 'max_depth': 7, 'learning_rate': 0.06459891546794501, 'subsample': 0.5753170685566219, 'colsample_bytree': 0.8318
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[I 2025-05-31 02:41:48,311] Trial 19 finished with value: 0.0006635933788735031 and parameters: {'n_estimators': 145, 'max_depth': 7, 'learning_rate': 0.03358474561581974, 'subsample': 0.5181730459448733, 'colsample_bytree': 0.7862
[I 2025-05-31 02:41:48,448] A new study created in memory with name: no-name-1433e808-11c4-423c-b5f3-934cf28be8fb
[I 2025-05-31 02:41:49,538] Trial 0 finished with value: 0.0014996709900167854 and parameters: {'n_estimators': 275, 'max_depth': 4, 'learning_rate': 0.028158701549576018, 'subsample': 0.8141729909611501, 'colsample_bytree': 0.6879
[I 2025-05-31 02:41:49,839] Trial 1 finished with value: 0.0014985081092706279 and parameters: {'n_estimators': 258, 'max_depth': 4, 'learning_rate': 0.023772354389520207, 'subsample': 0.7670524657837878, 'colsample_bytree': 0.5423
[I 2025-05-31 02:41:50,058] Trial 2 finished with value: 0.0014998082190427204 and parameters: {'n_estimators': 218, 'max_depth': 6, 'learning_rate': 0.011174595467086271, 'subsample': 0.8873891674993937, 'colsample_bytree': 0.9250
[I 2025-05-31 02:41:50,209] Trial 3 finished with value: 0.0015139448171434737 and parameters: {'n_estimators': 149, 'max_depth': 8, 'learning_rate': 0.10993095440190494, 'subsample': 0.6706389660963041, 'colsample_bytree': 0.94172
[I 2025-05-31 02:41:50,406] Trial 4 finished with value: 0.001492322125887893 and parameters: {'n_estimators': 295, 'max_depth': 3, 'learning_rate': 0.048444039419746766, 'subsample': 0.5303656118924548, 'colsample_bytree': 0.63278
[I 2025-05-31 02:41:50,494] Trial 5 finished with value: 0.0014983586644201031 and parameters: {'n_estimators': 124, 'max_depth': 8, 'learning_rate': 0.07771125177553044, 'subsample': 0.5323387495606258, 'colsample_bytree': 0.73105
[I 2025-05-31 02:41:50,579] Trial 6 finished with value: 0.0014947132655400352 and parameters: {'n_estimators': 121, 'max_depth': 5, 'learning_rate': 0.013432912784839159, 'subsample': 0.7206030513531558, 'colsample_bytree': 0.5697
[I 2025-05-31 02:41:50,667] Trial 7 finished with value: 0.0014890415169012067 and parameters: {'n_estimators': 62, 'max_depth': 3, 'learning_rate': 0.0377232503631957, 'subsample': 0.5783488497176148, 'colsample_bytree': 0.6915969
[I 2025-05-31 02:41:50,808] Trial 8 finished with value: 0.0014886956464354507 and parameters: {'n_estimators': 278, 'max_depth': 6, 'learning_rate': 0.23876433713054954, 'subsample': 0.8531224908269475, 'colsample_bytree': 0.74677
[I 2025-05-31 02:41:50,926] Trial 9 finished with value: 0.0014975927643244874 and parameters: {'n_estimators': 202, 'max_depth': 7, 'learning_rate': 0.011793626552687377, 'subsample': 0.7039317750424474, 'colsample_bytree': 0.6944
[I 2025-05-31 02:41:51,073] Trial 10 finished with value: 0.0014928068361180664 and parameters: {'n_estimators': 239, 'max_depth': 6, 'learning_rate': 0.2932652420661034, 'subsample': 0.9798915522667611, 'colsample_bytree': 0.83496
[I 2025-05-31 02:41:51,168] Trial 11 finished with value: 0.001486803092428558 and parameters: {'n_estimators': 61, 'max_depth': 3, 'learning_rate': 0.2512803471215565, 'subsample': 0.6018963227547707, 'colsample_bytree': 0.8332411
[I 2025-05-31 02:41:51,260] Trial 12 finished with value: 0.0015017595994927739 and parameters: {'n_estimators': 55, 'max_depth': 5, 'learning_rate': 0.20687122713548242, 'subsample': 0.8740289073427056, 'colsample_bytree': 0.82361
[I 2025-05-31 02:41:51,381] Trial 13 finished with value: 0.0015149935818082488 and parameters: {'n_estimators': 178, 'max_depth': 7, 'learning_rate': 0.15337150470304967, 'subsample': 0.6585124186581246, 'colsample_bytree': 0.8342
[I 2025-05-31 02:41:51,486] Trial 14 finished with value: 0.0014942434191251499 and parameters: {'n_estimators': 95, 'max_depth': 4, 'learning_rate': 0.2999035424231764, 'subsample': 0.605461440722997, 'colsample_bytree': 0.7804466
[I 2025-05-31 02:41:51,614] Trial 15 finished with value: 0.0014958837230356205 and parameters: {'n_estimators': 173, 'max_depth': 6, 'learning_rate': 0.13620603049319338, 'subsample': 0.9826190645636647, 'colsample_bytree': 0.9944
[I 2025-05-31 02:41:51,742] Trial 16 finished with value: 0.0015035300382305156 and parameters: {'n_estimators': 91, 'max_depth': 7, 'learning_rate': 0.10054336283155683, 'subsample': 0.8132310032239903, 'colsample_bytree': 0.88105
[I 2025-05-31 02:41:51,882] Trial 17 finished with value: 0.0014952028367927314 and parameters: {'n_estimators': 224, 'max_depth': 5, 'learning_rate': 0.2056366014721522, 'subsample': 0.9048095110488679, 'colsample_bytree': 0.76621
[I 2025-05-31 02:41:52,019] Trial 18 finished with value: 0.0015046703053588084 and parameters: {'n_estimators': 189, 'max_depth': 3, 'learning_rate': 0.06900793261063923, 'subsample': 0.7782309860388534, 'colsample_bytree': 0.6290
[I 2025-05-31 02:41:52,141] Trial 19 finished with value: 0.0014953551480675553 and parameters: {'n_estimators': 157, 'max_depth': 4, 'learning_rate': 0.18951788766331162, 'subsample': 0.5970895943246454, 'colsample_bytree': 0.8862
[I 2025-05-31 02:41:52,216] A new study created in memory with name: no-name-55889d00-634f-4432-b775-9592e32d4a57
[I 2025-05-31 02:41:52,327] Trial 0 finished with value: 0.002394849104564495 and parameters: {'n_estimators': 105, 'max_depth': 3, 'learning_rate': 0.2792884678972202, 'subsample': 0.6250717359895754, 'colsample_bytree': 0.8545528
[I 2025-05-31 02:41:52,461] Trial 1 finished with value: 0.0022308216022329853 and parameters: {'n_estimators': 266, 'max_depth': 6, 'learning_rate': 0.28934675675704036, 'subsample': 0.5225820181444731, 'colsample_bytree': 0.615252
[I 2025-05-31 02:41:52,530] Trial 2 finished with value: 0.002374955294140419 and parameters: {'n_estimators': 55, 'max_depth': 7, 'learning_rate': 0.026412071083842213, 'subsample': 0.6770380598060659, 'colsample_bytree': 0.827992
[I 2025-05-31 02:41:52,614] Trial 3 finished with value: 0.002367445958933424 and parameters: {'n_estimators': 99, 'max_depth': 3, 'learning_rate': 0.0251381073656097, 'subsample': 0.9640861878841624, 'colsample_bytree': 0.6363643
[I 2025-05-31 02:41:52,778] Trial 4 finished with value: 0.0023655930754817403 and parameters: {'n_estimators': 225, 'max_depth': 8, 'learning_rate': 0.014582873831128924, 'subsample': 0.5545835889391528, 'colsample_bytree': 0.9983
[I 2025-05-31 02:41:52,876] Trial 5 finished with value: 0.002363092311848942 and parameters: {'n_estimators': 163, 'max_depth': 3, 'learning_rate': 0.01116543300929429, 'subsample': 0.9811709548863514, 'colsample_bytree': 0.65838
[I 2025-05-31 02:41:52,987] Trial 6 finished with value: 0.002370625995318506 and parameters: {'n_estimators': 186, 'max_depth': 7, 'learning_rate': 0.010071815798034543, 'subsample': 0.8067057499986863, 'colsample_bytree': 0.60774
[I 2025-05-31 02:41:53,102] Trial 7 finished with value: 0.002343719698657755 and parameters: {'n_estimators': 211, 'max_depth': 3, 'learning_rate': 0.06121093393093758, 'subsample': 0.8311856417572675, 'colsample_bytree': 0.85025
[I 2025-05-31 02:41:53,242] Trial 8 finished with value: 0.002350687999174153 and parameters: {'n_estimators': 297, 'max_depth': 6, 'learning_rate': 0.0341829554590732, 'subsample': 0.8582538831965558, 'colsample_bytree': 0.530998
[I 2025-05-31 02:41:53,317] Trial 9 finished with value: 0.0023700030849739657 and parameters: {'n_estimators': 80, 'max_depth': 8, 'learning_rate': 0.03563533917118501, 'subsample': 0.7094334972769203, 'colsample_bytree': 0.898051
[I 2025-05-31 02:41:53,472] Trial 10 finished with value: 0.002286877172698983 and parameters: {'n_estimators': 268, 'max_depth': 4, 'learning_rate': 0.277414421907541, 'subsample': 0.5322323670958076, 'colsample_bytree': 0.7300066
[I 2025-05-31 02:41:53,636] Trial 11 finished with value: 0.002365176598491168 and parameters: {'n_estimators': 296, 'max_depth': 5, 'learning_rate': 0.262626905382015, 'subsample': 0.523874194866729, 'colsample_bytree': 0.73050490
[I 2025-05-31 02:41:53,828] Trial 12 finished with value: 0.002311980039974306 and parameters: {'n_estimators': 249, 'max_depth': 5, 'learning_rate': 0.12771909019647265, 'subsample': 0.5936286340892012, 'colsample_bytree': 0.72927
[I 2025-05-31 02:41:54,047] Trial 13 finished with value: 0.0023716424800548333 and parameters: {'n_estimators': 237, 'max_depth': 6, 'learning_rate': 0.14923839561382526, 'subsample': 0.5055598989005697, 'colsample_bytree': 0.5428
[I 2025-05-31 02:41:54,841] Trial 14 finished with value: 0.0022989043683857703 and parameters: {'n_estimators': 266, 'max_depth': 4, 'learning_rate': 0.13348227957615497, 'subsample': 0.6372666730608229, 'colsample_bytree': 0.6768
[I 2025-05-31 02:41:55,019] Trial 15 finished with value: 0.0023414334467661076 and parameters: {'n_estimators': 155, 'max_depth': 5, 'learning_rate': 0.07513956940741764, 'subsample': 0.5729941330787154, 'colsample_bytree': 0.7875
[I 2025-05-31 02:41:56,018] Trial 16 finished with value: 0.0022445406230152394 and parameters: {'n_estimators': 265, 'max_depth': 4, 'learning_rate': 0.19888704665098408, 'subsample': 0.5039244305893549, 'colsample_bytree': 0.5834
[I 2025-05-31 02:41:56,299] Trial 17 finished with value: 0.002306921441337113 and parameters: {'n_estimators': 200, 'max_depth': 4, 'learning_rate': 0.1587028672819774, 'subsample': 0.7525961517561147, 'colsample_bytree': 0.582699
[I 2025-05-31 02:41:56,489] Trial 18 finished with value: 0.0023368198365886703 and parameters: {'n_estimators': 255, 'max_depth': 4, 'learning_rate': 0.1926528869644673, 'subsample': 0.5025880490225799, 'colsample_bytree': 0.51260
[I 2025-05-31 02:41:56,649] Trial 19 finished with value: 0.0024056305302676876 and parameters: {'n_estimators': 144, 'max_depth': 7, 'learning_rate': 0.08883172637744934, 'subsample': 0.6391441149786525, 'colsample_bytree': 0.5812
[I 2025-05-31 02:41:56,979] A new study created in memory with name: no-name-c4a3ec4a-cb3f-4ea4-8803-6a404d8f5893
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[I 2025-05-31 02:42:16,541] Trial 18 finished with value: 0.0020058220227540387 and parameters: {'n_estimators': 292, 'max_depth': 5, 'learning_rate': 0.026299770301032185, 'subsample': 0.6348001606174274, 'colsample_bytree': 0.554
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[I 2025-05-31 02:42:17,007] Trial 1 finished with value: 0.0017635067509307787 and parameters: {'n_estimators': 178, 'max_depth': 6, 'learning_rate': 0.13719297991234405, 'subsample': 0.6871982620611012, 'colsample_bytree': 0.93234
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[I 2025-05-31 02:42:17,868] Trial 9 finished with value: 0.0017439571672179309 and parameters: {'n_estimators': 199, 'max_depth': 7, 'learning_rate': 0.024868669138725263, 'subsample': 0.5470558427811703, 'colsample_bytree': 0.6182
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[I 2025-05-31 02:42:18,659] Trial 16 finished with value: 0.0017870719605245927 and parameters: {'n_estimators': 218, 'max_depth': 6, 'learning_rate': 0.1956491220237452, 'subsample': 0.5849292248001949, 'colsample_bytree': 0.99177
[I 2025-05-31 02:42:18,759] Trial 17 finished with value: 0.0017485909677945617 and parameters: {'n_estimators': 91, 'max_depth': 5, 'learning_rate': 0.1694867064048587, 'subsample': 0.536449887094462, 'colsample_bytree': 0.5760416
[I 2025-05-31 02:42:18,876] Trial 18 finished with value: 0.0017754340836787293 and parameters: {'n_estimators': 153, 'max_depth': 6, 'learning_rate': 0.2901722238560667, 'subsample': 0.6479867417230318, 'colsample_bytree': 0.67547
[I 2025-05-31 02:42:19,031] Trial 19 finished with value: 0.0017807005439049648 and parameters: {'n_estimators': 260, 'max_depth': 4, 'learning_rate': 0.040630054169986426, 'subsample': 0.5730618440560713, 'colsample_bytree': 0.782
[I 2025-05-31 02:42:19,135] A new study created in memory with name: no-name-3b930ac0-8442-475f-a7ce-74b9e8c95abf
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[I 2025-05-31 02:42:19,860] Trial 6 finished with value: 0.0007658481689986778 and parameters: {'n_estimators': 83, 'max_depth': 8, 'learning_rate': 0.1161905403083239, 'subsample': 0.8395589398811073, 'colsample_bytree': 0.6342801
[I 2025-05-31 02:42:20,009] Trial 7 finished with value: 0.0007875443389115001 and parameters: {'n_estimators': 272, 'max_depth': 5, 'learning_rate': 0.12346502293383003, 'subsample': 0.9597809297344659, 'colsample_bytree': 0.51916
[I 2025-05-31 02:42:20,154] Trial 8 finished with value: 0.0007867315399664766 and parameters: {'n_estimators': 249, 'max_depth': 8, 'learning_rate': 0.011294627056372486, 'subsample': 0.5689275349833061, 'colsample_bytree': 0.8973
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[I 2025-05-31 02:42:28,294] A new study created in memory with name: no-name-9f5492e4-c185-4055-9dbf-3648b0139c93
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[I 2025-05-31 02:42:28,706] Trial 2 finished with value: 0.0012949511641506444 and parameters: {'n_estimators': 252, 'max_depth': 7, 'learning_rate': 0.16534054621622152, 'subsample': 0.5071609397963793, 'colsample_bytree': 0.69466
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[I 2025-05-31 02:42:30,501] Trial 16 finished with value: 0.0013184054730266785 and parameters: {'n_estimators': 194, 'max_depth': 6, 'learning_rate': 0.025394272574454112, 'subsample': 0.7240504760369779, 'colsample_bytree': 0.500
[I 2025-05-31 02:42:30,653] Trial 17 finished with value: 0.0013146873953478336 and parameters: {'n_estimators': 257, 'max_depth': 5, 'learning_rate': 0.08057630988064594, 'subsample': 0.5924569966426879, 'colsample_bytree': 0.7290
[I 2025-05-31 02:42:30,764] Trial 18 finished with value: 0.001300945324434651 and parameters: {'n_estimators': 142, 'max_depth': 7, 'learning_rate': 0.15239946738558344, 'subsample': 0.7817309055399885, 'colsample_bytree': 0.61863
[I 2025-05-31 02:42:31,023] Trial 19 finished with value: 0.0013136196398896524 and parameters: {'n_estimators': 211, 'max_depth': 4, 'learning_rate': 0.01389967757783768, 'subsample': 0.6827936618805192, 'colsample_bytree': 0.8302
[I 2025-05-31 02:42:31,159] A new study created in memory with name: no-name-37f0e0e9-de6a-4f68-a2ce-1bdaadd4fc7e
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[I 2025-05-31 02:42:31,441] Trial 2 finished with value: 0.0014762327441069558 and parameters: {'n_estimators': 223, 'max_depth': 3, 'learning_rate': 0.027895181129084203, 'subsample': 0.5677269825627216, 'colsample_bytree': 0.5217
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[I 2025-05-31 02:42:31,914] Trial 6 finished with value: 0.0014745091992751482 and parameters: {'n_estimators': 279, 'max_depth': 7, 'learning_rate': 0.05389786126828267, 'subsample': 0.6336010953755682, 'colsample_bytree': 0.63364
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[I 2025-05-31 02:42:32,191] Trial 9 finished with value: 0.0014720503667206208 and parameters: {'n_estimators': 150, 'max_depth': 6, 'learning_rate': 0.010606474769386205, 'subsample': 0.6148642610046315, 'colsample_bytree': 0.9036
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[I 2025-05-31 02:42:41,736] Trial 17 finished with value: 0.0028955608877688013 and parameters: {'n_estimators': 156, 'max_depth': 6, 'learning_rate': 0.023609554529500046, 'subsample': 0.6388997452783587, 'colsample_bytree': 0.709
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[I 2025-05-31 02:42:41,995] Trial 19 finished with value: 0.002861030018707241 and parameters: {'n_estimators': 122, 'max_depth': 4, 'learning_rate': 0.06812290205376727, 'subsample': 0.5533097997025792, 'colsample_bytree': 0.89816
[I 2025-05-31 02:42:42,068] A new study created in memory with name: no-name-fa3179cf-010a-49b4-b660-61c3b78d60f1
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[I 2025-05-31 02:42:42,340] Trial 2 finished with value: 0.003236562152066512 and parameters: {'n_estimators': 171, 'max_depth': 6, 'learning_rate': 0.12256982844308323, 'subsample': 0.5700846976628293, 'colsample_bytree': 0.536923
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[I 2025-05-31 02:42:43,594] Trial 12 finished with value: 0.003208818074803344 and parameters: {'n_estimators': 300, 'max_depth': 8, 'learning_rate': 0.12325581873408996, 'subsample': 0.9897625556062113, 'colsample_bytree': 0.77795
[I 2025-05-31 02:42:43,761] Trial 13 finished with value: 0.0031869553938483584 and parameters: {'n_estimators': 298, 'max_depth': 7, 'learning_rate': 0.28401260467769934, 'subsample': 0.8211119746059072, 'colsample_bytree': 0.6921
[I 2025-05-31 02:42:43,918] Trial 14 finished with value: 0.003190974903670399 and parameters: {'n_estimators': 272, 'max_depth': 7, 'learning_rate': 0.17287131295497352, 'subsample': 0.7999450410772634, 'colsample_bytree': 0.68995
[I 2025-05-31 02:42:44,075] Trial 15 finished with value: 0.003218374559097173 and parameters: {'n_estimators': 264, 'max_depth': 7, 'learning_rate': 0.17503114415764157, 'subsample': 0.773886688541873, 'colsample_bytree': 0.697780
[I 2025-05-31 02:42:44,200] Trial 16 finished with value: 0.003231816027854034 and parameters: {'n_estimators': 181, 'max_depth': 7, 'learning_rate': 0.19161098494894208, 'subsample': 0.6819770351116758, 'colsample_bytree': 0.68382
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[I 2025-05-31 02:42:44,488] Trial 18 finished with value: 0.0032012036931711976 and parameters: {'n_estimators': 275, 'max_depth': 7, 'learning_rate': 0.06347034288241572, 'subsample': 0.7289886700789653, 'colsample_bytree': 0.6401
[I 2025-05-31 02:42:44,636] Trial 19 finished with value: 0.0032093440866960464 and parameters: {'n_estimators': 229, 'max_depth': 5, 'learning_rate': 0.0399148211864137, 'subsample': 0.503241023350339, 'colsample_bytree': 0.714131
[I 2025-05-31 02:42:44,791] A new study created in memory with name: no-name-94390cd9-9d9e-4f97-8a43-0ea6dd210c81
[I 2025-05-31 02:42:44,929] Trial 0 finished with value: 0.0024516236717470534 and parameters: {'n_estimators': 176, 'max_depth': 6, 'learning_rate': 0.07180700697956428, 'subsample': 0.9552669559015485, 'colsample_bytree': 0.85863
[I 2025-05-31 02:42:45,067] Trial 1 finished with value: 0.002452545074027962 and parameters: {'n_estimators': 277, 'max_depth': 3, 'learning_rate': 0.05778103163530516, 'subsample': 0.8805292815365071, 'colsample_bytree': 0.815408
[I 2025-05-31 02:42:45,181] Trial 2 finished with value: 0.0024458059363856107 and parameters: {'n_estimators': 212, 'max_depth': 5, 'learning_rate': 0.04093184445443176, 'subsample': 0.6145895894910709, 'colsample_bytree': 0.75770
[I 2025-05-31 02:42:45,286] Trial 3 finished with value: 0.002453670054887306 and parameters: {'n_estimators': 176, 'max_depth': 6, 'learning_rate': 0.022888738299573472, 'subsample': 0.9697512646136707, 'colsample_bytree': 0.57451
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[I 2025-05-31 02:42:45,481] Trial 5 finished with value: 0.002453604405016033 and parameters: {'n_estimators': 74, 'max_depth': 7, 'learning_rate': 0.015043692141404122, 'subsample': 0.9714533384639952, 'colsample_bytree': 0.659295
[I 2025-05-31 02:42:45,615] Trial 6 finished with value: 0.0024541753187495414 and parameters: {'n_estimators': 262, 'max_depth': 3, 'learning_rate': 0.0420390861946615, 'subsample': 0.9760957378122043, 'colsample_bytree': 0.850350
[I 2025-05-31 02:42:45,726] Trial 7 finished with value: 0.002447214803630115 and parameters: {'n_estimators': 91, 'max_depth': 7, 'learning_rate': 0.028472920965503745, 'subsample': 0.6874191446634031, 'colsample_bytree': 0.960211
[I 2025-05-31 02:42:45,837] Trial 8 finished with value: 0.0024511143766377456 and parameters: {'n_estimators': 192, 'max_depth': 4, 'learning_rate': 0.1264089175932537, 'subsample': 0.8369006631237457, 'colsample_bytree': 0.633442
[I 2025-05-31 02:42:45,925] Trial 9 finished with value: 0.0024450383873293687 and parameters: {'n_estimators': 134, 'max_depth': 7, 'learning_rate': 0.01472691724447433, 'subsample': 0.5927210905756933, 'colsample_bytree': 0.57195
[I 2025-05-31 02:42:46,030] Trial 10 finished with value: 0.0024611749222532993 and parameters: {'n_estimators': 123, 'max_depth': 8, 'learning_rate': 0.2289698231745806, 'subsample': 0.502786867060794, 'colsample_bytree': 0.501340
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[I 2025-05-31 02:42:46,412] Trial 12 finished with value: 0.002439316807001186 and parameters: {'n_estimators': 234, 'max_depth': 7, 'learning_rate': 0.018784910768190822, 'subsample': 0.5815758679272374, 'colsample_bytree': 0.5449
[I 2025-05-31 02:42:47,153] Trial 13 finished with value: 0.002438137167777183 and parameters: {'n_estimators': 226, 'max_depth': 5, 'learning_rate': 0.017637811492317055, 'subsample': 0.5481956044525654, 'colsample_bytree': 0.5108
[I 2025-05-31 02:42:47,341] Trial 14 finished with value: 0.0024356507250337415 and parameters: {'n_estimators': 227, 'max_depth': 5, 'learning_rate': 0.021446560020980464, 'subsample': 0.5154774919247945, 'colsample_bytree': 0.510
[I 2025-05-31 02:42:47,606] Trial 15 finished with value: 0.002439504754014203 and parameters: {'n_estimators': 217, 'max_depth': 5, 'learning_rate': 0.010763271794903936, 'subsample': 0.5093026394313327, 'colsample_bytree': 0.5018
[I 2025-05-31 02:42:48,442] Trial 16 finished with value: 0.002447582193533633 and parameters: {'n_estimators': 295, 'max_depth': 4, 'learning_rate': 0.027833761967775077, 'subsample': 0.6567321046610582, 'colsample_bytree': 0.7233
[I 2025-05-31 02:42:48,693] Trial 17 finished with value: 0.002441503738506052 and parameters: {'n_estimators': 254, 'max_depth': 4, 'learning_rate': 0.02955626002204363, 'subsample': 0.5487743430349908, 'colsample_bytree': 0.58764
[I 2025-05-31 02:42:49,006] Trial 18 finished with value: 0.0024427775834600673 and parameters: {'n_estimators': 214, 'max_depth': 5, 'learning_rate': 0.08180995901790794, 'subsample': 0.6649638173240329, 'colsample_bytree': 0.9605
[I 2025-05-31 02:42:49,279] Trial 19 finished with value: 0.002441308033245421 and parameters: {'n_estimators': 155, 'max_depth': 6, 'learning_rate': 0.016042160908251224, 'subsample': 0.5526948569029224, 'colsample_bytree': 0.7283
[I 2025-05-31 02:42:49,406] A new study created in memory with name: no-name-994e811f-f775-495c-aa85-f3460b0f75e4
[I 2025-05-31 02:42:49,523] Trial 0 finished with value: 0.0019349836695023103 and parameters: {'n_estimators': 159, 'max_depth': 7, 'learning_rate': 0.10442173527895988, 'subsample': 0.7762711925206793, 'colsample_bytree': 0.71563
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[I 2025-05-31 02:42:49,792] Trial 3 finished with value: 0.001901740994009155 and parameters: {'n_estimators': 136, 'max_depth': 5, 'learning_rate': 0.03199448266263058, 'subsample': 0.739988042695586, 'colsample_bytree': 0.5287502
[I 2025-05-31 02:42:49,916] Trial 4 finished with value: 0.0019365381491534086 and parameters: {'n_estimators': 121, 'max_depth': 4, 'learning_rate': 0.258437646919947, 'subsample': 0.8491222805320121, 'colsample_bytree': 0.6717784
[I 2025-05-31 02:42:50,040] Trial 5 finished with value: 0.0019159269172572685 and parameters: {'n_estimators': 231, 'max_depth': 3, 'learning_rate': 0.012189951644398159, 'subsample': 0.5431915376428849, 'colsample_bytree': 0.7916
[I 2025-05-31 02:42:50,171] Trial 6 finished with value: 0.001916149248648479 and parameters: {'n_estimators': 282, 'max_depth': 7, 'learning_rate': 0.038172072576436775, 'subsample': 0.7860468412925595, 'colsample_bytree': 0.56443
[I 2025-05-31 02:42:50,239] Trial 7 finished with value: 0.001899541880678577 and parameters: {'n_estimators': 60, 'max_depth': 7, 'learning_rate': 0.06616150042378334, 'subsample': 0.8363073512450135, 'colsample_bytree': 0.9025342
[I 2025-05-31 02:42:50,346] Trial 8 finished with value: 0.0019123632727204634 and parameters: {'n_estimators': 183, 'max_depth': 7, 'learning_rate': 0.03015705620232613, 'subsample': 0.9990696132632413, 'colsample_bytree': 0.60172
[I 2025-05-31 02:42:50,473] Trial 9 finished with value: 0.001821944370336974 and parameters: {'n_estimators': 260, 'max_depth': 6, 'learning_rate': 0.2920898156392001, 'subsample': 0.6204823904269845, 'colsample_bytree': 0.6112569
[I 2025-05-31 02:42:50,634] Trial 10 finished with value: 0.001910824628732661 and parameters: {'n_estimators': 281, 'max_depth': 8, 'learning_rate': 0.24347631039962117, 'subsample': 0.6397854547618207, 'colsample_bytree': 0.63616
[I 2025-05-31 02:42:50,721] Trial 11 finished with value: 0.0019012996496682185 and parameters: {'n_estimators': 66, 'max_depth': 6, 'learning_rate': 0.08617699667743783, 'subsample': 0.8820060937232013, 'colsample_bytree': 0.80084
[I 2025-05-31 02:42:50,870] Trial 12 finished with value: 0.0018555951526168287 and parameters: {'n_estimators': 232, 'max_depth': 6, 'learning_rate': 0.12399216457522595, 'subsample': 0.6859424080001921, 'colsample_bytree': 0.8658
[I 2025-05-31 02:42:51,023] Trial 13 finished with value: 0.0018371075780991405 and parameters: {'n_estimators': 234, 'max_depth': 6, 'learning_rate': 0.1486614157010486, 'subsample': 0.6626195805794012, 'colsample_bytree': 0.85607
[I 2025-05-31 02:42:51,169] Trial 14 finished with value: 0.0018948098498634202 and parameters: {'n_estimators': 237, 'max_depth': 5, 'learning_rate': 0.16821023921692668, 'subsample': 0.5443633571185089, 'colsample_bytree': 0.7363
[I 2025-05-31 02:42:51,326] Trial 15 finished with value: 0.0019702151514608625 and parameters: {'n_estimators': 253, 'max_depth': 4, 'learning_rate': 0.17282311616568446, 'subsample': 0.6058554761171557, 'colsample_bytree': 0.8393
[I 2025-05-31 02:42:51,462] Trial 16 finished with value: 0.0019327384865736317 and parameters: {'n_estimators': 212, 'max_depth': 6, 'learning_rate': 0.2905797820352522, 'subsample': 0.6924259281001145, 'colsample_bytree': 0.50811
[I 2025-05-31 02:42:51,633] Trial 17 finished with value: 0.001966980264985253 and parameters: {'n_estimators': 298, 'max_depth': 8, 'learning_rate': 0.15068783903830485, 'subsample': 0.5092551327900596, 'colsample_bytree': 0.98470
[I 2025-05-31 02:42:51,788] Trial 18 finished with value: 0.0018983112631290524 and parameters: {'n_estimators': 265, 'max_depth': 4, 'learning_rate': 0.06180516803975867, 'subsample': 0.6983676812173281, 'colsample_bytree': 0.6875
[I 2025-05-31 02:42:51,959] Trial 19 finished with value: 0.0019564453696624034 and parameters: {'n_estimators': 211, 'max_depth': 6, 'learning_rate': 0.19875896016934946, 'subsample': 0.5892827395115267, 'colsample_bytree': 0.7804
[I 2025-05-31 02:42:52,096] A new study created in memory with name: no-name-9a5444fd-278b-454d-945f-4903965fa9df
[I 2025-05-31 02:42:52,234] Trial 0 finished with value: 0.0051592847921452375 and parameters: {'n_estimators': 220, 'max_depth': 6, 'learning_rate': 0.21920515082771472, 'subsample': 0.579693410714289, 'colsample_bytree': 0.584700
[I 2025-05-31 02:42:52,356] Trial 1 finished with value: 0.005165412659782174 and parameters: {'n_estimators': 220, 'max_depth': 5, 'learning_rate': 0.17000182763485416, 'subsample': 0.7808193707864743, 'colsample_bytree': 0.566520
[I 2025-05-31 02:42:52,460] Trial 2 finished with value: 0.005169231403515768 and parameters: {'n_estimators': 176, 'max_depth': 6, 'learning_rate': 0.15777218835878815, 'subsample': 0.7610808999943838, 'colsample_bytree': 0.674613
[I 2025-05-31 02:42:52,605] Trial 3 finished with value: 0.005185742565850548 and parameters: {'n_estimators': 298, 'max_depth': 8, 'learning_rate': 0.07851024118097176, 'subsample': 0.5254236674729206, 'colsample_bytree': 0.717771
[I 2025-05-31 02:42:52,679] Trial 4 finished with value: 0.00517061979093528 and parameters: {'n_estimators': 89, 'max_depth': 6, 'learning_rate': 0.010638530380453159, 'subsample': 0.5979697361048011, 'colsample_bytree': 0.6996973
[I 2025-05-31 02:42:52,770] Trial 5 finished with value: 0.00517130534845296 and parameters: {'n_estimators': 127, 'max_depth': 8, 'learning_rate': 0.12737418713403764, 'subsample': 0.7647052690175988, 'colsample_bytree': 0.7813826
[I 2025-05-31 02:42:52,889] Trial 6 finished with value: 0.005172747141299515 and parameters: {'n_estimators': 226, 'max_depth': 8, 'learning_rate': 0.032505737497472716, 'subsample': 0.6361886380935888, 'colsample_bytree': 0.75360
[I 2025-05-31 02:42:53,021] Trial 7 finished with value: 0.00516742799652881 and parameters: {'n_estimators': 132, 'max_depth': 3, 'learning_rate': 0.0735479919480454, 'subsample': 0.9331598459121399, 'colsample_bytree': 0.55221180
[I 2025-05-31 02:42:53,119] Trial 8 finished with value: 0.005178331261188993 and parameters: {'n_estimators': 163, 'max_depth': 6, 'learning_rate': 0.06712387783418725, 'subsample': 0.7848564052009022, 'colsample_bytree': 0.546559
[I 2025-05-31 02:42:53,237] Trial 9 finished with value: 0.005171325537051758 and parameters: {'n_estimators': 194, 'max_depth': 3, 'learning_rate': 0.01936165019622774, 'subsample': 0.6808344748140684, 'colsample_bytree': 0.801163
[I 2025-05-31 02:42:53,401] Trial 10 finished with value: 0.005211528444793958 and parameters: {'n_estimators': 280, 'max_depth': 5, 'learning_rate': 0.2839768983619027, 'subsample': 0.5395184007364173, 'colsample_bytree': 0.966183
[I 2025-05-31 02:42:53,544] Trial 11 finished with value: 0.005171348475515564 and parameters: {'n_estimators': 235, 'max_depth': 5, 'learning_rate': 0.2881274015748429, 'subsample': 0.8957229032004945, 'colsample_bytree': 0.610823
[I 2025-05-31 02:42:53,687] Trial 12 finished with value: 0.005164346332940237 and parameters: {'n_estimators': 238, 'max_depth': 4, 'learning_rate': 0.14314411731051285, 'subsample': 0.8511844005763505, 'colsample_bytree': 0.52535
[I 2025-05-31 02:42:53,834] Trial 13 finished with value: 0.005186743258687821 and parameters: {'n_estimators': 259, 'max_depth': 4, 'learning_rate': 0.12113688942264825, 'subsample': 0.8592156007297496, 'colsample_bytree': 0.51700
[I 2025-05-31 02:42:53,985] Trial 14 finished with value: 0.005170833252723832 and parameters: {'n_estimators': 255, 'max_depth': 7, 'learning_rate': 0.22376246587962703, 'subsample': 0.9847521257707419, 'colsample_bytree': 0.62844
[I 2025-05-31 02:42:54,121] Trial 15 finished with value: 0.005172099807604188 and parameters: {'n_estimators': 204, 'max_depth': 4, 'learning_rate': 0.04203775559765366, 'subsample': 0.699959982601916, 'colsample_bytree': 0.84055
[I 2025-05-31 02:42:54,205] Trial 16 finished with value: 0.005163810524229468 and parameters: {'n_estimators': 51, 'max_depth': 4, 'learning_rate': 0.10307058140234604, 'subsample': 0.8171483592247981, 'colsample_bytree': 0.616510
[I 2025-05-31 02:42:54,294] Trial 17 finished with value: 0.005170627720012131 and parameters: {'n_estimators': 68, 'max_depth': 7, 'learning_rate': 0.08439395862083056, 'subsample': 0.588864543217265, 'colsample_bytree': 0.6254118
[I 2025-05-31 02:42:54,381] Trial 18 finished with value: 0.005170913622060317 and parameters: {'n_estimators': 53, 'max_depth': 7, 'learning_rate': 0.04521207126186423, 'subsample': 0.7038148895877463, 'colsample_bytree': 0.875716
[I 2025-05-31 02:42:54,488] Trial 19 finished with value: 0.005171897417863199 and parameters: {'n_estimators': 121, 'max_depth': 4, 'learning_rate': 0.09861206564485005, 'subsample': 0.8127635807261255, 'colsample_bytree': 0.60533
[I 2025-05-31 02:42:54,611] A new study created in memory with name: no-name-56a3f3a2-dbee-45e0-865a-44fbf1c17740
[I 2025-05-31 02:42:54,721] Trial 0 finished with value: 0.003881785626204128 and parameters: {'n_estimators': 98, 'max_depth': 3, 'learning_rate': 0.0940572159356918, 'subsample': 0.7145962119588962, 'colsample_bytree': 0.80269823
[I 2025-05-31 02:42:54,850] Trial 1 finished with value: 0.0038605621132776742 and parameters: {'n_estimators': 259, 'max_depth': 4, 'learning_rate': 0.04619808587993679, 'subsample': 0.5562306272323573, 'colsample_bytree': 0.53388
[I 2025-05-31 02:42:54,960] Trial 2 finished with value: 0.003889233830162436 and parameters: {'n_estimators': 191, 'max_depth': 3, 'learning_rate': 0.01056184854508883, 'subsample': 0.6935447565279032, 'colsample_bytree': 0.61029
[I 2025-05-31 02:42:55,125] Trial 3 finished with value: 0.003881386880264394 and parameters: {'n_estimators': 247, 'max_depth': 4, 'learning_rate': 0.013192296489214507, 'subsample': 0.7654883446342917, 'colsample_bytree': 0.7173
[I 2025-05-31 02:42:55,224] Trial 4 finished with value: 0.003892265097722904 and parameters: {'n_estimators': 161, 'max_depth': 6, 'learning_rate': 0.03155175372611558, 'subsample': 0.7625946454330343, 'colsample_bytree': 0.875117
[I 2025-05-31 02:42:55,321] Trial 5 finished with value: 0.0038913020539134025 and parameters: {'n_estimators': 149, 'max_depth': 6, 'learning_rate': 0.05771769708198103, 'subsample': 0.6417857341941112, 'colsample_bytree': 0.99630
[I 2025-05-31 02:42:55,432] Trial 6 finished with value: 0.0038886336247059114 and parameters: {'n_estimators': 193, 'max_depth': 8, 'learning_rate': 0.013728798397417478, 'subsample': 0.7165220878250615, 'colsample_bytree': 0.6763
[I 2025-05-31 02:42:55,535] Trial 7 finished with value: 0.0038907306083872314 and parameters: {'n_estimators': 169, 'max_depth': 7, 'learning_rate': 0.019899780164971587, 'subsample': 0.7638024424800011, 'colsample_bytree': 0.92464
[I 2025-05-31 02:42:55,616] Trial 8 finished with value: 0.00381946443739727 and parameters: {'n_estimators': 111, 'max_depth': 3, 'learning_rate': 0.1137048068365677, 'subsample': 0.5558485364874821, 'colsample_bytree': 0.7709670
[I 2025-05-31 02:42:55,708] Trial 9 finished with value: 0.0038874829564375588 and parameters: {'n_estimators': 146, 'max_depth': 5, 'learning_rate': 0.024138852736038868, 'subsample': 0.8328399230181587, 'colsample_bytree': 0.6493
[I 2025-05-31 02:42:55,803] Trial 10 finished with value: 0.003904394605294506 and parameters: {'n_estimators': 54, 'max_depth': 4, 'learning_rate': 0.2810837735300105, 'subsample': 0.9537319620941724, 'colsample_bytree': 0.7950181
[I 2025-05-31 02:42:55,965] Trial 11 finished with value: 0.003906483913504356 and parameters: {'n_estimators': 296, 'max_depth': 4, 'learning_rate': 0.12342758426310614, 'subsample': 0.5033615122186686, 'colsample_bytree': 0.51560
[I 2025-05-31 02:42:56,192] Trial 12 finished with value: 0.003843226131090514 and parameters: {'n_estimators': 237, 'max_depth': 3, 'learning_rate': 0.05126496214977617, 'subsample': 0.517477247292875, 'colsample_bytree': 0.510334
[I 2025-05-31 02:42:56,308] Trial 13 finished with value: 0.0038782099237143924 and parameters: {'n_estimators': 108, 'max_depth': 3, 'learning_rate': 0.13502651154770273, 'subsample': 0.5779571826719355, 'colsample_bytree': 0.7811
[I 2025-05-31 02:42:56,449] Trial 14 finished with value: 0.0038796514769221654 and parameters: {'n_estimators': 228, 'max_depth': 5, 'learning_rate': 0.06866952463298769, 'subsample': 0.5031737381689393, 'colsample_bytree': 0.5860
[I 2025-05-31 02:42:56,547] Trial 15 finished with value: 0.003857064643586063 and parameters: {'n_estimators': 99, 'max_depth': 3, 'learning_rate': 0.19958301741221296, 'subsample': 0.6134515866130645, 'colsample_bytree': 0.862405
[I 2025-05-31 02:42:56,690] Trial 16 finished with value: 0.003889600215596195 and parameters: {'n_estimators': 225, 'max_depth': 5, 'learning_rate': 0.03432140986666564, 'subsample': 0.6395633483706886, 'colsample_bytree': 0.7233
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[I 2025-05-31 02:43:05,182] Trial 10 finished with value: 0.0043569226485709635 and parameters: {'n_estimators': 103, 'max_depth': 3, 'learning_rate': 0.2781727955975712, 'subsample': 0.7771535167650725, 'colsample_bytree': 0.97494
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[I 2025-05-31 02:43:06,302] A new study created in memory with name: no-name-7e0dfb22-eed1-4a75-b818-44cb62c916c6
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[I 2025-05-31 02:43:06,577] Trial 2 finished with value: 0.0034255120436237976 and parameters: {'n_estimators': 110, 'max_depth': 3, 'learning_rate': 0.05730289903684572, 'subsample': 0.841791401343688, 'colsample_bytree': 0.629631
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[I 2025-05-31 02:43:06,989] Trial 6 finished with value: 0.0034318979873253965 and parameters: {'n_estimators': 87, 'max_depth': 6, 'learning_rate': 0.012671731514546522, 'subsample': 0.6060049567443058, 'colsample_bytree': 0.71193
[I 2025-05-31 02:43:07,075] Trial 7 finished with value: 0.003432483701069918 and parameters: {'n_estimators': 114, 'max_depth': 7, 'learning_rate': 0.014941139567005183, 'subsample': 0.8270374352648339, 'colsample_bytree': 0.57291
[I 2025-05-31 02:43:07,208] Trial 8 finished with value: 0.0034420935657556028 and parameters: {'n_estimators': 275, 'max_depth': 5, 'learning_rate': 0.010529750433192927, 'subsample': 0.5465401070201613, 'colsample_bytree': 0.7821
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[I 2025-05-31 02:43:07,402] Trial 10 finished with value: 0.0034406147832776765 and parameters: {'n_estimators': 162, 'max_depth': 3, 'learning_rate': 0.2916150684762353, 'subsample': 0.7727938316889337, 'colsample_bytree': 0.97118
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[I 2025-05-31 02:43:16,968] Trial 8 finished with value: 0.005858770406690402 and parameters: {'n_estimators': 122, 'max_depth': 3, 'learning_rate': 0.04222483921972786, 'subsample': 0.9901164719133344, 'colsample_bytree': 0.610294
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[I 2025-05-31 02:43:19,064] Trial 3 finished with value: 0.008796860705712551 and parameters: {'n_estimators': 142, 'max_depth': 7, 'learning_rate': 0.018805633087294063, 'subsample': 0.9805391371775883, 'colsample_bytree': 0.95048
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[I 2025-05-31 02:43:19,299] Trial 5 finished with value: 0.008795931422470945 and parameters: {'n_estimators': 213, 'max_depth': 7, 'learning_rate': 0.038192379873259165, 'subsample': 0.8088964793408098, 'colsample_bytree': 0.62014
[I 2025-05-31 02:43:19,407] Trial 6 finished with value: 0.008795697403304246 and parameters: {'n_estimators': 193, 'max_depth': 6, 'learning_rate': 0.029812254481463712, 'subsample': 0.5168267166548677, 'colsample_bytree': 0.79208
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[I 2025-05-31 02:43:19,743] Trial 9 finished with value: 0.008797057131402093 and parameters: {'n_estimators': 169, 'max_depth': 5, 'learning_rate': 0.011688165778971263, 'subsample': 0.9068023652083916, 'colsample_bytree': 0.96554
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[I 2025-05-31 02:43:19,925] Trial 11 finished with value: 0.008795492222785603 and parameters: {'n_estimators': 94, 'max_depth': 4, 'learning_rate': 0.010036646989883991, 'subsample': 0.6144115863289646, 'colsample_bytree': 0.519700
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[I 2025-05-31 02:43:20,757] Trial 19 finished with value: 0.008795317985834678 and parameters: {'n_estimators': 148, 'max_depth': 7, 'learning_rate': 0.1324800126752084, 'subsample': 0.6091311460237572, 'colsample_bytree': 0.689485
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[I 2025-05-31 02:43:20,950] Trial 0 finished with value: 0.005872969931392401 and parameters: {'n_estimators': 94, 'max_depth': 4, 'learning_rate': 0.06847144758608861, 'subsample': 0.7604023552853162, 'colsample_bytree': 0.9681950
[I 2025-05-31 02:43:21,052] Trial 1 finished with value: 0.005866695842385071 and parameters: {'n_estimators': 77, 'max_depth': 7, 'learning_rate': 0.010139346390310253, 'subsample': 0.5993867973576624, 'colsample_bytree': 0.988259
[I 2025-05-31 02:43:21,157] Trial 2 finished with value: 0.0058403210385308685 and parameters: {'n_estimators': 186, 'max_depth': 3, 'learning_rate': 0.08130422641476376, 'subsample': 0.637407208699349, 'colsample_bytree': 0.609909
[I 2025-05-31 02:43:21,238] Trial 3 finished with value: 0.005870842001756814 and parameters: {'n_estimators': 101, 'max_depth': 4, 'learning_rate': 0.038428881667137524, 'subsample': 0.7938501935232267, 'colsample_bytree': 0.98020
[I 2025-05-31 02:43:21,332] Trial 4 finished with value: 0.005850234011270949 and parameters: {'n_estimators': 135, 'max_depth': 6, 'learning_rate': 0.02784656728476162, 'subsample': 0.5139016544022624, 'colsample_bytree': 0.958955
[I 2025-05-31 02:43:21,452] Trial 5 finished with value: 0.0058591982656940106 and parameters: {'n_estimators': 223, 'max_depth': 6, 'learning_rate': 0.26528584289594265, 'subsample': 0.7677808977984814, 'colsample_bytree': 0.97121
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[I 2025-05-31 02:43:21,693] Trial 7 finished with value: 0.005910085276934189 and parameters: {'n_estimators': 219, 'max_depth': 4, 'learning_rate': 0.10009799638470523, 'subsample': 0.5231421920044856, 'colsample_bytree': 0.707065
[I 2025-05-31 02:43:21,762] Trial 8 finished with value: 0.005854817423732857 and parameters: {'n_estimators': 70, 'max_depth': 5, 'learning_rate': 0.0853098527868779, 'subsample': 0.6827633084281337, 'colsample_bytree': 0.74264498
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[I 2025-05-31 02:43:22,022] Trial 10 finished with value: 0.005868773503530303 and parameters: {'n_estimators': 285, 'max_depth': 3, 'learning_rate': 0.018107651458174792, 'subsample': 0.9748715392137026, 'colsample_bytree': 0.5114
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[I 2025-05-31 02:43:22,275] Trial 12 finished with value: 0.0058509546952604866 and parameters: {'n_estimators': 167, 'max_depth': 8, 'learning_rate': 0.14494379165234725, 'subsample': 0.6342424250514508, 'colsample_bytree': 0.5552
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[I 2025-05-31 02:43:23,167] Trial 19 finished with value: 0.0058554961830357384 and parameters: {'n_estimators': 200, 'max_depth': 5, 'learning_rate': 0.01900042004078192, 'subsample': 0.5761649753765947, 'colsample_bytree': 0.5048
[I 2025-05-31 02:43:23,282] A new study created in memory with name: no-name-c1a1e28b-bab5-481d-8111-54a3725d36fe
[I 2025-05-31 02:43:23,390] Trial 0 finished with value: 0.00481539644529744 and parameters: {'n_estimators': 111, 'max_depth': 4, 'learning_rate': 0.041299020715090125, 'subsample': 0.8005955936566045, 'colsample_bytree': 0.644918
[I 2025-05-31 02:43:23,470] Trial 1 finished with value: 0.004788412067251456 and parameters: {'n_estimators': 101, 'max_depth': 3, 'learning_rate': 0.06838191157260826, 'subsample': 0.664555226009531, 'colsample_bytree': 0.958961
[I 2025-05-31 02:43:23,568] Trial 2 finished with value: 0.004743749318598492 and parameters: {'n_estimators': 147, 'max_depth': 4, 'learning_rate': 0.05014244214534771, 'subsample': 0.8163702762658605, 'colsample_bytree': 0.785355
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[I 2025-05-31 02:43:23,785] Trial 4 finished with value: 0.004809749146919128 and parameters: {'n_estimators': 296, 'max_depth': 5, 'learning_rate': 0.04313682801808327, 'subsample': 0.8137147418621098, 'colsample_bytree': 0.720115
[I 2025-05-31 02:43:23,871] Trial 5 finished with value: 0.004803809467659331 and parameters: {'n_estimators': 122, 'max_depth': 3, 'learning_rate': 0.020154690533519905, 'subsample': 0.6499424265407934, 'colsample_bytree': 0.90560
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[I 2025-05-31 02:43:24,162] Trial 7 finished with value: 0.0047885495378339245 and parameters: {'n_estimators': 260, 'max_depth': 8, 'learning_rate': 0.033291094916374865, 'subsample': 0.6573468943384303, 'colsample_bytree': 0.8045
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[I 2025-05-31 02:43:24,799] Trial 12 finished with value: 0.004942956730625054 and parameters: {'n_estimators': 172, 'max_depth': 6, 'learning_rate': 0.1461443684185624, 'subsample': 0.715424988501915, 'colsample_bytree': 0.8210814
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[I 2025-05-31 02:43:25,178] Trial 15 finished with value: 0.004735025931866114 and parameters: {'n_estimators': 151, 'max_depth': 7, 'learning_rate': 0.08808725972709308, 'subsample': 0.7317978539438534, 'colsample_bytree': 0.89381
[I 2025-05-31 02:43:25,312] Trial 16 finished with value: 0.004840362325034896 and parameters: {'n_estimators': 192, 'max_depth': 7, 'learning_rate': 0.21535380787792424, 'subsample': 0.7247281022279891, 'colsample_bytree': 0.88670
[I 2025-05-31 02:43:25,452] Trial 17 finished with value: 0.004810531128994937 and parameters: {'n_estimators': 230, 'max_depth': 8, 'learning_rate': 0.08914674267619999, 'subsample': 0.603494923624321, 'colsample_bytree': 0.560248
[I 2025-05-31 02:43:25,574] Trial 18 finished with value: 0.004703136872788927 and parameters: {'n_estimators': 144, 'max_depth': 7, 'learning_rate': 0.17989152608998582, 'subsample': 0.7545002680435492, 'colsample_bytree': 0.86774
[I 2025-05-31 02:43:25,744] Trial 19 finished with value: 0.0046191983170846595 and parameters: {'n_estimators': 257, 'max_depth': 6, 'learning_rate': 0.1841408761728394, 'subsample': 0.7705803414689276, 'colsample_bytree': 0.71093
[I 2025-05-31 02:43:26,284] A new study created in memory with name: no-name-b8afa416-ea77-4522-9046-95b4641c9160
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[I 2025-05-31 02:43:26,974] Trial 1 finished with value: 0.0033094849788224507 and parameters: {'n_estimators': 120, 'max_depth': 4, 'learning_rate': 0.01961748591298918, 'subsample': 0.5333896187796983, 'colsample_bytree': 0.81687
[I 2025-05-31 02:43:27,768] Trial 2 finished with value: 0.003308888134649797 and parameters: {'n_estimators': 131, 'max_depth': 6, 'learning_rate': 0.027305409729484736, 'subsample': 0.554295474873933, 'colsample_bytree': 0.825799
[I 2025-05-31 02:43:28,052] Trial 3 finished with value: 0.0033698945224969515 and parameters: {'n_estimators': 260, 'max_depth': 6, 'learning_rate': 0.07255234352956633, 'subsample': 0.8421761471927007, 'colsample_bytree': 0.50149
[I 2025-05-31 02:43:28,393] Trial 4 finished with value: 0.003354568996369562 and parameters: {'n_estimators': 300, 'max_depth': 8, 'learning_rate': 0.16347834065836134, 'subsample': 0.9649357985588218, 'colsample_bytree': 0.764288
[I 2025-05-31 02:43:28,511] Trial 5 finished with value: 0.0033209352921655323 and parameters: {'n_estimators': 83, 'max_depth': 4, 'learning_rate': 0.036053557554174574, 'subsample': 0.6366795867477174, 'colsample_bytree': 0.80898
[I 2025-05-31 02:43:28,674] Trial 6 finished with value: 0.0033683057688292 and parameters: {'n_estimators': 56, 'max_depth': 8, 'learning_rate': 0.030982030106913083, 'subsample': 0.9762926498852846, 'colsample_bytree': 0.73833604
[I 2025-05-31 02:43:28,791] Trial 7 finished with value: 0.003333117523784711 and parameters: {'n_estimators': 210, 'max_depth': 4, 'learning_rate': 0.07079676294642105, 'subsample': 0.7703474855294188, 'colsample_bytree': 0.882857
[I 2025-05-31 02:43:28,913] Trial 8 finished with value: 0.0033626633313187833 and parameters: {'n_estimators': 252, 'max_depth': 4, 'learning_rate': 0.022940134499002434, 'subsample': 0.976884215140152, 'colsample_bytree': 0.82455
[I 2025-05-31 02:43:29,035] Trial 9 finished with value: 0.0033589809862206946 and parameters: {'n_estimators': 229, 'max_depth': 4, 'learning_rate': 0.1920474149613166, 'subsample': 0.9504837091575211, 'colsample_bytree': 0.529679
[I 2025-05-31 02:43:29,152] Trial 10 finished with value: 0.003306389640374113 and parameters: {'n_estimators': 160, 'max_depth': 6, 'learning_rate': 0.01049622723562102, 'subsample': 0.5331063442738582, 'colsample_bytree': 0.62835
[I 2025-05-31 02:43:29,270] Trial 11 finished with value: 0.0033038160855443197 and parameters: {'n_estimators': 161, 'max_depth': 6, 'learning_rate': 0.011278214646395213, 'subsample': 0.500003584550751, 'colsample_bytree': 0.6199
[I 2025-05-31 02:43:29,391] Trial 12 finished with value: 0.0033060104697823457 and parameters: {'n_estimators': 170, 'max_depth': 6, 'learning_rate': 0.010706937223935866, 'subsample': 0.6149286484604836, 'colsample_bytree': 0.614
[I 2025-05-31 02:43:29,518] Trial 13 finished with value: 0.0033162563732748343 and parameters: {'n_estimators': 187, 'max_depth': 5, 'learning_rate': 0.010724314250516554, 'subsample': 0.6265660902885724, 'colsample_bytree': 0.633
[I 2025-05-31 02:43:29,644] Trial 14 finished with value: 0.003313997614498512 and parameters: {'n_estimators': 168, 'max_depth': 7, 'learning_rate': 0.015554561178580804, 'subsample': 0.6382573518023679, 'colsample_bytree': 0.9973
[I 2025-05-31 02:43:29,756] Trial 15 finished with value: 0.0033056189055331153 and parameters: {'n_estimators': 143, 'max_depth': 5, 'learning_rate': 0.04673149216515745, 'subsample': 0.6897709399385832, 'colsample_bytree': 0.5993
[I 2025-05-31 02:43:29,869] Trial 16 finished with value: 0.003348134624319096 and parameters: {'n_estimators': 139, 'max_depth': 3, 'learning_rate': 0.044589658477841666, 'subsample': 0.735073729955093, 'colsample_bytree': 0.57743
[I 2025-05-31 02:43:29,967] Trial 17 finished with value: 0.0033117399393177726 and parameters: {'n_estimators': 100, 'max_depth': 5, 'learning_rate': 0.10790443604103167, 'subsample': 0.7162412606539355, 'colsample_bytree': 0.6808
[I 2025-05-31 02:43:30,107] Trial 18 finished with value: 0.0033667491288951424 and parameters: {'n_estimators': 201, 'max_depth': 7, 'learning_rate': 0.25794644923204, 'subsample': 0.6965870292611124, 'colsample_bytree': 0.5526621
[I 2025-05-31 02:43:30,222] Trial 19 finished with value: 0.0033226148269006064 and parameters: {'n_estimators': 152, 'max_depth': 5, 'learning_rate': 0.06098949284849834, 'subsample': 0.5803898903924056, 'colsample_bytree': 0.6633
[I 2025-05-31 02:43:30,348] A new study created in memory with name: no-name-ba4f5baa-c3c9-4487-9c44-657d3c96bd47
[I 2025-05-31 02:43:30,446] Trial 0 finished with value: 0.005123790851908975 and parameters: {'n_estimators': 76, 'max_depth': 3, 'learning_rate': 0.013432824962195073, 'subsample': 0.6916199387522228, 'colsample_bytree': 0.810094
[I 2025-05-31 02:43:30,580] Trial 1 finished with value: 0.00512071760109737 and parameters: {'n_estimators': 253, 'max_depth': 6, 'learning_rate': 0.015657337918242805, 'subsample': 0.7536908871252614, 'colsample_bytree': 0.936592
[I 2025-05-31 02:43:30,710] Trial 2 finished with value: 0.005120021456712772 and parameters: {'n_estimators': 255, 'max_depth': 7, 'learning_rate': 0.04886053137659605, 'subsample': 0.5485941064380064, 'colsample_bytree': 0.797621
[I 2025-05-31 02:43:30,844] Trial 3 finished with value: 0.0051358018476393985 and parameters: {'n_estimators': 250, 'max_depth': 6, 'learning_rate': 0.2906647412074129, 'subsample': 0.6965090112711442, 'colsample_bytree': 0.727111
[I 2025-05-31 02:43:30,914] Trial 4 finished with value: 0.005127570448984974 and parameters: {'n_estimators': 68, 'max_depth': 4, 'learning_rate': 0.2536721615536224, 'subsample': 0.9053092410068359, 'colsample_bytree': 0.51332050
[I 2025-05-31 02:43:30,997] Trial 5 finished with value: 0.005160144203414786 and parameters: {'n_estimators': 105, 'max_depth': 4, 'learning_rate': 0.28749614749762664, 'subsample': 0.713154321047732, 'colsample_bytree': 0.7066352
[I 2025-05-31 02:43:31,071] Trial 6 finished with value: 0.005116505238119182 and parameters: {'n_estimators': 73, 'max_depth': 7, 'learning_rate': 0.1380236489109066, 'subsample': 0.5199732356003802, 'colsample_bytree': 0.92938994
[I 2025-05-31 02:43:31,184] Trial 7 finished with value: 0.005098079532716703 and parameters: {'n_estimators': 196, 'max_depth': 7, 'learning_rate': 0.19175815425827547, 'subsample': 0.7423160496699832, 'colsample_bytree': 0.667342
[I 2025-05-31 02:43:31,324] Trial 8 finished with value: 0.005130026319708926 and parameters: {'n_estimators': 284, 'max_depth': 5, 'learning_rate': 0.07471785778062633, 'subsample': 0.5419283057073474, 'colsample_bytree': 0.949013
[I 2025-05-31 02:43:31,491] Trial 9 finished with value: 0.00511730081844407 and parameters: {'n_estimators': 285, 'max_depth': 4, 'learning_rate': 0.015502676331523496, 'subsample': 0.9217990085902652, 'colsample_bytree': 0.605500
[I 2025-05-31 02:43:31,619] Trial 10 finished with value: 0.005122660920424814 and parameters: {'n_estimators': 177, 'max_depth': 8, 'learning_rate': 0.04020567032104572, 'subsample': 0.8351902654997154, 'colsample_bytree': 0.62749
[I 2025-05-31 02:43:31,743] Trial 11 finished with value: 0.00517886917288618 and parameters: {'n_estimators': 167, 'max_depth': 8, 'learning_rate': 0.14095396810481112, 'subsample': 0.599928503739446, 'colsample_bytree': 0.8715086
[I 2025-05-31 02:43:31,864] Trial 12 finished with value: 0.005122940812497774 and parameters: {'n_estimators': 166, 'max_depth': 7, 'learning_rate': 0.12007633437651498, 'subsample': 0.999762251381365, 'colsample_bytree': 0.987703
[I 2025-05-31 02:43:31,971] Trial 13 finished with value: 0.005068013672584347 and parameters: {'n_estimators': 128, 'max_depth': 7, 'learning_rate': 0.14124128925553606, 'subsample': 0.6204007206913715, 'colsample_bytree': 0.65046
[I 2025-05-31 02:43:32,078] Trial 14 finished with value: 0.0051153390098149475 and parameters: {'n_estimators': 125, 'max_depth': 7, 'learning_rate': 0.08623732291592935, 'subsample': 0.6156998003990688, 'colsample_bytree': 0.6350
[I 2025-05-31 02:43:32,210] Trial 15 finished with value: 0.005130081043306763 and parameters: {'n_estimators': 206, 'max_depth': 6, 'learning_rate': 0.19399290494082577, 'subsample': 0.7871786135000256, 'colsample_bytree': 0.53551
[I 2025-05-31 02:43:32,318] Trial 16 finished with value: 0.005102967510328137 and parameters: {'n_estimators': 127, 'max_depth': 8, 'learning_rate': 0.08140472803141031, 'subsample': 0.6337490076591679, 'colsample_bytree': 0.67811
[I 2025-05-31 02:43:32,484] Trial 17 finished with value: 0.00511388728088145 and parameters: {'n_estimators': 205, 'max_depth': 5, 'learning_rate': 0.03309116985349436, 'subsample': 0.8267838424579869, 'colsample_bytree': 0.572312
[I 2025-05-31 02:43:32,625] Trial 18 finished with value: 0.005041408961635785 and parameters: {'n_estimators': 201, 'max_depth': 7, 'learning_rate': 0.1871416626869739, 'subsample': 0.6452696277244558, 'colsample_bytree': 0.779642
[I 2025-05-31 02:43:32,739] Trial 19 finished with value: 0.005119641193659272 and parameters: {'n_estimators': 142, 'max_depth': 8, 'learning_rate': 0.026143346410308438, 'subsample': 0.6549243649824195, 'colsample_bytree': 0.7779
[I 2025-05-31 02:43:32,864] A new study created in memory with name: no-name-74a99b17-3744-4fc6-8fa3-08be8a375e6d
[I 2025-05-31 02:43:33,030] Trial 0 finished with value: 0.003504534743474469 and parameters: {'n_estimators': 287, 'max_depth': 5, 'learning_rate': 0.03286194944692372, 'subsample': 0.7864273786285046, 'colsample_bytree': 0.643700
[I 2025-05-31 02:43:33,171] Trial 1 finished with value: 0.003573700108518764 and parameters: {'n_estimators': 288, 'max_depth': 7, 'learning_rate': 0.08317194964745879, 'subsample': 0.5433533662364118, 'colsample_bytree': 0.592928
[I 2025-05-31 02:43:33,266] Trial 2 finished with value: 0.003532643530528285 and parameters: {'n_estimators': 143, 'max_depth': 4, 'learning_rate': 0.10865911630321494, 'subsample': 0.5674581758458022, 'colsample_bytree': 0.897294
[I 2025-05-31 02:43:33,382] Trial 3 finished with value: 0.0035733496158606606 and parameters: {'n_estimators': 215, 'max_depth': 3, 'learning_rate': 0.21563654811833038, 'subsample': 0.5973471047138075, 'colsample_bytree': 0.57246
[I 2025-05-31 02:43:33,493] Trial 4 finished with value: 0.0035230655391254063 and parameters: {'n_estimators': 99, 'max_depth': 8, 'learning_rate': 0.01096433529296859, 'subsample': 0.5186038480172482, 'colsample_bytree': 0.857113
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[I 2025-05-31 02:43:44,490] Trial 17 finished with value: 0.0017665025378988928 and parameters: {'n_estimators': 51, 'max_depth': 5, 'learning_rate': 0.2827231517667052, 'subsample': 0.617249937611814, 'colsample_bytree': 0.6710359
[I 2025-05-31 02:43:44,597] Trial 18 finished with value: 0.001781246375515405 and parameters: {'n_estimators': 103, 'max_depth': 7, 'learning_rate': 0.2943601903758719, 'subsample': 0.6037589228816362, 'colsample_bytree': 0.644823
[I 2025-05-31 02:43:44,724] Trial 19 finished with value: 0.0018035364660467898 and parameters: {'n_estimators': 158, 'max_depth': 6, 'learning_rate': 0.28385307729172976, 'subsample': 0.6384238986417771, 'colsample_bytree': 0.6111
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[I 2025-05-31 02:43:59,152] Trial 11 finished with value: 0.002415136078402829 and parameters: {'n_estimators': 298, 'max_depth': 8, 'learning_rate': 0.1800868303821464, 'subsample': 0.6736334090018217, 'colsample_bytree': 0.898883
[I 2025-05-31 02:43:59,275] Trial 12 finished with value: 0.0024206273356843213 and parameters: {'n_estimators': 166, 'max_depth': 7, 'learning_rate': 0.10876612088679323, 'subsample': 0.7124674554210526, 'colsample_bytree': 0.6742
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[I 2025-05-31 02:44:00,971] Trial 5 finished with value: 0.0059806723738621064 and parameters: {'n_estimators': 244, 'max_depth': 3, 'learning_rate': 0.04775660849784585, 'subsample': 0.7601653637643517, 'colsample_bytree': 0.91516
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[I 2025-05-31 02:44:02,013] Trial 13 finished with value: 0.006001688280043236 and parameters: {'n_estimators': 298, 'max_depth': 6, 'learning_rate': 0.021197210490998313, 'subsample': 0.6736439939233027, 'colsample_bytree': 0.6568
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[I 2025-05-31 02:44:02,919] A new study created in memory with name: no-name-c0baee1e-b853-45e4-923f-d46b2f8a24b2
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[I 2025-05-31 02:44:04,274] Trial 11 finished with value: 0.002212846151146467 and parameters: {'n_estimators': 63, 'max_depth': 8, 'learning_rate': 0.010496808234175148, 'subsample': 0.8827973324470653, 'colsample_bytree': 0.83563
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[I 2025-05-31 02:44:04,906] Trial 17 finished with value: 0.0020884088639438595 and parameters: {'n_estimators': 209, 'max_depth': 4, 'learning_rate': 0.10083169106178015, 'subsample': 0.7380895988426341, 'colsample_bytree': 0.7475
[I 2025-05-31 02:44:05,046] Trial 18 finished with value: 0.0021045485513421303 and parameters: {'n_estimators': 213, 'max_depth': 4, 'learning_rate': 0.13907148508539877, 'subsample': 0.7241370738007225, 'colsample_bytree': 0.8820
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[I 2025-05-31 02:44:06,337] Trial 1 finished with value: 0.0022770879371414093 and parameters: {'n_estimators': 201, 'max_depth': 7, 'learning_rate': 0.055253145650823225, 'subsample': 0.9449800188423181, 'colsample_bytree': 0.7514
[I 2025-05-31 02:44:06,542] Trial 2 finished with value: 0.0024377998204802628 and parameters: {'n_estimators': 84, 'max_depth': 8, 'learning_rate': 0.17134794477510426, 'subsample': 0.5934951597499548, 'colsample_bytree': 0.819759
[I 2025-05-31 02:44:07,335] Trial 3 finished with value: 0.0022848708791299646 and parameters: {'n_estimators': 170, 'max_depth': 8, 'learning_rate': 0.11753619031410738, 'subsample': 0.6723763857930627, 'colsample_bytree': 0.58998
[I 2025-05-31 02:44:07,506] Trial 4 finished with value: 0.002370618612532961 and parameters: {'n_estimators': 212, 'max_depth': 3, 'learning_rate': 0.018248152291270744, 'subsample': 0.5512466061383792, 'colsample_bytree': 0.92471
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[I 2025-05-31 02:44:08,069] Trial 7 finished with value: 0.002303853029369949 and parameters: {'n_estimators': 235, 'max_depth': 6, 'learning_rate': 0.01581719693469325, 'subsample': 0.6371171654478714, 'colsample_bytree': 0.655695
[I 2025-05-31 02:44:08,170] Trial 8 finished with value: 0.0022962226771019393 and parameters: {'n_estimators': 105, 'max_depth': 5, 'learning_rate': 0.015463896081982656, 'subsample': 0.7408115952399943, 'colsample_bytree': 0.8875
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[I 2025-05-31 02:44:08,704] Trial 11 finished with value: 0.0022631781814302612 and parameters: {'n_estimators': 290, 'max_depth': 3, 'learning_rate': 0.2711937078513618, 'subsample': 0.9994530406250585, 'colsample_bytree': 0.50941
[I 2025-05-31 02:44:08,888] Trial 12 finished with value: 0.00227503000760034 and parameters: {'n_estimators': 299, 'max_depth': 3, 'learning_rate': 0.2576214646184674, 'subsample': 0.9778925119607289, 'colsample_bytree': 0.5261968
[I 2025-05-31 02:44:09,058] Trial 13 finished with value: 0.002299265966180163 and parameters: {'n_estimators': 293, 'max_depth': 4, 'learning_rate': 0.2952231012350982, 'subsample': 0.8593842341683754, 'colsample_bytree': 0.503544
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[I 2025-05-31 02:44:09,355] Trial 15 finished with value: 0.0022708442855635786 and parameters: {'n_estimators': 261, 'max_depth': 4, 'learning_rate': 0.035266153956660495, 'subsample': 0.9842667790431316, 'colsample_bytree': 0.506
[I 2025-05-31 02:44:09,440] Trial 16 finished with value: 0.0022295210511309206 and parameters: {'n_estimators': 50, 'max_depth': 3, 'learning_rate': 0.18173912636962664, 'subsample': 0.7890033804317167, 'colsample_bytree': 0.73964
[I 2025-05-31 02:44:09,525] Trial 17 finished with value: 0.0023070304066669465 and parameters: {'n_estimators': 52, 'max_depth': 4, 'learning_rate': 0.16385316068209113, 'subsample': 0.7657950746042292, 'colsample_bytree': 0.74411
[I 2025-05-31 02:44:09,639] Trial 18 finished with value: 0.002232463639044639 and parameters: {'n_estimators': 124, 'max_depth': 3, 'learning_rate': 0.11155452097348666, 'subsample': 0.7564144499283623, 'colsample_bytree': 0.82795
[I 2025-05-31 02:44:09,747] Trial 19 finished with value: 0.0022904715984234875 and parameters: {'n_estimators': 122, 'max_depth': 5, 'learning_rate': 0.033992202885027585, 'subsample': 0.7541194872312309, 'colsample_bytree': 0.823
[I 2025-05-31 02:44:09,857] A new study created in memory with name: no-name-20ae5b50-a970-4e56-9c18-4f53405c4d09
[I 2025-05-31 02:44:10,012] Trial 0 finished with value: 0.002900009024677419 and parameters: {'n_estimators': 237, 'max_depth': 6, 'learning_rate': 0.054867169540135714, 'subsample': 0.9424745712073781, 'colsample_bytree': 0.66882
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[I 2025-05-31 02:44:10,166] Trial 2 finished with value: 0.002896316764704736 and parameters: {'n_estimators': 148, 'max_depth': 6, 'learning_rate': 0.14215878725207873, 'subsample': 0.632419147627678, 'colsample_bytree': 0.5160353
[I 2025-05-31 02:44:10,236] Trial 3 finished with value: 0.002895722400069601 and parameters: {'n_estimators': 54, 'max_depth': 7, 'learning_rate': 0.022272725926080705, 'subsample': 0.7474515922281055, 'colsample_bytree': 0.618983
[I 2025-05-31 02:44:10,304] Trial 4 finished with value: 0.0028856815934554555 and parameters: {'n_estimators': 76, 'max_depth': 3, 'learning_rate': 0.017878062957796155, 'subsample': 0.8120812154152713, 'colsample_bytree': 0.71130
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[I 2025-05-31 02:44:10,697] Trial 8 finished with value: 0.002889050701812838 and parameters: {'n_estimators': 147, 'max_depth': 7, 'learning_rate': 0.0441156805948019, 'subsample': 0.7771872562839217, 'colsample_bytree': 0.7814334
[I 2025-05-31 02:44:10,823] Trial 9 finished with value: 0.0029173763810500493 and parameters: {'n_estimators': 235, 'max_depth': 4, 'learning_rate': 0.1932830652019449, 'subsample': 0.6995538279837079, 'colsample_bytree': 0.932826
[I 2025-05-31 02:44:10,990] Trial 10 finished with value: 0.0028838360795981847 and parameters: {'n_estimators': 298, 'max_depth': 4, 'learning_rate': 0.011168879194865788, 'subsample': 0.8471770446361768, 'colsample_bytree': 0.705
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[I 2025-05-31 02:44:11,268] Trial 12 finished with value: 0.002888836246834532 and parameters: {'n_estimators': 290, 'max_depth': 4, 'learning_rate': 0.0101682129298851, 'subsample': 0.9987720158735288, 'colsample_bytree': 0.692447
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[I 2025-05-31 02:44:20,978] Trial 19 finished with value: 0.0029499347154297024 and parameters: {'n_estimators': 245, 'max_depth': 8, 'learning_rate': 0.01004954538945506, 'subsample': 0.9266604927838566, 'colsample_bytree': 0.8005
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[I 2025-05-31 02:44:32,687] Trial 9 finished with value: 0.0068452993415215055 and parameters: {'n_estimators': 70, 'max_depth': 7, 'learning_rate': 0.024656899670203, 'subsample': 0.5091631836334236, 'colsample_bytree': 0.89582656
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[I 2025-05-31 02:44:34,124] Trial 12 finished with value: 0.006787205511639895 and parameters: {'n_estimators': 159, 'max_depth': 3, 'learning_rate': 0.013513123441285638, 'subsample': 0.9370205020695993, 'colsample_bytree': 0.5869
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[I 2025-05-31 02:44:34,914] Trial 17 finished with value: 0.0068182193943205 and parameters: {'n_estimators': 259, 'max_depth': 4, 'learning_rate': 0.1197379779043706, 'subsample': 0.7189944903458665, 'colsample_bytree': 0.66883953
[I 2025-05-31 02:44:35,019] Trial 18 finished with value: 0.006795157132529047 and parameters: {'n_estimators': 98, 'max_depth': 3, 'learning_rate': 0.050729377117697316, 'subsample': 0.8769926630181503, 'colsample_bytree': 0.75490
[I 2025-05-31 02:44:35,155] Trial 19 finished with value: 0.006781008942970882 and parameters: {'n_estimators': 200, 'max_depth': 4, 'learning_rate': 0.02023953879223911, 'subsample': 0.9885579978329984, 'colsample_bytree': 0.50071
[I 2025-05-31 02:44:35,271] A new study created in memory with name: no-name-1d742faa-8638-4d44-aecf-3ba21794dab2
[I 2025-05-31 02:44:35,398] Trial 0 finished with value: 0.001280645348552552 and parameters: {'n_estimators': 174, 'max_depth': 3, 'learning_rate': 0.011581475185312542, 'subsample': 0.9828954902724993, 'colsample_bytree': 0.60418
[I 2025-05-31 02:44:35,500] Trial 1 finished with value: 0.001282249206710528 and parameters: {'n_estimators': 157, 'max_depth': 5, 'learning_rate': 0.03887811617255457, 'subsample': 0.5620706787995455, 'colsample_bytree': 0.984810
[I 2025-05-31 02:44:35,567] Trial 2 finished with value: 0.001283139946438917 and parameters: {'n_estimators': 60, 'max_depth': 3, 'learning_rate': 0.028123217662939164, 'subsample': 0.9457750965167651, 'colsample_bytree': 0.549618
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[I 2025-05-31 02:44:35,795] Trial 4 finished with value: 0.0012820165435997778 and parameters: {'n_estimators': 216, 'max_depth': 4, 'learning_rate': 0.04283722165364836, 'subsample': 0.7447730018081047, 'colsample_bytree': 0.52132
[I 2025-05-31 02:44:35,933] Trial 5 finished with value: 0.0012767012328050284 and parameters: {'n_estimators': 261, 'max_depth': 7, 'learning_rate': 0.010341552664465896, 'subsample': 0.7661363216744803, 'colsample_bytree': 0.9873
[I 2025-05-31 02:44:36,089] Trial 6 finished with value: 0.0012938387774960108 and parameters: {'n_estimators': 289, 'max_depth': 5, 'learning_rate': 0.0860896810322202, 'subsample': 0.9317788403156873, 'colsample_bytree': 0.726637
[I 2025-05-31 02:44:36,196] Trial 7 finished with value: 0.0012740630155037224 and parameters: {'n_estimators': 196, 'max_depth': 3, 'learning_rate': 0.02203565668712966, 'subsample': 0.8208166318330364, 'colsample_bytree': 0.66620
[I 2025-05-31 02:44:36,335] Trial 8 finished with value: 0.0012800924113887664 and parameters: {'n_estimators': 251, 'max_depth': 7, 'learning_rate': 0.24037339409983738, 'subsample': 0.8038752994592304, 'colsample_bytree': 0.91711
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[I 2025-05-31 02:44:36,529] Trial 10 finished with value: 0.0012937092643781057 and parameters: {'n_estimators': 113, 'max_depth': 8, 'learning_rate': 0.09327352606966435, 'subsample': 0.6597720296619835, 'colsample_bytree': 0.7165
[I 2025-05-31 02:44:36,674] Trial 11 finished with value: 0.0012839430556019756 and parameters: {'n_estimators': 230, 'max_depth': 7, 'learning_rate': 0.026331088689067746, 'subsample': 0.858910552922091, 'colsample_bytree': 0.7929
[I 2025-05-31 02:44:36,869] Trial 12 finished with value: 0.0012767298706026196 and parameters: {'n_estimators': 272, 'max_depth': 6, 'learning_rate': 0.018962289798331738, 'subsample': 0.6874008986781113, 'colsample_bytree': 0.672
[I 2025-05-31 02:44:37,003] Trial 13 finished with value: 0.0012751946778108859 and parameters: {'n_estimators': 207, 'max_depth': 8, 'learning_rate': 0.021261457367279937, 'subsample': 0.8505386123281049, 'colsample_bytree': 0.825
[I 2025-05-31 02:44:37,135] Trial 14 finished with value: 0.0012743343824804714 and parameters: {'n_estimators': 203, 'max_depth': 8, 'learning_rate': 0.06968222059635004, 'subsample': 0.8635295775802512, 'colsample_bytree': 0.8099
[I 2025-05-31 02:44:37,265] Trial 15 finished with value: 0.0012722893426374885 and parameters: {'n_estimators': 199, 'max_depth': 6, 'learning_rate': 0.0786429884882255, 'subsample': 0.8695772693659128, 'colsample_bytree': 0.67343
[I 2025-05-31 02:44:37,374] Trial 16 finished with value: 0.0012746490931237638 and parameters: {'n_estimators': 131, 'max_depth': 6, 'learning_rate': 0.1521581271467471, 'subsample': 0.9245323651291341, 'colsample_bytree': 0.66368
[I 2025-05-31 02:44:37,500] Trial 17 finished with value: 0.0012627690580205176 and parameters: {'n_estimators': 185, 'max_depth': 4, 'learning_rate': 0.1195774237044058, 'subsample': 0.5031645978899187, 'colsample_bytree': 0.66188
[I 2025-05-31 02:44:37,603] Trial 18 finished with value: 0.0012685797901104102 and parameters: {'n_estimators': 109, 'max_depth': 4, 'learning_rate': 0.14274847698840692, 'subsample': 0.5196575943396147, 'colsample_bytree': 0.6078
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[I 2025-05-31 02:44:37,826] A new study created in memory with name: no-name-f5939bf5-3fc5-4e90-b9e4-03dcb436f803
[I 2025-05-31 02:44:37,928] Trial 0 finished with value: 0.0016568341270273396 and parameters: {'n_estimators': 80, 'max_depth': 3, 'learning_rate': 0.08077025739194243, 'subsample': 0.8192451097708944, 'colsample_bytree': 0.914306
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[I 2025-05-31 02:44:38,117] Trial 2 finished with value: 0.001662370796007976 and parameters: {'n_estimators': 100, 'max_depth': 8, 'learning_rate': 0.06984468166232767, 'subsample': 0.868265797622372, 'colsample_bytree': 0.8852383
[I 2025-05-31 02:44:38,252] Trial 3 finished with value: 0.0016308564394635554 and parameters: {'n_estimators': 254, 'max_depth': 4, 'learning_rate': 0.16567802795733055, 'subsample': 0.5417467060114978, 'colsample_bytree': 0.53076
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[I 2025-05-31 02:44:38,479] Trial 5 finished with value: 0.001653414786477807 and parameters: {'n_estimators': 274, 'max_depth': 3, 'learning_rate': 0.0538193717181858, 'subsample': 0.5892831049639594, 'colsample_bytree': 0.7732541
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[I 2025-05-31 02:44:38,704] Trial 7 finished with value: 0.0016675739392023668 and parameters: {'n_estimators': 164, 'max_depth': 6, 'learning_rate': 0.011625340940097983, 'subsample': 0.898399933181909, 'colsample_bytree': 0.61901
[I 2025-05-31 02:44:38,771] Trial 8 finished with value: 0.0016638439021683868 and parameters: {'n_estimators': 67, 'max_depth': 6, 'learning_rate': 0.02874891433563033, 'subsample': 0.9543759106830247, 'colsample_bytree': 0.835491
[I 2025-05-31 02:44:38,897] Trial 9 finished with value: 0.0016709549970037908 and parameters: {'n_estimators': 150, 'max_depth': 6, 'learning_rate': 0.03527363117554168, 'subsample': 0.8282714299230141, 'colsample_bytree': 0.50919
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[I 2025-05-31 02:44:39,377] Trial 12 finished with value: 0.001628024101329238 and parameters: {'n_estimators': 250, 'max_depth': 4, 'learning_rate': 0.13523329341056348, 'subsample': 0.6372586580762836, 'colsample_bytree': 0.71814
[I 2025-05-31 02:44:39,527] Trial 13 finished with value: 0.0016567653387791555 and parameters: {'n_estimators': 239, 'max_depth': 5, 'learning_rate': 0.15317473993090291, 'subsample': 0.680527712300524, 'colsample_bytree': 0.99915
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[I 2025-05-31 02:44:39,809] Trial 15 finished with value: 0.0016309109057651597 and parameters: {'n_estimators': 213, 'max_depth': 4, 'learning_rate': 0.2009692453603309, 'subsample': 0.5203195665864105, 'colsample_bytree': 0.62106
[I 2025-05-31 02:44:39,994] Trial 16 finished with value: 0.001658897764127015 and parameters: {'n_estimators': 265, 'max_depth': 5, 'learning_rate': 0.09366162516716649, 'subsample': 0.7559755656333367, 'colsample_bytree': 0.57342
[I 2025-05-31 02:44:40,129] Trial 17 finished with value: 0.001671534463938712 and parameters: {'n_estimators': 198, 'max_depth': 7, 'learning_rate': 0.1083238711245787, 'subsample': 0.6069862829544832, 'colsample_bytree': 0.688648
[I 2025-05-31 02:44:40,277] Trial 18 finished with value: 0.0016490190594600242 and parameters: {'n_estimators': 255, 'max_depth': 4, 'learning_rate': 0.2839242339890822, 'subsample': 0.7431128231540769, 'colsample_bytree': 0.70927
[I 2025-05-31 02:44:40,424] Trial 19 finished with value: 0.0016212315455156768 and parameters: {'n_estimators': 248, 'max_depth': 3, 'learning_rate': 0.2062816002159467, 'subsample': 0.5014837275095811, 'colsample_bytree': 0.60094
[I 2025-05-31 02:44:40,555] A new study created in memory with name: no-name-c1e613e8-4b16-4680-9f34-ad7f3eb339f7
[I 2025-05-31 02:44:40,711] Trial 0 finished with value: 0.0020395114433787616 and parameters: {'n_estimators': 219, 'max_depth': 6, 'learning_rate': 0.24656163123561645, 'subsample': 0.7145857031577394, 'colsample_bytree': 0.50981
[I 2025-05-31 02:44:40,795] Trial 1 finished with value: 0.002001858620733597 and parameters: {'n_estimators': 110, 'max_depth': 7, 'learning_rate': 0.13148426101590482, 'subsample': 0.8534501824127491, 'colsample_bytree': 0.648082
[I 2025-05-31 02:44:40,968] Trial 2 finished with value: 0.001982125179879614 and parameters: {'n_estimators': 276, 'max_depth': 8, 'learning_rate': 0.19708496974411777, 'subsample': 0.5676244477935442, 'colsample_bytree': 0.523320
[I 2025-05-31 02:44:41,045] Trial 3 finished with value: 0.002011024908724625 and parameters: {'n_estimators': 96, 'max_depth': 7, 'learning_rate': 0.04287306704373918, 'subsample': 0.9023261166455246, 'colsample_bytree': 0.6876113
[I 2025-05-31 02:44:41,161] Trial 4 finished with value: 0.0020028367988247416 and parameters: {'n_estimators': 209, 'max_depth': 8, 'learning_rate': 0.01223520073604896, 'subsample': 0.7483321925854668, 'colsample_bytree': 0.79430
[I 2025-05-31 02:44:41,240] Trial 5 finished with value: 0.001997888204843818 and parameters: {'n_estimators': 93, 'max_depth': 5, 'learning_rate': 0.013813650416347223, 'subsample': 0.7558815604429281, 'colsample_bytree': 0.687290
[I 2025-05-31 02:44:41,353] Trial 6 finished with value: 0.0020141745435815293 and parameters: {'n_estimators': 210, 'max_depth': 5, 'learning_rate': 0.053814214305724285, 'subsample': 0.7442599596654287, 'colsample_bytree': 0.7887
[I 2025-05-31 02:44:41,470] Trial 7 finished with value: 0.0020018856054932976 and parameters: {'n_estimators': 209, 'max_depth': 4, 'learning_rate': 0.011588162096375008, 'subsample': 0.7183326343066256, 'colsample_bytree': 0.9543
[I 2025-05-31 02:44:41,548] Trial 8 finished with value: 0.001991324258263695 and parameters: {'n_estimators': 101, 'max_depth': 7, 'learning_rate': 0.013498475155714396, 'subsample': 0.6262956802327322, 'colsample_bytree': 0.73899
[I 2025-05-31 02:44:41,687] Trial 9 finished with value: 0.002017103806629313 and parameters: {'n_estimators': 261, 'max_depth': 4, 'learning_rate': 0.17330460055015662, 'subsample': 0.6391704951608319, 'colsample_bytree': 0.940026
[I 2025-05-31 02:44:41,845] Trial 10 finished with value: 0.0019819438331295856 and parameters: {'n_estimators': 289, 'max_depth': 8, 'learning_rate': 0.10087485641918015, 'subsample': 0.5206180458281426, 'colsample_bytree': 0.5140
[I 2025-05-31 02:44:42,043] Trial 11 finished with value: 0.0019826475950257805 and parameters: {'n_estimators': 299, 'max_depth': 8, 'learning_rate': 0.09701672476222542, 'subsample': 0.5137190677180148, 'colsample_bytree': 0.5071
[I 2025-05-31 02:44:42,203] Trial 12 finished with value: 0.001967992705935535 and parameters: {'n_estimators': 297, 'max_depth': 8, 'learning_rate': 0.0795799572617909, 'subsample': 0.5126438896208233, 'colsample_bytree': 0.597486
[I 2025-05-31 02:44:42,346] Trial 13 finished with value: 0.001992393788341565 and parameters: {'n_estimators': 254, 'max_depth': 3, 'learning_rate': 0.08286065426409506, 'subsample': 0.5180241318349109, 'colsample_bytree': 0.59218
[I 2025-05-31 02:44:42,463] Trial 14 finished with value: 0.0020136614241317756 and parameters: {'n_estimators': 171, 'max_depth': 6, 'learning_rate': 0.03095584257496831, 'subsample': 0.6062760617809438, 'colsample_bytree': 0.5896
[I 2025-05-31 02:44:42,620] Trial 15 finished with value: 0.001982666291650722 and parameters: {'n_estimators': 299, 'max_depth': 8, 'learning_rate': 0.07778542097822466, 'subsample': 0.5021871066077198, 'colsample_bytree': 0.58914
[I 2025-05-31 02:44:42,705] Trial 16 finished with value: 0.0020007665347030945 and parameters: {'n_estimators': 50, 'max_depth': 7, 'learning_rate': 0.027633629201036094, 'subsample': 0.5797257095875916, 'colsample_bytree': 0.5834
[I 2025-05-31 02:44:42,826] Trial 17 finished with value: 0.002008267241220554 and parameters: {'n_estimators': 151, 'max_depth': 6, 'learning_rate': 0.13465300526272295, 'subsample': 0.9641751542622758, 'colsample_bytree': 0.89911
[I 2025-05-31 02:44:42,975] Trial 18 finished with value: 0.002010394830575505 and parameters: {'n_estimators': 243, 'max_depth': 8, 'learning_rate': 0.06291320906868494, 'subsample': 0.6681436147475763, 'colsample_bytree': 0.64299
[I 2025-05-31 02:44:43,140] Trial 19 finished with value: 0.002000902038129017 and parameters: {'n_estimators': 277, 'max_depth': 7, 'learning_rate': 0.11790905033505757, 'subsample': 0.8097178021617187, 'colsample_bytree': 0.85638
[I 2025-05-31 02:44:43,287] A new study created in memory with name: no-name-e02205d1-51e5-4ae1-9474-6a6553d7f53d
[I 2025-05-31 02:44:43,394] Trial 0 finished with value: 0.0026362150038047242 and parameters: {'n_estimators': 97, 'max_depth': 6, 'learning_rate': 0.07084088224348997, 'subsample': 0.9249481245750926, 'colsample_bytree': 0.848267
[I 2025-05-31 02:44:43,512] Trial 1 finished with value: 0.0026493987705394277 and parameters: {'n_estimators': 217, 'max_depth': 3, 'learning_rate': 0.194209186057978, 'subsample': 0.9448683901636727, 'colsample_bytree': 0.8662708
[I 2025-05-31 02:44:43,634] Trial 2 finished with value: 0.002659383971110622 and parameters: {'n_estimators': 236, 'max_depth': 7, 'learning_rate': 0.2602022561290105, 'subsample': 0.9057480299286663, 'colsample_bytree': 0.6203884
[I 2025-05-31 02:44:43,775] Trial 3 finished with value: 0.002696047962308542 and parameters: {'n_estimators': 259, 'max_depth': 6, 'learning_rate': 0.15898988869188543, 'subsample': 0.7883410420530397, 'colsample_bytree': 0.960224
[I 2025-05-31 02:44:43,850] Trial 4 finished with value: 0.002741846581651846 and parameters: {'n_estimators': 81, 'max_depth': 5, 'learning_rate': 0.08932717639088736, 'subsample': 0.5897967820379868, 'colsample_bytree': 0.8359667
[I 2025-05-31 02:44:43,957] Trial 5 finished with value: 0.002641416150271255 and parameters: {'n_estimators': 198, 'max_depth': 4, 'learning_rate': 0.20008714295251456, 'subsample': 0.9760217295465228, 'colsample_bytree': 0.725328
[I 2025-05-31 02:44:44,130] Trial 6 finished with value: 0.0027005463744280496 and parameters: {'n_estimators': 268, 'max_depth': 4, 'learning_rate': 0.02630989686785416, 'subsample': 0.573575475355655, 'colsample_bytree': 0.580531
[I 2025-05-31 02:44:44,254] Trial 7 finished with value: 0.002693622472434513 and parameters: {'n_estimators': 241, 'max_depth': 8, 'learning_rate': 0.09362109330347043, 'subsample': 0.8925406503268918, 'colsample_bytree': 0.824413
[I 2025-05-31 02:44:44,365] Trial 8 finished with value: 0.002640723756884042 and parameters: {'n_estimators': 195, 'max_depth': 5, 'learning_rate': 0.18376452100271867, 'subsample': 0.722559051441321, 'colsample_bytree': 0.6388752
[I 2025-05-31 02:44:44,463] Trial 9 finished with value: 0.002584819562369125 and parameters: {'n_estimators': 172, 'max_depth': 8, 'learning_rate': 0.06519053545607505, 'subsample': 0.6001633438606907, 'colsample_bytree': 0.521514
[I 2025-05-31 02:44:44,584] Trial 10 finished with value: 0.0026998925695141136 and parameters: {'n_estimators': 130, 'max_depth': 8, 'learning_rate': 0.011547709510330947, 'subsample': 0.5040517258268721, 'colsample_bytree': 0.528
[I 2025-05-31 02:44:44,742] Trial 11 finished with value: 0.002692151235600055 and parameters: {'n_estimators': 137, 'max_depth': 7, 'learning_rate': 0.04171782177573706, 'subsample': 0.7236233780873124, 'colsample_bytree': 0.72641
[I 2025-05-31 02:44:44,853] Trial 12 finished with value: 0.0026710199983089288 and parameters: {'n_estimators': 59, 'max_depth': 7, 'learning_rate': 0.05815188223302623, 'subsample': 0.8065175061609127, 'colsample_bytree': 0.96555
[I 2025-05-31 02:44:45,564] Trial 13 finished with value: 0.002690591498355264 and parameters: {'n_estimators': 155, 'max_depth': 6, 'learning_rate': 0.029219358720272773, 'subsample': 0.6549340620253152, 'colsample_bytree': 0.5030
[I 2025-05-31 02:44:46,622] Trial 14 finished with value: 0.0026670659725864638 and parameters: {'n_estimators': 107, 'max_depth': 8, 'learning_rate': 0.09120466625334682, 'subsample': 0.8322330205105252, 'colsample_bytree': 0.9046
[I 2025-05-31 02:44:46,888] Trial 15 finished with value: 0.0026357949748719695 and parameters: {'n_estimators': 169, 'max_depth': 6, 'learning_rate': 0.05788256524338485, 'subsample': 0.6618275613834594, 'colsample_bytree': 0.7647
[I 2025-05-31 02:44:47,060] Trial 16 finished with value: 0.0026201308944370015 and parameters: {'n_estimators': 174, 'max_depth': 7, 'learning_rate': 0.037895731562239555, 'subsample': 0.6464125894997603, 'colsample_bytree': 0.762
[I 2025-05-31 02:44:47,317] Trial 17 finished with value: 0.0026933292607698948 and parameters: {'n_estimators': 300, 'max_depth': 7, 'learning_rate': 0.016572499495296506, 'subsample': 0.6370822457252368, 'colsample_bytree': 0.671
[I 2025-05-31 02:44:47,550] Trial 18 finished with value: 0.002690870998441474 and parameters: {'n_estimators': 190, 'max_depth': 8, 'learning_rate': 0.03998245636616002, 'subsample': 0.529491513102826, 'colsample_bytree': 0.776894
[I 2025-05-31 02:44:47,674] Trial 19 finished with value: 0.002694106464005216 and parameters: {'n_estimators': 153, 'max_depth': 7, 'learning_rate': 0.0240403858675242, 'subsample': 0.6064609626250832, 'colsample_bytree': 0.691264
[I 2025-05-31 02:44:47,784] A new study created in memory with name: no-name-bd349485-bb3e-48e4-910a-875379cf9588
[I 2025-05-31 02:44:47,913] Trial 0 finished with value: 0.0011054679677035037 and parameters: {'n_estimators': 124, 'max_depth': 7, 'learning_rate': 0.017677978428126667, 'subsample': 0.8710586501170055, 'colsample_bytree': 0.5978
[I 2025-05-31 02:44:47,980] Trial 1 finished with value: 0.0011170524447035677 and parameters: {'n_estimators': 58, 'max_depth': 4, 'learning_rate': 0.020715652489985296, 'subsample': 0.7086891649555556, 'colsample_bytree': 0.99386
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[I 2025-05-31 02:44:53,848] Trial 3 finished with value: 0.00624715000180704 and parameters: {'n_estimators': 286, 'max_depth': 4, 'learning_rate': 0.046471656596044665, 'subsample': 0.8149486436678808, 'colsample_bytree': 0.724317
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[I 2025-05-31 02:44:54,482] Trial 8 finished with value: 0.006236779368668063 and parameters: {'n_estimators': 189, 'max_depth': 3, 'learning_rate': 0.015294053115479832, 'subsample': 0.835012394726928, 'colsample_bytree': 0.939029
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[I 2025-05-31 02:45:11,139] Trial 8 finished with value: 0.0049519772321158445 and parameters: {'n_estimators': 236, 'max_depth': 4, 'learning_rate': 0.05021121297033741, 'subsample': 0.7986058275589868, 'colsample_bytree': 0.58765
[I 2025-05-31 02:45:11,855] Trial 9 finished with value: 0.004937193554847492 and parameters: {'n_estimators': 292, 'max_depth': 5, 'learning_rate': 0.11760911156721615, 'subsample': 0.9930457978449755, 'colsample_bytree': 0.888082
[I 2025-05-31 02:45:12,042] Trial 10 finished with value: 0.004936488333981856 and parameters: {'n_estimators': 143, 'max_depth': 8, 'learning_rate': 0.010199195599416728, 'subsample': 0.6837764873503, 'colsample_bytree': 0.7111326
[I 2025-05-31 02:45:12,957] Trial 11 finished with value: 0.004935552707965256 and parameters: {'n_estimators': 58, 'max_depth': 6, 'learning_rate': 0.2944757329469453, 'subsample': 0.6737754570529854, 'colsample_bytree': 0.6913549
[I 2025-05-31 02:45:13,177] Trial 12 finished with value: 0.004926275604311201 and parameters: {'n_estimators': 52, 'max_depth': 5, 'learning_rate': 0.1920258285335482, 'subsample': 0.7682304348089279, 'colsample_bytree': 0.6592565
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[I 2025-05-31 02:45:13,939] Trial 16 finished with value: 0.00493893083225873 and parameters: {'n_estimators': 215, 'max_depth': 6, 'learning_rate': 0.024659119362845032, 'subsample': 0.5000941767373035, 'colsample_bytree': 0.51703
[I 2025-05-31 02:45:14,055] Trial 17 finished with value: 0.004967269368386145 and parameters: {'n_estimators': 150, 'max_depth': 5, 'learning_rate': 0.08485168009144055, 'subsample': 0.5891566713244083, 'colsample_bytree': 0.62011
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[I 2025-05-31 02:45:14,423] A new study created in memory with name: no-name-13c991d0-1c89-44a2-90b0-2f18789192cf
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[I 2025-05-31 02:45:14,624] Trial 1 finished with value: 0.01708557394273439 and parameters: {'n_estimators': 51, 'max_depth': 6, 'learning_rate': 0.23893686805667358, 'subsample': 0.8319222649369302, 'colsample_bytree': 0.76625805
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[I 2025-05-31 02:45:15,403] Trial 8 finished with value: 0.01710871711337736 and parameters: {'n_estimators': 130, 'max_depth': 3, 'learning_rate': 0.03923529417329475, 'subsample': 0.6153954484882009, 'colsample_bytree': 0.7779072
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[I 2025-05-31 02:45:16,205] Trial 14 finished with value: 0.017096181819887597 and parameters: {'n_estimators': 177, 'max_depth': 4, 'learning_rate': 0.17346677262222987, 'subsample': 0.995827199863, 'colsample_bytree': 0.935697932
[I 2025-05-31 02:45:16,357] Trial 15 finished with value: 0.017128293919061156 and parameters: {'n_estimators': 259, 'max_depth': 6, 'learning_rate': 0.16553895408721714, 'subsample': 0.5021331776924874, 'colsample_bytree': 0.69991
[I 2025-05-31 02:45:16,488] Trial 16 finished with value: 0.01709703627580242 and parameters: {'n_estimators': 197, 'max_depth': 7, 'learning_rate': 0.06767733837939308, 'subsample': 0.5712471198650354, 'colsample_bytree': 0.947530
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[I 2025-05-31 02:45:16,994] A new study created in memory with name: no-name-c30f40c9-9ef7-4b28-b30e-94a7b587ab11
[I 2025-05-31 02:45:17,142] Trial 0 finished with value: 0.0047862915292488 and parameters: {'n_estimators': 220, 'max_depth': 3, 'learning_rate': 0.031839667181429374, 'subsample': 0.5649627567228886, 'colsample_bytree': 0.9744476
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[I 2025-05-31 02:45:17,636] Trial 4 finished with value: 0.004797344891579085 and parameters: {'n_estimators': 189, 'max_depth': 4, 'learning_rate': 0.021533712676853688, 'subsample': 0.6962771383566548, 'colsample_bytree': 0.82827
[I 2025-05-31 02:45:17,775] Trial 5 finished with value: 0.0047929038097511475 and parameters: {'n_estimators': 285, 'max_depth': 5, 'learning_rate': 0.103832326514857981, 'subsample': 0.6898220043269595, 'colsample_bytree': 0.97042
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[I 2025-05-31 02:45:17,990] Trial 7 finished with value: 0.00478725182106034 and parameters: {'n_estimators': 190, 'max_depth': 4, 'learning_rate': 0.08399401573574193, 'subsample': 0.5514570451179022, 'colsample_bytree': 0.8900375
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[I 2025-05-31 02:45:18,246] Trial 10 finished with value: 0.004773989322094688 and parameters: {'n_estimators': 61, 'max_depth': 8, 'learning_rate': 0.2788155064197161, 'subsample': 0.852133488036712, 'colsample_bytree': 0.67452937
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[I 2025-05-31 02:45:18,455] Trial 12 finished with value: 0.00478976945209944 and parameters: {'n_estimators': 109, 'max_depth': 8, 'learning_rate': 0.2709755800433623, 'subsample': 0.9802566728810739, 'colsample_bytree': 0.6385962
[I 2025-05-31 02:45:18,564] Trial 13 finished with value: 0.004771884065372543 and parameters: {'n_estimators': 126, 'max_depth': 7, 'learning_rate': 0.15485159495821121, 'subsample': 0.8402590260642974, 'colsample_bytree': 0.75567
[I 2025-05-31 02:45:18,671] Trial 14 finished with value: 0.004771178129046794 and parameters: {'n_estimators': 126, 'max_depth': 8, 'learning_rate': 0.13994445574841927, 'subsample': 0.7974040580569162, 'colsample_bytree': 0.78735
[I 2025-05-31 02:45:18,779] Trial 15 finished with value: 0.004786015998058907 and parameters: {'n_estimators': 110, 'max_depth': 7, 'learning_rate': 0.156456443665967, 'subsample': 0.7643370947958743, 'colsample_bytree': 0.7891725
[I 2025-05-31 02:45:18,888] Trial 16 finished with value: 0.004784275443675928 and parameters: {'n_estimators': 119, 'max_depth': 7, 'learning_rate': 0.1396888762145839, 'subsample': 0.910817303566799, 'colsample_bytree': 0.7617689
[I 2025-05-31 02:45:18,999] Trial 17 finished with value: 0.004773763895345505 and parameters: {'n_estimators': 130, 'max_depth': 7, 'learning_rate': 0.19148695513251549, 'subsample': 0.7685051363753557, 'colsample_bytree': 0.91891
[I 2025-05-31 02:45:19,097] Trial 18 finished with value: 0.0047845857305814 and parameters: {'n_estimators': 87, 'max_depth': 6, 'learning_rate': 0.059208509229040376, 'subsample': 0.9175705583468245, 'colsample_bytree': 0.8011233
[I 2025-05-31 02:45:19,193] Trial 19 finished with value: 0.004829443039547314 and parameters: {'n_estimators': 90, 'max_depth': 6, 'learning_rate': 0.09878748914232656, 'subsample': 0.6977935548998916, 'colsample_bytree': 0.612502
[I 2025-05-31 02:45:19,290] A new study created in memory with name: no-name-23a9437a-5ef5-4faa-b59e-3d562c81371f
[I 2025-05-31 02:45:19,446] Trial 0 finished with value: 0.017576978044161796 and parameters: {'n_estimators': 207, 'max_depth': 6, 'learning_rate': 0.04740340059964692, 'subsample': 0.9463094246488581, 'colsample_bytree': 0.836688
[I 2025-05-31 02:45:19,579] Trial 1 finished with value: 0.0175768671206843 and parameters: {'n_estimators': 270, 'max_depth': 3, 'learning_rate': 0.019643002217916768, 'subsample': 0.8187462085432928, 'colsample_bytree': 0.8132410
[I 2025-05-31 02:45:19,724] Trial 2 finished with value: 0.017545062334801617 and parameters: {'n_estimators': 292, 'max_depth': 6, 'learning_rate': 0.02732322837140476, 'subsample': 0.7031865062393565, 'colsample_bytree': 0.738937
[I 2025-05-31 02:45:19,865] Trial 3 finished with value: 0.0174512775272285 and parameters: {'n_estimators': 291, 'max_depth': 8, 'learning_rate': 0.28424166962140124, 'subsample': 0.7668458917451416, 'colsample_bytree': 0.66390366
[I 2025-05-31 02:45:19,981] Trial 4 finished with value: 0.0175844311904 and parameters: {'n_estimators': 225, 'max_depth': 7, 'learning_rate': 0.014098481904385094, 'subsample': 0.7800585177685113, 'colsample_bytree': 0.5922690
[I 2025-05-31 02:45:20,094] Trial 5 finished with value: 0.01755738656289144 and parameters: {'n_estimators': 195, 'max_depth': 6, 'learning_rate': 0.05348180766756475, 'subsample': 0.7601184634676839, 'colsample_bytree': 0.9664524
[I 2025-05-31 02:45:20,209] Trial 6 finished with value: 0.01758404724941429 and parameters: {'n_estimators': 222, 'max_depth': 5, 'learning_rate': 0.023414265548277382, 'subsample': 0.92134289737688, 'colsample_bytree': 0.59274206
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[I 2025-05-31 02:45:20,420] Trial 8 finished with value: 0.017616312850029483 and parameters: {'n_estimators': 175, 'max_depth': 4, 'learning_rate': 0.07236362416137197, 'subsample': 0.592000590945255, 'colsample_bytree': 0.9028194
[I 2025-05-31 02:45:20,498] Trial 9 finished with value: 0.01755866160399998 and parameters: {'n_estimators': 99, 'max_depth': 7, 'learning_rate': 0.2511272046608803, 'subsample': 0.9500737214766559, 'colsample_bytree': 0.840488254
[I 2025-05-31 02:45:20,616] Trial 10 finished with value: 0.0174411920163992 and parameters: {'n_estimators': 125, 'max_depth': 8, 'learning_rate': 0.27982717236647237, 'subsample': 0.5504273478605797, 'colsample_bytree': 0.6904914
[I 2025-05-31 02:45:20,730] Trial 11 finished with value: 0.017673610653823016 and parameters: {'n_estimators': 134, 'max_depth': 8, 'learning_rate': 0.29643372630508025, 'subsample': 0.505168581736906, 'colsample_bytree': 0.678764
[I 2025-05-31 02:45:20,844] Trial 12 finished with value: 0.017592088637298192 and parameters: {'n_estimators': 135, 'max_depth': 8, 'learning_rate': 0.14809371125551768, 'subsample': 0.6367577727828418, 'colsample_bytree': 0.67786
[I 2025-05-31 02:45:20,955] Trial 13 finished with value: 0.01758149872188514 and parameters: {'n_estimators': 133, 'max_depth': 8, 'learning_rate': 0.1295700980825731, 'subsample': 0.8444069646500363, 'colsample_bytree': 0.5310597
[I 2025-05-31 02:45:21,079] Trial 14 finished with value: 0.017640990002688477 and parameters: {'n_estimators': 165, 'max_depth': 8, 'learning_rate': 0.1525946362906371, 'subsample': 0.6888930859100064, 'colsample_bytree': 0.698931
[I 2025-05-31 02:45:21,166] Trial 15 finished with value: 0.017350618736973876 and parameters: {'n_estimators': 62, 'max_depth': 7, 'learning_rate': 0.21033550126297856, 'subsample': 0.5233669394700582, 'colsample_bytree': 0.614798
[I 2025-05-31 02:45:21,250] Trial 16 finished with value: 0.01751149455322978 and parameters: {'n_estimators': 50, 'max_depth': 7, 'learning_rate': 0.0982461188486872, 'subsample': 0.5042047030411078, 'colsample_bytree': 0.51658471
[I 2025-05-31 02:45:21,334] Trial 17 finished with value: 0.017423700968734534 and parameters: {'n_estimators': 56, 'max_depth': 5, 'learning_rate': 0.19022824646808376, 'subsample': 0.5871105797828058, 'colsample_bytree': 0.634155
[I 2025-05-31 02:45:21,452] Trial 18 finished with value: 0.017455969697475184 and parameters: {'n_estimators': 51, 'max_depth': 5, 'learning_rate': 0.1886911636930949, 'subsample': 0.5997431353623094, 'colsample_bytree': 0.6041905
[I 2025-05-31 02:45:21,547] Trial 19 finished with value: 0.017624759218948155 and parameters: {'n_estimators': 91, 'max_depth': 4, 'learning_rate': 0.0973034173870786, 'subsample': 0.6562062310386715, 'colsample_bytree': 0.7724449
[I 2025-05-31 02:45:21,623] A new study created in memory with name: no-name-9b3800e5-2d9e-4fe4-9179-609660957970
[I 2025-05-31 02:45:21,715] Trial 0 finished with value: 0.004314281751754206 and parameters: {'n_estimators': 58, 'max_depth': 3, 'learning_rate': 0.03683010233991448, 'subsample': 0.9091865364358154, 'colsample_bytree': 0.7011384
[I 2025-05-31 02:45:21,792] Trial 1 finished with value: 0.004313150356202391 and parameters: {'n_estimators': 76, 'max_depth': 3, 'learning_rate': 0.022706590457444102, 'subsample': 0.7487996213595854, 'colsample_bytree': 0.804318
[I 2025-05-31 02:45:21,902] Trial 2 finished with value: 0.004369246527587756 and parameters: {'n_estimators': 188, 'max_depth': 3, 'learning_rate': 0.06383171178290123, 'subsample': 0.7307593115189173, 'colsample_bytree': 0.844168
[I 2025-05-31 02:45:21,976] Trial 3 finished with value: 0.004315164349903817 and parameters: {'n_estimators': 72, 'max_depth': 8, 'learning_rate': 0.04013883485236527, 'subsample': 0.8031081115737027, 'colsample_bytree': 0.9091360
[I 2025-05-31 02:45:22,048] Trial 4 finished with value: 0.004367038120680453 and parameters: {'n_estimators': 87, 'max_depth': 3, 'learning_rate': 0.07807731652335877, 'subsample': 0.5184197541197779, 'colsample_bytree': 0.5317129
[I 2025-05-31 02:45:22,178] Trial 5 finished with value: 0.004324588138372428 and parameters: {'n_estimators': 260, 'max_depth': 3, 'learning_rate': 0.04146040183602064, 'subsample': 0.8953646760294114, 'colsample_bytree': 0.904965
[I 2025-05-31 02:45:22,294] Trial 6 finished with value: 0.004321477999740969 and parameters: {'n_estimators': 193, 'max_depth': 6, 'learning_rate': 0.1040416650685251, 'subsample': 0.9723302881399365, 'colsample_bytree': 0.7197290
[I 2025-05-31 02:45:22,417] Trial 7 finished with value: 0.00431385520470073 and parameters: {'n_estimators': 235, 'max_depth': 4, 'learning_rate': 0.13812867876609342, 'subsample': 0.8382543275515213, 'colsample_bytree': 0.9917567
[I 2025-05-31 02:45:22,526] Trial 8 finished with value: 0.004330609367366446 and parameters: {'n_estimators': 151, 'max_depth': 3, 'learning_rate': 0.03926483131539064, 'subsample': 0.6640206410591911, 'colsample_bytree': 0.609344
[I 2025-05-31 02:45:22,663] Trial 9 finished with value: 0.00433033865952974 and parameters: {'n_estimators': 269, 'max_depth': 7, 'learning_rate': 0.03185005765696174, 'subsample': 0.566710716275072, 'colsample_bytree': 0.87109333
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[I 2025-05-31 02:45:45,535] Trial 6 finished with value: 0.004908264329144537 and parameters: {'n_estimators': 241, 'max_depth': 4, 'learning_rate': 0.10256771827871417, 'subsample': 0.5466819778920882, 'colsample_bytree': 0.603510
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[I 2025-05-31 02:45:46,606] Trial 15 finished with value: 0.004940353177450971 and parameters: {'n_estimators': 210, 'max_depth': 7, 'learning_rate': 0.03491522996939215, 'subsample': 0.6614194116786875, 'colsample_bytree': 0.70202
[I 2025-05-31 02:45:46,716] Trial 16 finished with value: 0.004720021407139868 and parameters: {'n_estimators': 118, 'max_depth': 7, 'learning_rate': 0.1971965096440457, 'subsample': 0.5711315378796992, 'colsample_bytree': 0.500901
[I 2025-05-31 02:45:46,854] Trial 17 finished with value: 0.004824844659299975 and parameters: {'n_estimators': 205, 'max_depth': 5, 'learning_rate': 0.11624526559105386, 'subsample': 0.7903389275615662, 'colsample_bytree': 0.57696
[I 2025-05-31 02:45:47,004] Trial 18 finished with value: 0.004841293474342567 and parameters: {'n_estimators': 232, 'max_depth': 4, 'learning_rate': 0.06708498805281377, 'subsample': 0.5182945545907605, 'colsample_bytree': 0.99470
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[I 2025-05-31 02:45:47,209] A new study created in memory with name: no-name-7c59ccc8-1183-4511-8cea-1b6901bff8db
[I 2025-05-31 02:45:47,350] Trial 0 finished with value: 0.0037815117608592337 and parameters: {'n_estimators': 226, 'max_depth': 7, 'learning_rate': 0.06257264944315098, 'subsample': 0.7694351350368266, 'colsample_bytree': 0.65899
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[I 2025-05-31 02:45:47,965] Trial 5 finished with value: 0.0037873746623555936 and parameters: {'n_estimators': 260, 'max_depth': 7, 'learning_rate': 0.23792748548211443, 'subsample': 0.9160853885151612, 'colsample_bytree': 0.83670
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[I 2025-05-31 02:45:48,138] Trial 7 finished with value: 0.0037895221450867838 and parameters: {'n_estimators': 104, 'max_depth': 7, 'learning_rate': 0.030970468539855595, 'subsample': 0.838183600588512, 'colsample_bytree': 0.68204
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[I 2025-05-31 02:45:48,559] Trial 11 finished with value: 0.0042423710460609025 and parameters: {'n_estimators': 163, 'max_depth': 4, 'learning_rate': 0.11870687180123281, 'subsample': 0.5604466926131091, 'colsample_bytree': 0.5636
[I 2025-05-31 02:45:48,714] Trial 12 finished with value: 0.0035177296984024954 and parameters: {'n_estimators': 245, 'max_depth': 5, 'learning_rate': 0.12037894876972499, 'subsample': 0.6417421108099155, 'colsample_bytree': 0.9679
[I 2025-05-31 02:45:48,869] Trial 13 finished with value: 0.004033365259184422 and parameters: {'n_estimators': 240, 'max_depth': 4, 'learning_rate': 0.26900196354038663, 'subsample': 0.6253389809846506, 'colsample_bytree': 0.99509
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[I 2025-05-31 02:45:49,889] Trial 19 finished with value: 0.0035991812412069306 and parameters: {'n_estimators': 284, 'max_depth': 4, 'learning_rate': 0.17159141188842947, 'subsample': 0.7175919647635565, 'colsample_bytree': 0.71299
[I 2025-05-31 02:45:50,155] A new study created in memory with name: no-name-4d4e831e-5a1f-46cc-9b5c-dd6e6a73b383
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[I 2025-05-31 02:45:53,322] Trial 11 finished with value: 0.00788874810171273 and parameters: {'n_estimators': 52, 'max_depth': 6, 'learning_rate': 0.29071826182491745, 'subsample': 0.5956758546728772, 'colsample_bytree': 0.5307533
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[I 2025-05-31 02:45:53,904] Trial 16 finished with value: 0.007824199008169195 and parameters: {'n_estimators': 90, 'max_depth': 6, 'learning_rate': 0.14012830887117658, 'subsample': 0.7582584778095606, 'colsample_bytree': 0.720482
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[I 2025-05-31 02:45:54,408] A new study created in memory with name: no-name-7808e80c-f39f-46fe-8b63-1360f84654ca
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[I 2025-05-31 02:45:56,950] Trial 6 finished with value: 0.0024062476921875562 and parameters: {'n_estimators': 188, 'max_depth': 8, 'learning_rate': 0.05842575588536221, 'subsample': 0.9109043615023309, 'colsample_bytree': 0.99341
[I 2025-05-31 02:45:57,140] Trial 7 finished with value: 0.0024235622934567634 and parameters: {'n_estimators': 236, 'max_depth': 3, 'learning_rate': 0.019908386404519734, 'subsample': 0.9206294466619316, 'colsample_bytree': 0.5051
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[I 2025-05-31 02:45:57,360] Trial 9 finished with value: 0.0024138937740987862 and parameters: {'n_estimators': 204, 'max_depth': 4, 'learning_rate': 0.01940606244448105, 'subsample': 0.9744568464684369, 'colsample_bytree': 0.68541
[I 2025-05-31 02:45:57,447] Trial 10 finished with value: 0.002431008490383037 and parameters: {'n_estimators': 55, 'max_depth': 7, 'learning_rate': 0.07342287185232023, 'subsample': 0.7357701867614548, 'colsample_bytree': 0.966658
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[I 2025-05-31 02:45:57,646] Trial 12 finished with value: 0.0024109031258775586 and parameters: {'n_estimators': 106, 'max_depth': 6, 'learning_rate': 0.1177664832167326, 'subsample': 0.6475158205090715, 'colsample_bytree': 0.89690
[I 2025-05-31 02:45:57,735] Trial 13 finished with value: 0.002443639174085231 5 and parameters: {'n_estimators': 51, 'max_depth': 3, 'learning_rate': 0.052574247672048144, 'subsample': 0.8166474660055318, 'colsample_bytree': 0.9280
[I 2025-05-31 02:45:57,888] Trial 14 finished with value: 0.0023771261873002303 and parameters: {'n_estimators': 143, 'max_depth': 7, 'learning_rate': 0.2682901158499673, 'subsample': 0.6750649760846823, 'colsample_bytree': 0.87108
[I 2025-05-31 02:45:58,008] Trial 15 finished with value: 0.0024262668245486133 and parameters: {'n_estimators': 158, 'max_depth': 7, 'learning_rate': 0.2896119749036685, 'subsample': 0.6512615943972304, 'colsample_bytree': 0.86325
[I 2025-05-31 02:45:58,146] Trial 16 finished with value: 0.002412167800036805 and parameters: {'n_estimators': 211, 'max_depth': 7, 'learning_rate': 0.05593139606784133, 'subsample': 0.6235750755939293, 'colsample_bytree': 0.99145
[I 2025-05-31 02:45:58,312] Trial 17 finished with value: 0.002424525864940816 and parameters: {'n_estimators': 291, 'max_depth': 8, 'learning_rate': 0.2055947131661071, 'subsample': 0.8090342692056346, 'colsample_bytree': 0.870861
[I 2025-05-31 02:45:58,437] Trial 18 finished with value: 0.002404148996706412 and parameters: {'n_estimators': 181, 'max_depth': 7, 'learning_rate': 0.03641924382038183, 'subsample': 0.5916343069114398, 'colsample_bytree': 0.69827
[I 2025-05-31 02:45:58,550] Trial 19 finished with value: 0.002412042560485408 and parameters: {'n_estimators': 145, 'max_depth': 6, 'learning_rate': 0.033936148711801846, 'subsample': 0.590343168069286 6, 'colsample_bytree': 0.6952
[I 2025-05-31 02:45:58,651] A new study created in memory with name: no-name-9e262f9d-268e-44ac-9227-b5b926b7fe07
[I 2025-05-31 02:45:58,910] Trial 0 finished with value: 0.003301319629716379 and parameters: {'n_estimators': 252, 'max_depth': 5, 'learning_rate': 0.23300105488992146, 'subsample': 0.8292767194577366, 'colsample_bytree': 0.573387
[I 2025-05-31 02:45:58,984] Trial 1 finished with value: 0.0031379121716303394 and parameters: {'n_estimators': 77, 'max_depth': 4, 'learning_rate': 0.05676084344265651, 'subsample': 0.548905629491355, 'colsample_bytree': 0.7325661
[I 2025-05-31 02:45:59,108] Trial 2 finished with value: 0.0031867636623942697 and parameters: {'n_estimators': 248, 'max_depth': 8, 'learning_rate': 0.0980495261370138, 'subsample': 0.9770024538697059, 'colsample_bytree': 0.650651
[I 2025-05-31 02:45:59,173] Trial 3 finished with value: 0.0031527698449418753 and parameters: {'n_estimators': 61, 'max_depth': 4, 'learning_rate': 0.2856332897334804, 'subsample': 0.7260498261865596, 'colsample_bytree': 0.5576354
[I 2025-05-31 02:45:59,240] Trial 4 finished with value: 0.0031066157142835642 and parameters: {'n_estimators': 64, 'max_depth': 7, 'learning_rate': 0.04764990950195396, 'subsample': 0.7259558985376098, 'colsample_bytree': 0.611276
[I 2025-05-31 02:45:59,322] Trial 5 finished with value: 0.0032669760192876366 and parameters: {'n_estimators': 117, 'max_depth': 7, 'learning_rate': 0.2202905618970544, 'subsample': 0.6455228403167714, 'colsample_bytree': 0.650495
[I 2025-05-31 02:45:59,426] Trial 6 finished with value: 0.0031494685173570893 and parameters: {'n_estimators': 177, 'max_depth': 8, 'learning_rate': 0.02619449013547369, 'subsample': 0.5695760307184325, 'colsample_bytree': 0.66589
[I 2025-05-31 02:45:59,531] Trial 7 finished with value: 0.0031286153044791628 and parameters: {'n_estimators': 178, 'max_depth': 5, 'learning_rate': 0.05286413700850261, 'subsample': 0.5243653502735899, 'colsample_bytree': 0.93990
[I 2025-05-31 02:45:59,632] Trial 8 finished with value: 0.0030947483650614165 and parameters: {'n_estimators': 143, 'max_depth': 3, 'learning_rate': 0.19953786282911007, 'subsample': 0.8892253184553617, 'colsample_bytree': 0.78168
[I 2025-05-31 02:45:59,715] Trial 9 finished with value: 0.0030878507859915232 and parameters: {'n_estimators': 109, 'max_depth': 6, 'learning_rate': 0.14484950966605353, 'subsample': 0.6435190929762067, 'colsample_bytree': 0.82677
[I 2025-05-31 02:45:59,906] Trial 10 finished with value: 0.0031732207001127066 and parameters: {'n_estimators': 300, 'max_depth': 6, 'learning_rate': 0.01217403115580279, 'subsample': 0.6471165040818935, 'colsample_bytree': 0.8970
[I 2025-05-31 02:46:00,018] Trial 11 finished with value: 0.003156724156405656 and parameters: {'n_estimators': 128, 'max_depth': 3, 'learning_rate': 0.12427010982081606, 'subsample': 0.8904541069850287, 'colsample_bytree': 0.83494
[I 2025-05-31 02:46:00,137] Trial 12 finished with value: 0.003112248469216793 and parameters: {'n_estimators': 132, 'max_depth': 3, 'learning_rate': 0.12731738680551588, 'subsample': 0.824637982810201, 'colsample_bytree': 0.793550
[I 2025-05-31 02:46:00,255] Trial 13 finished with value: 0.003184010311997995 and parameters: {'n_estimators': 152, 'max_depth': 6, 'learning_rate': 0.16224331494593588, 'subsample': 0.9908824627692921, 'colsample_bytree': 0.85322
[I 2025-05-31 02:46:00,358] Trial 14 finished with value: 0.003152101943403354 and parameters: {'n_estimators': 95, 'max_depth': 4, 'learning_rate': 0.08256889296075384, 'subsample': 0.8945599449426658, 'colsample_bytree': 0.983187
[I 2025-05-31 02:46:00,494] Trial 15 finished with value: 0.003086598336834483 and parameters: {'n_estimators': 202, 'max_depth': 6, 'learning_rate': 0.172654860836001, 'subsample': 0.6229780548992174, 'colsample_bytree': 0.7433273
[I 2025-05-31 02:46:00,634] Trial 16 finished with value: 0.0031283086268406807 and parameters: {'n_estimators': 208, 'max_depth': 7, 'learning_rate': 0.030557749069965286, 'subsample': 0.6317355219539521, 'colsample_bytree': 0.769
[I 2025-05-31 02:46:00,774] Trial 17 finished with value: 0.0032921673491956246 and parameters: {'n_estimators': 211, 'max_depth': 6, 'learning_rate': 0.07945154515558273, 'subsample': 0.5974072889639453, 'colsample_bytree': 0.7071
[I 2025-05-31 02:46:00,929] Trial 18 finished with value: 0.0031754514155305784 and parameters: {'n_estimators': 208, 'max_depth': 5, 'learning_rate': 0.14980282731971986, 'subsample': 0.6900873493376334, 'colsample_bytree': 0.5120
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[I 2025-05-31 02:46:01,208] A new study created in memory with name: no-name-5034a50b-e433-491c-b42c-6eddf7cd9377
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[I 2025-05-31 02:46:11,807] Trial 8 finished with value: 0.003808356100803105 and parameters: {'n_estimators': 239, 'max_depth': 7, 'learning_rate': 0.01393822107887515, 'subsample': 0.7052845943618966, 'colsample_bytree': 0.89158
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[I 2025-05-31 02:46:23,917] Trial 2 finished with value: 0.01444028818721668 and parameters: {'n_estimators': 270, 'max_depth': 4, 'learning_rate': 0.049957923574435216, 'subsample': 0.7032576561116465, 'colsample_bytree': 0.791760
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[I 2025-05-31 02:46:25,437] Trial 17 finished with value: 0.01439812790731674 and parameters: {'n_estimators': 83, 'max_depth': 5, 'learning_rate': 0.15024639973188497, 'subsample': 0.5888331090338743, 'colsample_bytree': 0.8830103
[I 2025-05-31 02:46:25,530] Trial 18 finished with value: 0.014331348696070988 and parameters: {'n_estimators': 81, 'max_depth': 5, 'learning_rate': 0.16685924329286833, 'subsample': 0.6606921185097223, 'colsample_bytree': 0.688868
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[I 2025-05-31 02:46:26,199] Trial 3 finished with value: 0.005858937756621244 and parameters: {'n_estimators': 260, 'max_depth': 5, 'learning_rate': 0.13119549858582308, 'subsample': 0.6936098067378844, 'colsample_bytree': 0.955294
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[I 2025-05-31 02:46:26,517] Trial 6 finished with value: 0.005825097175470417 and parameters: {'n_estimators': 167, 'max_depth': 7, 'learning_rate': 0.012861897884183213, 'subsample': 0.7559578870014776, 'colsample_bytree': 0.82847
[I 2025-05-31 02:46:26,579] Trial 7 finished with value: 0.005814437010020988 and parameters: {'n_estimators': 50, 'max_depth': 3, 'learning_rate': 0.010259622670149128, 'subsample': 0.5631536047732411, 'colsample_bytree': 0.5693331
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[I 2025-05-31 02:46:26,935] Trial 10 finished with value: 0.005709813647957603 and parameters: {'n_estimators': 221, 'max_depth': 8, 'learning_rate': 0.03298030202498565, 'subsample': 0.8097049402875912, 'colsample_bytree': 0.73087
[I 2025-05-31 02:46:27,077] Trial 11 finished with value: 0.0057298775096645055 and parameters: {'n_estimators': 219, 'max_depth': 8, 'learning_rate': 0.03287862719044211, 'subsample': 0.7922863925653804, 'colsample_bytree': 0.7164
[I 2025-05-31 02:46:27,218] Trial 12 finished with value: 0.0057749967032468316 and parameters: {'n_estimators': 232, 'max_depth': 8, 'learning_rate': 0.03365119087012388, 'subsample': 0.8338264509155993, 'colsample_bytree': 0.6801
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[I 2025-05-31 02:46:27,974] Trial 17 finished with value: 0.005826668105283126 and parameters: {'n_estimators': 252, 'max_depth': 7, 'learning_rate': 0.13642360036572493, 'subsample': 0.7795054531702424, 'colsample_bytree': 0.66265
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[I 2025-05-31 02:46:28,904] Trial 4 finished with value: 0.005653541104431153 and parameters: {'n_estimators': 234, 'max_depth': 5, 'learning_rate': 0.0868597855631299, 'subsample': 0.8911908809063951, 'colsample_bytree': 0.7498637
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[I 2025-05-31 02:46:31,532] Trial 12 finished with value: 0.00559051552420278 and parameters: {'n_estimators': 291, 'max_depth': 5, 'learning_rate': 0.038074751120845164, 'subsample': 0.7644352091482299, 'colsample_bytree': 0.81753
[I 2025-05-31 02:46:31,704] Trial 13 finished with value: 0.005456968885673568 and parameters: {'n_estimators': 108, 'max_depth': 6, 'learning_rate': 0.12235860540308317, 'subsample': 0.5854727651146416, 'colsample_bytree': 0.89483
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[I 2025-05-31 02:46:33,986] Trial 9 finished with value: 0.0021418657201185006 and parameters: {'n_estimators': 148, 'max_depth': 7, 'learning_rate': 0.23268056003072693, 'subsample': 0.8798112296517405, 'colsample_bytree': 0.61810
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[I 2025-05-31 02:46:34,339] Trial 12 finished with value: 0.002225394732804933 and parameters: {'n_estimators': 194, 'max_depth': 8, 'learning_rate': 0.08817144718319263, 'subsample': 0.8405899630847596, 'colsample_bytree': 0.62925
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[I 2025-05-31 02:46:34,561] Trial 14 finished with value: 0.0024932668577923927 and parameters: {'n_estimators': 54, 'max_depth': 7, 'learning_rate': 0.14483219820020296, 'subsample': 0.511095059894356, 'colsample_bytree': 0.729274
[I 2025-05-31 02:46:34,705] Trial 15 finished with value: 0.0020387176357262622 and parameters: {'n_estimators': 233, 'max_depth': 7, 'learning_rate': 0.29677277889199416, 'subsample': 0.8081522247182322, 'colsample_bytree': 0.5707
[I 2025-05-31 02:46:34,858] Trial 16 finished with value: 0.002161872305757318 and parameters: {'n_estimators': 243, 'max_depth': 4, 'learning_rate': 0.26786538896790074, 'subsample': 0.7947566694133564, 'colsample_bytree': 0.58018
[I 2025-05-31 02:46:34,978] Trial 17 finished with value: 0.0021895791550450966 and parameters: {'n_estimators': 146, 'max_depth': 7, 'learning_rate': 0.06651251604517662, 'subsample': 0.9880098790829831, 'colsample_bytree': 0.5780
[I 2025-05-31 02:46:35,083] Trial 18 finished with value: 0.0023052751869996105 and parameters: {'n_estimators': 108, 'max_depth': 7, 'learning_rate': 0.16994502560644376, 'subsample': 0.7866189011222053, 'colsample_bytree': 0.6034
[I 2025-05-31 02:46:35,210] Trial 19 finished with value: 0.002366624260286321 and parameters: {'n_estimators': 174, 'max_depth': 5, 'learning_rate': 0.24494232452254697, 'subsample': 0.9304882008249069, 'colsample_bytree': 0.53909
[I 2025-05-31 02:46:35,343] A new study created in memory with name: no-name-841625d9-7e9f-4941-9bee-c4b8e36a078b
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[I 2025-05-31 02:46:35,589] Trial 1 finished with value: 0.0026669542674421665 and parameters: {'n_estimators': 270, 'max_depth': 7, 'learning_rate': 0.014145051525093428, 'subsample': 0.8810081065792016, 'colsample_bytree': 0.6180
[I 2025-05-31 02:46:35,685] Trial 2 finished with value: 0.002670280550225527 and parameters: {'n_estimators': 151, 'max_depth': 6, 'learning_rate': 0.042424624519391184, 'subsample': 0.7848898345729021, 'colsample_bytree': 0.86638
[I 2025-05-31 02:46:35,815] Trial 3 finished with value: 0.00269176401137643 and parameters: {'n_estimators': 201, 'max_depth': 7, 'learning_rate': 0.2587193811194021, 'subsample': 0.603168638565083, 'colsample_bytree': 0.971342135
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[I 2025-05-31 02:46:36,009] Trial 5 finished with value: 0.0026615639532506525 and parameters: {'n_estimators': 100, 'max_depth': 7, 'learning_rate': 0.020687146725860323, 'subsample': 0.919824578827844, 'colsample_bytree': 0.87627
[I 2025-05-31 02:46:36,120] Trial 6 finished with value: 0.0026613262668770867 and parameters: {'n_estimators': 199, 'max_depth': 7, 'learning_rate': 0.02799532717549972, 'subsample': 0.6440078927242023, 'colsample_bytree': 0.77103
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[I 2025-05-31 02:46:36,375] Trial 8 finished with value: 0.0026664064150454334 and parameters: {'n_estimators': 234, 'max_depth': 3, 'learning_rate': 0.04182275567656399, 'subsample': 0.9095345817623812, 'colsample_bytree': 0.61516
[I 2025-05-31 02:46:36,478] Trial 9 finished with value: 0.002662702765622277 and parameters: {'n_estimators': 163, 'max_depth': 3, 'learning_rate': 0.012749380986013312, 'subsample': 0.9928878690847132, 'colsample_bytree': 0.917026
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[I 2025-05-31 02:46:36,738] Trial 12 finished with value: 0.00266912265261123 and parameters: {'n_estimators': 53, 'max_depth': 5, 'learning_rate': 0.08271703465769734, 'subsample': 0.7724813913147167, 'colsample_bytree': 0.6410858
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[I 2025-05-31 02:46:37,048] Trial 14 finished with value: 0.002649869669592703 and parameters: {'n_estimators': 237, 'max_depth': 4, 'learning_rate': 0.06615977373198323, 'subsample': 0.523873435621407 2, 'colsample_bytree': 0.55115
[I 2025-05-31 02:46:37,229] Trial 15 finished with value: 0.002663375271290 6487 and parameters: {'n_estimators': 244, 'max_depth': 4, 'learning_rate': 0.07250611828784084, 'subsample': 0.5077009715073127, 'colsample_bytree': 0.7081
[I 2025-05-31 02:46:37,330] Trial 16 finished with value: 0.0026511982826253173 and parameters: {'n_estimators': 97, 'max_depth': 4, 'learning_rate': 0.14431881743801758, 'subsample': 0.5521044378288564, 'colsample_bytree': 0.57652
[I 2025-05-31 02:46:37,479] Trial 17 finished with value: 0.0026586723828580677 and parameters: {'n_estimators': 240, 'max_depth': 4, 'learning_rate': 0.06827703669027342, 'subsample': 0.657774272887551, 'colsample_bytree': 0.76683
[I 2025-05-31 02:46:37,580] Trial 18 finished with value: 0.002679007490362121 and parameters: {'n_estimators': 98, 'max_depth': 5, 'learning_rate': 0.2379237349847646, 'subsample': 0.8372699299633827, 'colsample_bytree': 0.6635324
[I 2025-05-31 02:46:37,691] Trial 19 finished with value: 0.002669509050919153 and parameters: {'n_estimators': 129, 'max_depth': 6, 'learning_rate': 0.12837145904949512, 'subsample': 0.5609724942946538, 'colsample_bytree': 0.57431
[I 2025-05-31 02:46:37,767] A new study created in memory with name: no-name-25244ab8-707a-4c35-975e-d216a0cb7321
[I 2025-05-31 02:46:37,923] Trial 0 finished with value: 0.002349189421679253 and parameters: {'n_estimators': 272, 'max_depth': 7, 'learning_rate': 0.09975165018644624, 'subsample': 0.6679170449274922, 'colsample_bytree': 0.649757
[I 2025-05-31 02:46:38,065] Trial 1 finished with value: 0.002381885455562975 and parameters: {'n_estimators': 285, 'max_depth': 3, 'learning_rate': 0.0930373302906548, 'subsample': 0.5007491671676955, 'colsample_bytree': 0.9562815
[I 2025-05-31 02:46:38,174] Trial 2 finished with value: 0.0023671861594438607 and parameters: {'n_estimators': 169, 'max_depth': 7, 'learning_rate': 0.04128186352468199, 'subsample': 0.8733950252779095, 'colsample_bytree': 0.88765
[I 2025-05-31 02:46:38,286] Trial 3 finished with value: 0.0023677831259325487 and parameters: {'n_estimators': 92, 'max_depth': 7, 'learning_rate': 0.06998920754176895, 'subsample': 0.841202902281 8546, 'colsample_bytree': 0.993063
[I 2025-05-31 02:46:38,425] Trial 4 finished with value: 0.0023609922764901608 and parameters: {'n_estimators': 272, 'max_depth': 4, 'learning_rate': 0.020284604081540907, 'subsample': 0.7283955456275683, 'colsample_bytree': 0.8384
[I 2025-05-31 02:46:38,547] Trial 5 finished with value: 0.0023804384515628773 and parameters: {'n_estimators': 230, 'max_depth': 6, 'learning_rate': 0.019739411897222288, 'subsample': 0.6184150505450154, 'colsample_bytree': 0.9638
[I 2025-05-31 02:46:38,656] Trial 6 finished with value: 0.0023697692919440743 and parameters: {'n_estimators': 181, 'max_depth': 5, 'learning_rate': 0.03579585975978256, 'subsample': 0.7984363928241395, 'colsample_bytree': 0.64824
[I 2025-05-31 02:46:38,726] Trial 7 finished with value: 0.0023467428638356378 and parameters: {'n_estimators': 77, 'max_depth': 7, 'learning_rate': 0.12175364334964135, 'subsample': 0.738945460134 2371, 'colsample_bytree': 0.519671
[I 2025-05-31 02:46:38,805] Trial 8 finished with value: 0.002373352206228108 and parameters: {'n_estimators': 99, 'max_depth': 6, 'learning_rate': 0.05988351596422759, 'subsample': 0.9249253239881385, 'colsample_bytree': 0.8137629
[I 2025-05-31 02:46:38,913] Trial 9 finished with value: 0.0023749923493753527 and parameters: {'n_estimators': 169, 'max_depth': 4, 'learning_rate': 0.012606628468880906, 'subsample': 0.7546741126542853, 'colsample_bytree': 0.5315
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[I 2025-05-31 02:47:03,856] Trial 17 finished with value: 0.006488913400031458 and parameters: {'n_estimators': 93, 'max_depth': 8, 'learning_rate': 0.0460822449235154, 'subsample': 0.8124560903837044, 'colsample_bytree': 0.6346918
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[I 2025-05-31 02:47:04,341] A new study created in memory with name: no-name-3e5162b4-d071-4779-aae2-36597620510a
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[I 2025-05-31 02:47:04,829] Trial 3 finished with value: 0.0015063245408484895 and parameters: {'n_estimators': 125, 'max_depth': 6, 'learning_rate': 0.021952533785519982, 'subsample': 0.9591496920992726, 'colsample_bytree': 0.6070
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[I 2025-05-31 02:47:05,132] Trial 6 finished with value: 0.0014915230834394964 and parameters: {'n_estimators': 265, 'max_depth': 7, 'learning_rate': 0.06498059969459324, 'subsample': 0.737977242014155, 'colsample_bytree': 0.836618
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[I 2025-05-31 02:47:11,951] Trial 7 finished with value: 0.00198916888004545 and parameters: {'n_estimators': 164, 'max_depth': 6, 'learning_rate': 0.11276988550990787, 'subsample': 0.7915365223253724, 'colsample_bytree': 0.5377413
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[I 2025-05-31 02:47:13,386] A new study created in memory with name: no-name-82b7e8e1-0a7d-4617-8048-2ba3dfb71bbe
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[I 2025-05-31 02:47:13,850] Trial 3 finished with value: 0.002941543947725623 and parameters: {'n_estimators': 129, 'max_depth': 8, 'learning_rate': 0.029909606936661545, 'subsample': 0.9418479366237948, 'colsample_bytree': 0.79482
[I 2025-05-31 02:47:13,940] Trial 4 finished with value: 0.002921448715460629 and parameters: {'n_estimators': 124, 'max_depth': 7, 'learning_rate': 0.197397190747305, 'subsample': 0.944200443971571, 'colsample_bytree': 0.988346555
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[I 2025-05-31 02:47:15,443] Trial 16 finished with value: 0.002996606001176823 and parameters: {'n_estimators': 173, 'max_depth': 4, 'learning_rate': 0.14737013862765969, 'subsample': 0.6828263304388017, 'colsample_bytree': 0.94060
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[I 2025-05-31 02:47:15,705] Trial 18 finished with value: 0.0030071400724612702 and parameters: {'n_estimators': 77, 'max_depth': 8, 'learning_rate': 0.19217814998948352, 'subsample': 0.560318322932905 1, 'colsample_bytree': 0.85042
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[I 2025-05-31 02:47:16,122] Trial 0 finished with value: 0.002814690951237954 and parameters: {'n_estimators': 244, 'max_depth': 5, 'learning_rate': 0.04400624273372662, 'subsample': 0.9997533318250635, 'colsample_bytree': 0.994765
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[I 2025-05-31 02:47:26,949] Trial 14 finished with value: 0.004228848580148841 and parameters: {'n_estimators': 267, 'max_depth': 3, 'learning_rate': 0.01020936537988175, 'subsample': 0.9011199112502444, 'colsample_bytree': 0.92609
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[I 2025-05-31 02:47:28,101] Trial 2 finished with value: 0.0009964892498763567 and parameters: {'n_estimators': 86, 'max_depth': 6, 'learning_rate': 0.07792720283086794, 'subsample': 0.6533622589928959, 'colsample_bytree': 0.743121
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[I 2025-05-31 02:47:28,344] Trial 4 finished with value: 0.0011332656504203019 and parameters: {'n_estimators': 174, 'max_depth': 5, 'learning_rate': 0.044312456333651135, 'subsample': 0.6349700267958944, 'colsample_bytree': 0.6009
[I 2025-05-31 02:47:28,442] Trial 5 finished with value: 0.0011162638582177399 and parameters: {'n_estimators': 156, 'max_depth': 5, 'learning_rate': 0.14817581847136072, 'subsample': 0.7759780815173598, 'colsample_bytree': 0.88699
[I 2025-05-31 02:47:28,576] Trial 6 finished with value: 0.0010353524644235897 and parameters: {'n_estimators': 276, 'max_depth': 3, 'learning_rate': 0.027365551907115756, 'subsample': 0.5837200277158814, 'colsample_bytree': 0.7240
[I 2025-05-31 02:47:28,697] Trial 7 finished with value: 0.0010370460404392845 and parameters: {'n_estimators': 235, 'max_depth': 3, 'learning_rate': 0.011385145784302416, 'subsample': 0.766532987657661, 'colsample_bytree': 0.76688
[I 2025-05-31 02:47:28,833] Trial 8 finished with value: 0.0009907068130924302 and parameters: {'n_estimators': 257, 'max_depth': 5, 'learning_rate': 0.05082869100451121, 'subsample': 0.7990737471783582, 'colsample_bytree': 0.95823
[I 2025-05-31 02:47:28,950] Trial 9 finished with value: 0.0010557626855658322 and parameters: {'n_estimators': 216, 'max_depth': 3, 'learning_rate': 0.031551941926880815, 'subsample': 0.5944578051248048, 'colsample_bytree': 0.6200
[I 2025-05-31 02:47:29,164] Trial 10 finished with value: 0.0010657232618475885 and parameters: {'n_estimators': 297, 'max_depth': 8, 'learning_rate': 0.27672780394893903, 'subsample': 0.853204612392681, 'colsample_bytree': 0.97651
[I 2025-05-31 02:47:29,253] Trial 11 finished with value: 0.0009316356170411194 and parameters: {'n_estimators': 70, 'max_depth': 7, 'learning_rate': 0.09423759864951246, 'subsample': 0.7069114869019464, 'colsample_bytree': 0.51155
[I 2025-05-31 02:47:29,358] Trial 12 finished with value: 0.0008956583946680973 and parameters: {'n_estimators': 126, 'max_depth': 7, 'learning_rate': 0.08434204075986905, 'subsample': 0.5045387117489406, 'colsample_bytree': 0.5040
[I 2025-05-31 02:47:29,439] Trial 13 finished with value: 0.001168953061917549 and parameters: {'n_estimators': 50, 'max_depth': 8, 'learning_rate': 0.11865002888230408, 'subsample': 0.5002983742040891, 'colsample_bytree': 0.506830
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[I 2025-05-31 02:47:29,648] Trial 15 finished with value: 0.001109628105209697 and parameters: {'n_estimators': 107, 'max_depth': 7, 'learning_rate': 0.20128890784648934, 'subsample': 0.6839728655211494, 'colsample_bytree': 0.60651
[I 2025-05-31 02:47:29,752] Trial 16 finished with value: 0.0009683756249947499 and parameters: {'n_estimators': 124, 'max_depth': 7, 'learning_rate': 0.07552671602943574, 'subsample': 0.7157272647126603, 'colsample_bytree': 0.5444
[I 2025-05-31 02:47:29,840] Trial 17 finished with value: 0.0010208851208603263 and parameters: {'n_estimators': 69, 'max_depth': 7, 'learning_rate': 0.017735209049763112, 'subsample': 0.9927560508812455, 'colsample_bytree': 0.6771
[I 2025-05-31 02:47:29,942] Trial 18 finished with value: 0.0010665532553945818 and parameters: {'n_estimators': 107, 'max_depth': 8, 'learning_rate': 0.11668182928794911, 'subsample': 0.5681479663248344, 'colsample_bytree': 0.5640
[I 2025-05-31 02:47:30,026] Trial 19 finished with value: 0.0009954389732221038 and parameters: {'n_estimators': 58, 'max_depth': 6, 'learning_rate': 0.18062875337132214, 'subsample': 0.8393614547994126, 'colsample_bytree': 0.66327
[I 2025-05-31 02:47:30,125] A new study created in memory with name: no-name-bc2e650d-d10a-43f0-84f6-fb90729b9ace
[I 2025-05-31 02:47:30,231] Trial 0 finished with value: 0.000862245193821732 and parameters: {'n_estimators': 80, 'max_depth': 4, 'learning_rate': 0.03520635558750159, 'subsample': 0.5089429669554952, 'colsample_bytree': 0.9811798
[I 2025-05-31 02:47:30,352] Trial 1 finished with value: 0.0008280149064817798 and parameters: {'n_estimators': 233, 'max_depth': 5, 'learning_rate': 0.19973138266636645, 'subsample': 0.9532335601724121, 'colsample_bytree': 0.74480
[I 2025-05-31 02:47:30,463] Trial 2 finished with value: 0.0008874835880828797 and parameters: {'n_estimators': 215, 'max_depth': 3, 'learning_rate': 0.1019045044877083, 'subsample': 0.7867264942825205, 'colsample_bytree': 0.606197
[I 2025-05-31 02:47:30,554] Trial 3 finished with value: 0.0008715340475882406 and parameters: {'n_estimators': 136, 'max_depth': 7, 'learning_rate': 0.08290095011055419, 'subsample': 0.6120927299903649, 'colsample_bytree': 0.57271
[I 2025-05-31 02:47:30,721] Trial 4 finished with value: 0.0008168536531047792 and parameters: {'n_estimators': 202, 'max_depth': 6, 'learning_rate': 0.014832073492181061, 'subsample': 0.7598019531237644, 'colsample_bytree': 0.9959
[I 2025-05-31 02:47:30,811] Trial 5 finished with value: 0.0008004215648438945 and parameters: {'n_estimators': 130, 'max_depth': 7, 'learning_rate': 0.19164790158426728, 'subsample': 0.9172382454345644, 'colsample_bytree': 0.78194
[I 2025-05-31 02:47:30,904] Trial 6 finished with value: 0.0008357328181440596 and parameters: {'n_estimators': 156, 'max_depth': 3, 'learning_rate': 0.12523333823049596, 'subsample': 0.7714234336718213, 'colsample_bytree': 0.81161
[I 2025-05-31 02:47:31,006] Trial 7 finished with value: 0.0008497719606547792 and parameters: {'n_estimators': 178, 'max_depth': 3, 'learning_rate': 0.011651183170947443, 'subsample': 0.5205826772897948, 'colsample_bytree': 0.8574
[I 2025-05-31 02:47:31,091] Trial 8 finished with value: 0.0008219960336606919 and parameters: {'n_estimators': 126, 'max_depth': 8, 'learning_rate': 0.15824092336808696, 'subsample': 0.6711159197387888, 'colsample_bytree': 0.82910
[I 2025-05-31 02:47:31,252] Trial 9 finished with value: 0.0008682803785110839 and parameters: {'n_estimators': 248, 'max_depth': 4, 'learning_rate': 0.20517244749671013, 'subsample': 0.613933576643652, 'colsample_bytree': 0.805507
[I 2025-05-31 02:47:31,411] Trial 10 finished with value: 0.000828837171627183 and parameters: {'n_estimators': 291, 'max_depth': 8, 'learning_rate': 0.04284401828184228, 'subsample': 0.9507724542983291, 'colsample_bytree': 0.71585
[I 2025-05-31 02:47:31,499] Trial 11 finished with value: 0.0008283688594705359 and parameters: {'n_estimators': 66, 'max_depth': 6, 'learning_rate': 0.01121124303176306, 'subsample': 0.8508621010828812, 'colsample_bytree': 0.96400
[I 2025-05-31 02:47:31,622] Trial 12 finished with value: 0.0008197418381868968 and parameters: {'n_estimators': 184, 'max_depth': 6, 'learning_rate': 0.023733230031519708, 'subsample': 0.8631648231059077, 'colsample_bytree': 0.658
[I 2025-05-31 02:47:31,723] Trial 13 finished with value: 0.0008350609032549813 and parameters: {'n_estimators': 104, 'max_depth': 7, 'learning_rate': 0.020720269003296043, 'subsample': 0.8502025581945065, 'colsample_bytree': 0.913
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[I 2025-05-31 02:47:32,026] Trial 15 finished with value: 0.0008400237079692467 and parameters: {'n_estimators': 297, 'max_depth': 7, 'learning_rate': 0.06909834546582422, 'subsample': 0.6889891607949274, 'colsample_bytree': 0.8990
[I 2025-05-31 02:47:32,144] Trial 16 finished with value: 0.0008221650829295708 and parameters: {'n_estimators': 158, 'max_depth': 8, 'learning_rate': 0.24685926514353196, 'subsample': 0.9766429290167314, 'colsample_bytree': 0.5050
[I 2025-05-31 02:47:32,277] Trial 17 finished with value: 0.0008120844475659863 and parameters: {'n_estimators': 98, 'max_depth': 7, 'learning_rate': 0.2944030699116027, 'subsample': 0.8956538730624338, 'colsample_bytree': 0.679911
[I 2025-05-31 02:47:32,375] Trial 18 finished with value: 0.0008163074509343703 and parameters: {'n_estimators': 98, 'max_depth': 5, 'learning_rate': 0.2737444224686812, 'subsample': 0.915976719189237, 'colsample_bytree': 0.6882653
[I 2025-05-31 02:47:32,463] Trial 19 finished with value: 0.0008219778993326038 and parameters: {'n_estimators': 57, 'max_depth': 7, 'learning_rate': 0.14752592576688967, 'subsample': 0.8970578967652041, 'colsample_bytree': 0.76809
[I 2025-05-31 02:47:32,674] A new study created in memory with name: no-name-6ae4bf42-298c-4393-8368-0c52b5210e4f
[I 2025-05-31 02:47:32,812] Trial 0 finished with value: 0.011120350681475013 and parameters: {'n_estimators': 257, 'max_depth': 7, 'learning_rate': 0.0766554900098828, 'subsample': 0.657614898734904, 'colsample_bytree': 0.76215106
[I 2025-05-31 02:47:32,938] Trial 1 finished with value: 0.011110655078505643 and parameters: {'n_estimators': 233, 'max_depth': 4, 'learning_rate': 0.028713327505753682, 'subsample': 0.5529894451441866, 'colsample_bytree': 0.98503
[I 2025-05-31 02:47:33,026] Trial 2 finished with value: 0.011065013315671522 and parameters: {'n_estimators': 126, 'max_depth': 8, 'learning_rate': 0.04219945143094022, 'subsample': 0.9612886715510476, 'colsample_bytree': 0.624349
[I 2025-05-31 02:47:33,159] Trial 3 finished with value: 0.011018513943527488 and parameters: {'n_estimators': 263, 'max_depth': 3, 'learning_rate': 0.2742136774845631, 'subsample': 0.9371263196865492, 'colsample_bytree': 0.5649056
[I 2025-05-31 02:47:33,329] Trial 4 finished with value: 0.011067359652359708 and parameters: {'n_estimators': 259, 'max_depth': 4, 'learning_rate': 0.020105880144974487, 'subsample': 0.933630376141709, 'colsample_bytree': 0.786178
[I 2025-05-31 02:47:33,401] Trial 5 finished with value: 0.011094333381435766 and parameters: {'n_estimators': 75, 'max_depth': 8, 'learning_rate': 0.07727829701672018, 'subsample': 0.5503974863798411, 'colsample_bytree': 0.9262421
[I 2025-05-31 02:47:33,543] Trial 6 finished with value: 0.011051750247384536 and parameters: {'n_estimators': 285, 'max_depth': 6, 'learning_rate': 0.10107685187772665, 'subsample': 0.789489841160858, 'colsample_bytree': 0.7563946
[I 2025-05-31 02:47:33,620] Trial 7 finished with value: 0.011124885007118923 and parameters: {'n_estimators': 94, 'max_depth': 3, 'learning_rate': 0.18217259301079114, 'subsample': 0.6475631509579537, 'colsample_bytree': 0.8836590
[I 2025-05-31 02:47:33,713] Trial 8 finished with value: 0.011058883280144604 and parameters: {'n_estimators': 142, 'max_depth': 5, 'learning_rate': 0.24349028011577595, 'subsample': 0.990338738855798, 'colsample_bytree': 0.5616278
[I 2025-05-31 02:47:33,821] Trial 9 finished with value: 0.011061925355452237 and parameters: {'n_estimators': 188, 'max_depth': 3, 'learning_rate': 0.03849912519945266, 'subsample': 0.763889033868369, 'colsample_bytree': 0.6821478
[I 2025-05-31 02:47:33,956] Trial 10 finished with value: 0.011066400500506907 and parameters: {'n_estimators': 204, 'max_depth': 5, 'learning_rate': 0.011781342059838518, 'subsample': 0.8689001692942945, 'colsample_bytree': 0.5003
[I 2025-05-31 02:47:34,119] Trial 11 finished with value: 0.011074964168433087 and parameters: {'n_estimators': 296, 'max_depth': 6, 'learning_rate': 0.14318430211900074, 'subsample': 0.825082387214397, 'colsample_bytree': 0.686108
[I 2025-05-31 02:47:34,303] Trial 12 finished with value: 0.011077863840883018 and parameters: {'n_estimators': 298, 'max_depth': 6, 'learning_rate': 0.13151401858981226, 'subsample': 0.8554324418260513, 'colsample_bytree': 0.82118
[I 2025-05-31 02:47:34,446] Trial 13 finished with value: 0.011108535598146244 and parameters: {'n_estimators': 227, 'max_depth': 7, 'learning_rate': 0.27742919330952504, 'subsample': 0.7594053142528459, 'colsample_bytree': 0.69099
[I 2025-05-31 02:47:34,624] Trial 14 finished with value: 0.011069173058541971 and parameters: {'n_estimators': 269, 'max_depth': 4, 'learning_rate': 0.09015212196387166, 'subsample': 0.896546058894637, 'colsample_bytree': 0.590708
[I 2025-05-31 02:47:34,834] Trial 15 finished with value: 0.01113096733004926 and parameters: {'n_estimators': 155, 'max_depth': 6, 'learning_rate': 0.12189272213835707, 'subsample': 0.6759893248579345, 'colsample_bytree': 0.839110
[I 2025-05-31 02:47:35,540] Trial 16 finished with value: 0.011093829466078757 and parameters: {'n_estimators': 223, 'max_depth': 7, 'learning_rate': 0.29349088882673474, 'subsample': 0.8078095866723962, 'colsample_bytree': 0.50833
[I 2025-05-31 02:47:35,809] Trial 17 finished with value: 0.011089484278231835 and parameters: {'n_estimators': 282, 'max_depth': 5, 'learning_rate': 0.20234991838628869, 'subsample': 0.7060505307870374, 'colsample_bytree': 0.74050
[I 2025-05-31 02:47:36,768] Trial 18 finished with value: 0.011070516296077802 and parameters: {'n_estimators': 244, 'max_depth': 3, 'learning_rate': 0.05604661808094839, 'subsample': 0.9196212754201296, 'colsample_bytree': 0.63776
[I 2025-05-31 02:47:37,021] Trial 19 finished with value: 0.011064937129431972 and parameters: {'n_estimators': 194, 'max_depth': 4, 'learning_rate': 0.10623562922491289, 'subsample': 0.9988710419113374, 'colsample_bytree': 0.72711
[I 2025-05-31 02:47:37,259] A new study created in memory with name: no-name-5459d45a-22d5-4c9d-b8ca-efc5d5632aa6
[I 2025-05-31 02:47:37,456] Trial 0 finished with value: 0.0011301216322084772 and parameters: {'n_estimators': 156, 'max_depth': 6, 'learning_rate': 0.0474775152508975, 'subsample': 0.6100239385629129, 'colsample_bytree': 0.602052
[I 2025-05-31 02:47:37,694] Trial 1 finished with value: 0.0011396981668068034 and parameters: {'n_estimators': 219, 'max_depth': 8, 'learning_rate': 0.03801165801595266, 'subsample': 0.935124624174185, 'colsample_bytree': 0.546556
[I 2025-05-31 02:47:37,757] Trial 2 finished with value: 0.0011328004990245881 and parameters: {'n_estimators': 51, 'max_depth': 3, 'learning_rate': 0.043895307648976735, 'subsample': 0.5372630345722642, 'colsample_bytree': 0.61317
[I 2025-05-31 02:47:37,887] Trial 3 finished with value: 0.001136665575621235 and parameters: {'n_estimators': 243, 'max_depth': 8, 'learning_rate': 0.026944446488955203, 'subsample': 0.8444578627908206, 'colsample_bytree': 0.53898
[I 2025-05-31 02:47:37,977] Trial 4 finished with value: 0.0011307113358129455 and parameters: {'n_estimators': 117, 'max_depth': 7, 'learning_rate': 0.22826288108597229, 'subsample': 0.7614422059413203, 'colsample_bytree': 0.55200
[I 2025-05-31 02:47:38,069] Trial 5 finished with value: 0.0011411431740703084 and parameters: {'n_estimators': 131, 'max_depth': 3, 'learning_rate': 0.056041058596472515, 'subsample': 0.9877471797920594, 'colsample_bytree': 0.8484
[I 2025-05-31 02:47:38,196] Trial 6 finished with value: 0.0011442369032710303 and parameters: {'n_estimators': 236, 'max_depth': 6, 'learning_rate': 0.032716600395715056, 'subsample': 0.6164077468899667, 'colsample_bytree': 0.7782
[I 2025-05-31 02:47:38,330] Trial 7 finished with value: 0.001138034395366831 and parameters: {'n_estimators': 258, 'max_depth': 8, 'learning_rate': 0.06373888332565358, 'subsample': 0.8715120799879009, 'colsample_bytree': 0.848974
[I 2025-05-31 02:47:38,423] Trial 8 finished with value: 0.0011402485990256739 and parameters: {'n_estimators': 157, 'max_depth': 3, 'learning_rate': 0.03428258147047173, 'subsample': 0.7935523808355563, 'colsample_bytree': 0.56205
[I 2025-05-31 02:47:38,532] Trial 9 finished with value: 0.0011345503778403185 and parameters: {'n_estimators': 103, 'max_depth': 7, 'learning_rate': 0.026639437676435992, 'subsample': 0.5537284458185154, 'colsample_bytree': 0.8304
[I 2025-05-31 02:47:38,691] Trial 10 finished with value: 0.0011328893709381701 and parameters: {'n_estimators': 295, 'max_depth': 5, 'learning_rate': 0.01156611106103879, 'subsample': 0.6529483953967528, 'colsample_bytree': 0.6715
[I 2025-05-31 02:47:38,794] Trial 11 finished with value: 0.001129817264836701 and parameters: {'n_estimators': 93, 'max_depth': 6, 'learning_rate': 0.2751273719800698, 'subsample': 0.7169976652727864, 'colsample_bytree': 0.9914739
[I 2025-05-31 02:47:38,884] Trial 12 finished with value: 0.0011396737477412046 and parameters: {'n_estimators': 68, 'max_depth': 5, 'learning_rate': 0.26163983699697213, 'subsample': 0.6821145488275735, 'colsample_bytree': 0.96615
[I 2025-05-31 02:47:39,020] Trial 13 finished with value: 0.001131871152754519 and parameters: {'n_estimators': 184, 'max_depth': 6, 'learning_rate': 0.1073228701942092, 'subsample': 0.7033657481694813, 'colsample_bytree': 0.991263
[I 2025-05-31 02:47:39,148] Trial 14 finished with value: 0.0011327132856957859 and parameters: {'n_estimators': 176, 'max_depth': 4, 'learning_rate': 0.11251612699616408, 'subsample': 0.6036396467697017, 'colsample_bytree': 0.6885
[I 2025-05-31 02:47:39,244] Trial 15 finished with value: 0.0011354714440109366 and parameters: {'n_estimators': 86, 'max_depth': 6, 'learning_rate': 0.1395271330819576, 'subsample': 0.5003474605179892, 'colsample_bytree': 0.719896
[I 2025-05-31 02:47:39,362] Trial 16 finished with value: 0.0011404715499805677 and parameters: {'n_estimators': 147, 'max_depth': 7, 'learning_rate': 0.016365576468227262, 'subsample': 0.7238292299437536, 'colsample_bytree': 0.913
[I 2025-05-31 02:47:39,497] Trial 17 finished with value: 0.0011375631180465576 and parameters: {'n_estimators': 201, 'max_depth': 5, 'learning_rate': 0.07495318291530718, 'subsample': 0.6213127612624225, 'colsample_bytree': 0.7670
[I 2025-05-31 02:47:39,602] Trial 18 finished with value: 0.0011331298300994248 and parameters: {'n_estimators': 94, 'max_depth': 4, 'learning_rate': 0.17057148044270423, 'subsample': 0.7656699549004806, 'colsample_bytree': 0.65367
[I 2025-05-31 02:47:39,715] Trial 19 finished with value: 0.0011462554949392997 and parameters: {'n_estimators': 142, 'max_depth': 6, 'learning_rate': 0.08889547394016514, 'subsample': 0.827214163839932, 'colsample_bytree': 0.61624
[I 2025-05-31 02:47:39,800] A new study created in memory with name: no-name-08bd6de7-840c-4004-90f5-d2f2f32bc951
[I 2025-05-31 02:47:39,915] Trial 0 finished with value: 0.0030128513748665883 and parameters: {'n_estimators': 54, 'max_depth': 5, 'learning_rate': 0.02437144963528666, 'subsample': 0.7842304482978526, 'colsample_bytree': 0.597127
[I 2025-05-31 02:47:40,034] Trial 1 finished with value: 0.003135746900679883 and parameters: {'n_estimators': 219, 'max_depth': 8, 'learning_rate': 0.10276423861605585, 'subsample': 0.7924193229518496, 'colsample_bytree': 0.630086
[I 2025-05-31 02:47:40,094] Trial 2 finished with value: 0.0030243588579799 and parameters: {'n_estimators': 52, 'max_depth': 4, 'learning_rate': 0.11594811134997846, 'subsample': 0.9929471355142652, 'colsample_bytree': 0.528520950
[I 2025-05-31 02:47:40,156] Trial 3 finished with value: 0.0030171139126248226 and parameters: {'n_estimators': 51, 'max_depth': 4, 'learning_rate': 0.04765819709650706, 'subsample': 0.9987932202192868, 'colsample_bytree': 0.881430
[I 2025-05-31 02:47:40,237] Trial 4 finished with value: 0.003038094361802192 and parameters: {'n_estimators': 91, 'max_depth': 3, 'learning_rate': 0.09003594466432219, 'subsample': 0.5550772031596068, 'colsample_bytree': 0.6344979
[I 2025-05-31 02:47:40,344] Trial 5 finished with value: 0.0030207499790099865 and parameters: {'n_estimators': 160, 'max_depth': 6, 'learning_rate': 0.14389543381259187, 'subsample': 0.739491336199141, 'colsample_bytree': 0.698649
[I 2025-05-31 02:47:40,453] Trial 6 finished with value: 0.0030381367388808166 and parameters: {'n_estimators': 194, 'max_depth': 7, 'learning_rate': 0.011301565239272006, 'subsample': 0.5347277407205511, 'colsample_bytree': 0.8150
[I 2025-05-31 02:47:40,553] Trial 7 finished with value: 0.003029941302585527 and parameters: {'n_estimators': 112, 'max_depth': 3, 'learning_rate': 0.015992038130141117, 'subsample': 0.8071983918802463, 'colsample_bytree': 0.76476
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[I 2025-05-31 02:47:40,920] Trial 10 finished with value: 0.0030299905235238378 and parameters: {'n_estimators': 270, 'max_depth': 5, 'learning_rate': 0.29673380858723675, 'subsample': 0.8925564278563379, 'colsample_bytree': 0.9775
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[I 2025-05-31 02:47:47,550] Trial 6 finished with value: 0.0024120046026743147 and parameters: {'n_estimators': 193, 'max_depth': 4, 'learning_rate': 0.038114731802800846, 'subsample': 0.6705216701509924, 'colsample_bytree': 0.8738
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[I 2025-05-31 02:47:47,815] Trial 9 finished with value: 0.0023930535328122683 and parameters: {'n_estimators': 53, 'max_depth': 3, 'learning_rate': 0.058137558460896556, 'subsample': 0.5056709898598595, 'colsample_bytree': 0.59429
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[I 2025-05-31 02:47:51,230] Trial 18 finished with value: 0.002397854786297692 and parameters: {'n_estimators': 277, 'max_depth': 8, 'learning_rate': 0.0900656453241038, 'subsample': 0.6554810436736397, 'colsample_bytree': 0.754023
[I 2025-05-31 02:47:51,377] Trial 19 finished with value: 0.0024064076403778837 and parameters: {'n_estimators': 218, 'max_depth': 7, 'learning_rate': 0.20270388841587275, 'subsample': 0.9913698302748459, 'colsample_bytree': 0.9345
[I 2025-05-31 02:47:51,534] A new study created in memory with name: no-name-c7087993-de11-43d8-a891-488c2f86d9b4
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[I 2025-05-31 02:47:51,783] Trial 1 finished with value: 0.0019767930270908284 and parameters: {'n_estimators': 82, 'max_depth': 7, 'learning_rate': 0.06880612372823117, 'subsample': 0.7638520242518526, 'colsample_bytree': 0.819892
[I 2025-05-31 02:47:51,886] Trial 2 finished with value: 0.0019769459515081088 and parameters: {'n_estimators': 170, 'max_depth': 6, 'learning_rate': 0.10486161297924483, 'subsample': 0.6457133525410943, 'colsample_bytree': 0.74342
[I 2025-05-31 02:47:52,052] Trial 3 finished with value: 0.0019723431731909786 and parameters: {'n_estimators': 251, 'max_depth': 6, 'learning_rate': 0.17498978746893568, 'subsample': 0.5893676173075633, 'colsample_bytree': 0.81006
[I 2025-05-31 02:47:52,155] Trial 4 finished with value: 0.0019747294004921734 and parameters: {'n_estimators': 172, 'max_depth': 7, 'learning_rate': 0.011205151315236798, 'subsample': 0.9354200501475858, 'colsample_bytree': 0.5132
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[I 2025-05-31 02:48:05,412] Trial 19 finished with value: 0.002342946531066625 and parameters: {'n_estimators': 159, 'max_depth': 4, 'learning_rate': 0.07667973198294349, 'subsample': 0.667312021078603, 'colsample_bytree': 0.956890
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[I 2025-05-31 02:48:06,974] Trial 12 finished with value: 0.0017868026184594274 and parameters: {'n_estimators': 90, 'max_depth': 7, 'learning_rate': 0.297711558997254, 'subsample': 0.816108102676584, 'colsample_bytree': 0.62227754
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[I 2025-05-31 02:48:07,297] Trial 15 finished with value: 0.001788420642092774 and parameters: {'n_estimators': 147, 'max_depth': 6, 'learning_rate': 0.277009586922359, 'subsample': 0.9007084268943771, 'colsample_bytree': 0.5068246
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[I 2025-05-31 02:48:13,157] Trial 19 finished with value: 0.002826831998478179 and parameters: {'n_estimators': 281, 'max_depth': 7, 'learning_rate': 0.013960923986236962, 'subsample': 0.9905224061024618, 'colsample_bytree': 0.9420
[I 2025-05-31 02:48:13,307] A new study created in memory with name: no-name-4d08a5ff-77bd-4686-a0b3-f8e6b362d01c
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[I 2025-05-31 02:48:13,514] Trial 1 finished with value: 0.0062047199612523685 and parameters: {'n_estimators': 113, 'max_depth': 7, 'learning_rate': 0.04448936370433874, 'subsample': 0.7593510179875633, 'colsample_bytree': 0.97914
[I 2025-05-31 02:48:13,592] Trial 2 finished with value: 0.006202257478920951 and parameters: {'n_estimators': 71, 'max_depth': 4, 'learning_rate': 0.08242754171037517, 'subsample': 0.8716425245277089, 'colsample_bytree': 0.9466887
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[I 2025-05-31 02:48:14,106] Trial 6 finished with value: 0.006191694387904688 and parameters: {'n_estimators': 281, 'max_depth': 8, 'learning_rate': 0.047264737689737074, 'subsample': 0.5880133902870366, 'colsample_bytree': 0.56614
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[I 2025-05-31 02:48:16,558] Trial 13 finished with value: 0.006185016685787037 and parameters: {'n_estimators': 145, 'max_depth': 5, 'learning_rate': 0.18595533950230245, 'subsample': 0.5747507483462316, 'colsample_bytree': 0.50879
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[I 2025-05-31 02:48:16,879] Trial 15 finished with value: 0.0061883853663537835 and parameters: {'n_estimators': 150, 'max_depth': 6, 'learning_rate': 0.023489365116041938, 'subsample': 0.6700482027474017, 'colsample_bytree': 0.595
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[I 2025-05-31 02:48:17,352] Trial 17 finished with value: 0.006186270257876903 and parameters: {'n_estimators': 298, 'max_depth': 7, 'learning_rate': 0.20680562758553925, 'subsample': 0.5846690816092248, 'colsample_bytree': 0.72739
[I 2025-05-31 02:48:17,441] Trial 18 finished with value: 0.00620673699794231 and parameters: {'n_estimators': 59, 'max_depth': 5, 'learning_rate': 0.11050888771320092, 'subsample': 0.8145083925412996, 'colsample_bytree': 0.6524797
[I 2025-05-31 02:48:17,574] Trial 19 finished with value: 0.006167081868087194 and parameters: {'n_estimators': 196, 'max_depth': 8, 'learning_rate': 0.2028630042291488, 'subsample': 0.6622766977955263, 'colsample_bytree': 0.574132
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[I 2025-05-31 02:48:17,959] Trial 1 finished with value: 0.000744487563590874 and parameters: {'n_estimators': 193, 'max_depth': 3, 'learning_rate': 0.24626975016218275, 'subsample': 0.5014912391426314, 'colsample_bytree': 0.736562
[I 2025-05-31 02:48:18,073] Trial 2 finished with value: 0.0007639294025583 and parameters: {'n_estimators': 199, 'max_depth': 5, 'learning_rate': 0.10805541949267919, 'subsample': 0.6382998482066216, 'colsample_bytree': 0.94291551
[I 2025-05-31 02:48:18,183] Trial 3 finished with value: 0.0007474420798424403 and parameters: {'n_estimators': 195, 'max_depth': 6, 'learning_rate': 0.20943619065747848, 'subsample': 0.5678539006678078, 'colsample_bytree': 0.91427
[I 2025-05-31 02:48:18,298] Trial 4 finished with value: 0.0007528765916374369 and parameters: {'n_estimators': 210, 'max_depth': 5, 'learning_rate': 0.12856686745697748, 'subsample': 0.7420520466610534, 'colsample_bytree': 0.65173
[I 2025-05-31 02:48:18,389] Trial 5 finished with value: 0.0007270163198277889 and parameters: {'n_estimators': 130, 'max_depth': 6, 'learning_rate': 0.1952190136634978, 'subsample': 0.5885719146653604, 'colsample_bytree': 0.774641
[I 2025-05-31 02:48:18,456] Trial 6 finished with value: 0.0007265327964804107 and parameters: {'n_estimators': 58, 'max_depth': 3, 'learning_rate': 0.036758464022353804, 'subsample': 0.5025705485641396, 'colsample_bytree': 0.64220
[I 2025-05-31 02:48:18,594] Trial 7 finished with value: 0.0007282980809147424 and parameters: {'n_estimators': 293, 'max_depth': 3, 'learning_rate': 0.020016235759169346, 'subsample': 0.5680589955254607, 'colsample_bytree': 0.5743
[I 2025-05-31 02:48:18,742] Trial 8 finished with value: 0.0007387786585904772 and parameters: {'n_estimators': 298, 'max_depth': 7, 'learning_rate': 0.03402431141937244, 'subsample': 0.8735601269127113, 'colsample_bytree': 0.89836
[I 2025-05-31 02:48:18,876] Trial 9 finished with value: 0.0007385741377633067 and parameters: {'n_estimators': 277, 'max_depth': 6, 'learning_rate': 0.010146672988881045, 'subsample': 0.8646485582005481, 'colsample_bytree': 0.5651
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[I 2025-05-31 02:48:19,247] Trial 13 finished with value: 0.0007445051363515087 and parameters: {'n_estimators': 93, 'max_depth': 4, 'learning_rate': 0.08205375813017715, 'subsample': 0.6982269853281078, 'colsample_bytree': 0.65488
[I 2025-05-31 02:48:19,347] Trial 14 finished with value: 0.0007311151768064926 and parameters: {'n_estimators': 103, 'max_depth': 4, 'learning_rate': 0.03623508302878841, 'subsample': 0.5110133232799823, 'colsample_bytree': 0.5023
[I 2025-05-31 02:48:19,441] Trial 15 finished with value: 0.0007383065673841321 and parameters: {'n_estimators': 90, 'max_depth': 3, 'learning_rate': 0.03294587223546847, 'subsample': 0.6149311996035266, 'colsample_bytree': 0.66350
[I 2025-05-31 02:48:19,548] Trial 16 finished with value: 0.0007271173556772991 and parameters: {'n_estimators': 134, 'max_depth': 4, 'learning_rate': 0.08662411849679143, 'subsample': 0.5376116683520126, 'colsample_bytree': 0.5944
[I 2025-05-31 02:48:19,641] Trial 17 finished with value: 0.0007825797337124414 and parameters: {'n_estimators': 75, 'max_depth': 3, 'learning_rate': 0.14488176169626027, 'subsample': 0.7136393718232777, 'colsample_bytree': 0.82209
[I 2025-05-31 02:48:19,758] Trial 18 finished with value: 0.0007383526418461374 and parameters: {'n_estimators': 128, 'max_depth': 5, 'learning_rate': 0.022898719149704067, 'subsample': 0.7799479032427139, 'colsample_bytree': 0.501
[I 2025-05-31 02:48:19,900] Trial 19 finished with value: 0.0007432008821754676 and parameters: {'n_estimators': 238, 'max_depth': 4, 'learning_rate': 0.06678056532663114, 'subsample': 0.9935054057185373, 'colsample_bytree': 0.6955
[I 2025-05-31 02:48:19,978] A new study created in memory with name: no-name-6a7375fe-86eb-4088-96ef-8ca8469200e3
[I 2025-05-31 02:48:20,133] Trial 0 finished with value: 0.00320508341001716 and parameters: {'n_estimators': 212, 'max_depth': 4, 'learning_rate': 0.02246820527768591, 'subsample': 0.8025108781560372, 'colsample_bytree': 0.5256295
[I 2025-05-31 02:48:20,196] Trial 1 finished with value: 0.0032040288809931476 and parameters: {'n_estimators': 52, 'max_depth': 7, 'learning_rate': 0.010149091936972205, 'subsample': 0.5770817701669253, 'colsample_bytree': 0.55746
[I 2025-05-31 02:48:20,303] Trial 2 finished with value: 0.0032050733727029316 and parameters: {'n_estimators': 194, 'max_depth': 6, 'learning_rate': 0.026231199096453012, 'subsample': 0.7908166399216972, 'colsample_bytree': 0.5517
[I 2025-05-31 02:48:20,435] Trial 3 finished with value: 0.003201859734879679 and parameters: {'n_estimators': 271, 'max_depth': 3, 'learning_rate': 0.016939897154142472, 'subsample': 0.9342054892830735, 'colsample_bytree': 0.78956
[I 2025-05-31 02:48:20,533] Trial 4 finished with value: 0.003215890499614636 and parameters: {'n_estimators': 160, 'max_depth': 5, 'learning_rate': 0.2550529920214787, 'subsample': 0.8132712382419678, 'colsample_bytree': 0.8514658
```
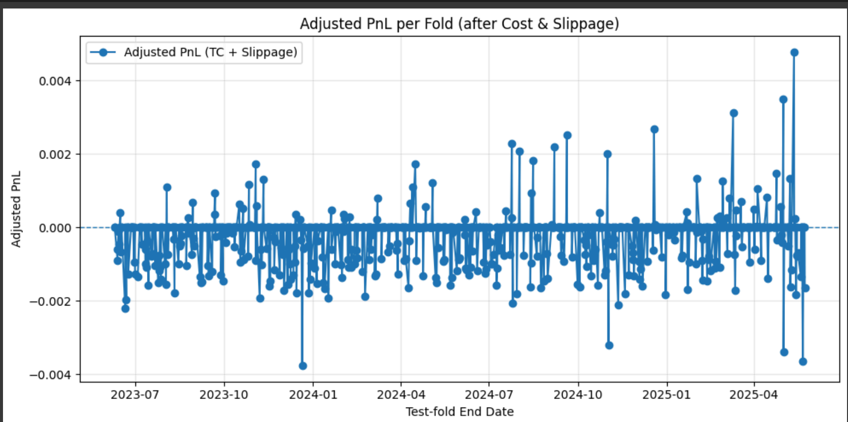

```
[I 2025-05-31 02:48:20,799] Trial 6 finished with value: 0.003202292398602716 6 and parameters: {'n_estimators': 284, 'max_depth': 5, 'learning_rate': 0.025531761413350427, 'subsample': 0.859137971002661, 'colsample_bytree': 0.84469
[I 2025-05-31 02:48:20,915] Trial 7 finished with value: 0.0032048575992061736 and parameters: {'n_estimators': 216, 'max_depth': 6, 'learning_rate': 0.010956188232955761, 'subsample': 0.7244958086247895, 'colsample_bytree': 0.5733
[I 2025-05-31 02:48:20,987] Trial 8 finished with value: 0.00320459777162048 4 and parameters: {'n_estimators': 85, 'max_depth': 3, 'learning_rate': 0.03180919413586276, 'subsample': 0.6422151191862138, 'colsample_bytree': 0.5615833
[I 2025-05-31 02:48:21,090] Trial 9 finished with value: 0.0032043599320626297 and parameters: {'n_estimators': 100, 'max_depth': 8, 'learning_rate': 0.21549838367601004, 'subsample': 0.8639600807535284, 'colsample_bytree': 0.56873
[I 2025-05-31 02:48:21,243] Trial 10 finished with value: 0.003202115187057519 and parameters: {'n_estimators': 252, 'max_depth': 4, 'learning_rate': 0.08576165332636682, 'subsample': 0.9964721233929005, 'colsample_bytree': 0.99562
[I 2025-05-31 02:48:21,410] Trial 11 finished with value: 0.003202279519728766 and parameters: {'n_estimators': 294, 'max_depth': 3, 'learning_rate': 0.03975727876359032, 'subsample': 0.9960018757638028, 'colsample_bytree': 0.73199
[I 2025-05-31 02:48:21,552] Trial 12 finished with value: 0.003198955867598951 and parameters: {'n_estimators': 245, 'max_depth': 4, 'learning_rate': 0.07552210932343803, 'subsample': 0.702131905914507, 'colsample_bytree': 0.723986
[I 2025-05-31 02:48:21,702] Trial 13 finished with value: 0.0031986344216973443 and parameters: {'n_estimators': 245, 'max_depth': 4, 'learning_rate': 0.08508337916423525, 'subsample': 0.6934657229691662, 'colsample_bytree': 0.6819
[I 2025-05-31 02:48:21,825] Trial 14 finished with value: 0.003210979603188167 and parameters: {'n_estimators': 155, 'max_depth': 4, 'learning_rate': 0.08481779574417835, 'subsample': 0.657864488531743, 'colsample_bytree': 0.664370
[I 2025-05-31 02:48:21,969] Trial 15 finished with value: 0.003203189294386349 and parameters: {'n_estimators': 238, 'max_depth': 5, 'learning_rate': 0.12234858447480572, 'subsample': 0.510948883560919, 'colsample_bytree': 0.671366
[I 2025-05-31 02:48:22,091] Trial 16 finished with value: 0.003207221132747995 and parameters: {'n_estimators': 139, 'max_depth': 4, 'learning_rate': 0.06747640466651468, 'subsample': 0.6568140658557786, 'colsample_bytree': 0.66745
[I 2025-05-31 02:48:22,223] Trial 17 finished with value: 0.0032237711722717007 and parameters: {'n_estimators': 184, 'max_depth': 5, 'learning_rate': 0.14748576008952596, 'subsample': 0.6043312892059589, 'colsample_bytree': 0.7308
[I 2025-05-31 02:48:22,363] Trial 18 finished with value: 0.003206291643475286 and parameters: {'n_estimators': 218, 'max_depth': 3, 'learning_rate': 0.05179349984931969, 'subsample': 0.7036908983078465, 'colsample_bytree': 0.63486
[I 2025-05-31 02:48:22,510] Trial 19 finished with value: 0.0032045105830804358 and parameters: {'n_estimators': 257, 'max_depth': 6, 'learning_rate': 0.15958820795615802, 'subsample': 0.534696647278269, 'colsample_bytree': 0.94594
[I 2025-05-31 02:48:22,644] A new study created in memory with name: no-name-feb0eb9f-bfdf-4599-ad38-5e8267eda082
[I 2025-05-31 02:48:22,809] Trial 0 finished with value: 0.003980062924775745 and parameters: {'n_estimators': 270, 'max_depth': 7, 'learning_rate': 0.25315582790202684, 'subsample': 0.7440894557641401, 'colsample_bytree': 0.782959
[I 2025-05-31 02:48:22,945] Trial 1 finished with value: 0.003986931912578826 and parameters: {'n_estimators': 277, 'max_depth': 8, 'learning_rate': 0.023404625854002138, 'subsample': 0.5297118777890013, 'colsample_bytree': 0.64555
[I 2025-05-31 02:48:23,072] Trial 2 finished with value: 0.004000367418787733 and parameters: {'n_estimators': 240, 'max_depth': 8, 'learning_rate': 0.10236441297534259, 'subsample': 0.6680942744408618, 'colsample_bytree': 0.842152
[I 2025-05-31 02:48:23,219] Trial 3 finished with value: 0.003989341013422905 and parameters: {'n_estimators': 182, 'max_depth': 6, 'learning_rate': 0.29164357817623465, 'subsample': 0.5011908787822487, 'colsample_bytree': 0.817243
[I 2025-05-31 02:48:23,323] Trial 4 finished with value: 0.003990431598324596 5 and parameters: {'n_estimators': 172, 'max_depth': 5, 'learning_rate': 0.29212916815696344, 'subsample': 0.6497526706776809, 'colsample_bytree': 0.68526
[I 2025-05-31 02:48:23,388] Trial 5 finished with value: 0.003991432791789066 and parameters: {'n_estimators': 51, 'max_depth': 7, 'learning_rate': 0.18872342048829288, 'subsample': 0.5678819259844423, 'colsample_bytree': 0.9377079
```

Step 10 : Robust Execution & Risk Modeling

1. Step 10A : Transaction Cost & Slippage Modeling
2. Step 10B : Market Impact Modeling (Almgren−Chriss)

Step 10A : Transaction Cost & Slippage Modeling

```python
# (plug-and-play after Step 9B - expects df_metrics_optuna in memory)

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

def run_execution_step_10a(
    df_metrics: pd.DataFrame,
    tc_perc: float   = 0.001,   # 0.10 % per executed trade
    slip_mean: float = 0.0005,  # 0.05 % mean slippage
    slip_std: float  = 0.0002,  # slippage volatility
    random_state: int = 42
) -> pd.DataFrame:
    """
    Add transaction-cost & slippage-adjusted PnL to walk-forward metrics.

    Expected columns in df_metrics:
        end (datetime) · avg_pnl · directional_accuracy · num_trades (optional)
    Returns the same frame with extra cols:
        tc_cost · slippage_cost · adj_pnl
    """
    df = df_metrics.copy().reset_index(drop=True)

    # Sanity checks
    if not {'avg_pnl', 'directional_accuracy'}.issubset(df.columns):
        raise ValueError("df_metrics must contain 'avg_pnl' and 'directional_accuracy'")

    # If num_trades is missing, assume one trade per fold
    if 'num_trades' not in df.columns:
        df['num_trades'] = 1

    # Vectorised cost generation
    rng = np.random.default_rng(random_state)
    df['tc_cost']       = tc_perc * df['num_trades']
    df['slippage_cost'] = rng.normal(slip_mean, slip_std, size=len(df)) * df['num_trades']

    # Apply only if strategy beats coin-flip
    mask          = df['directional_accuracy'] > 0.50
    df['adj_pnl'] = 0.0
    df.loc[mask, 'adj_pnl'] = (
        df.loc[mask, 'avg_pnl']
        - df.loc[mask, 'tc_cost']
        - df.loc[mask, 'slippage_cost']
    )

    return df

# run the execution adjustment
try:
    df_metrics_exec = run_execution_step_10a(df_metrics_optuna)
except NameError as e:
    raise RuntimeError(
        "df_metrics_optuna is not defined - execute Step 9B first "
        "or reload its output before running Step 10A."
    ) from e

# visualise fold-level impact
plt.figure(figsize=(10, 5))
plt.plot(
    df_metrics_exec['end'],
    df_metrics_exec['adj_pnl'],
    label='Adjusted PnL (TC + Slippage)',
    marker='o'
)
plt.axhline(0, linestyle='--', linewidth=1)
plt.title("Adjusted PnL per Fold (after Cost & Slippage)")
plt.xlabel("Test-fold End Date")
plt.ylabel("Adjusted PnL")
plt.grid(alpha=0.3)
plt.legend()
plt.tight_layout()
plt.show()

# (optional) quick comparison
summary = df_metrics_exec[['avg_pnl', 'adj_pnl']].describe().loc[['mean', 'std']]
print("₩nPnL summary (before vs after costs)₩n", summary)
```



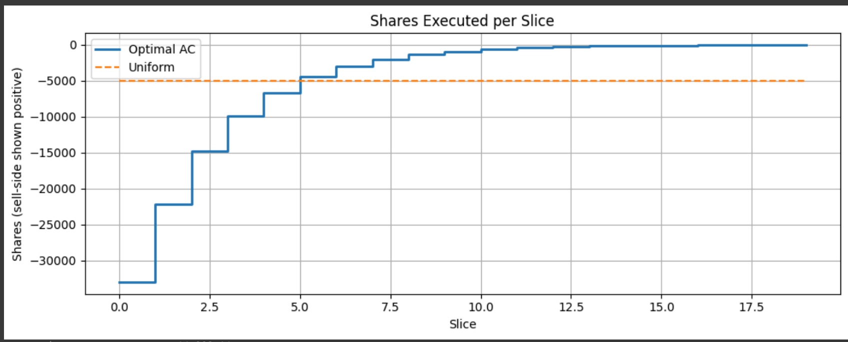

```
PnL summary (before vs after costs)
        avg_pnl   adj_pnl
mean  0.000223 -0.000214
```

Step 10B : Market Impact Modeling (Almgren−Chriss)

```python
# MARKET-IMPACT MODEL (Almgren-Chriss 2001)
# Full, self-contained implementation + demo
import numpy as np
```

```python
import pandas as pd
import matplotlib.pyplot as plt

# CORE HELPERS
def _almgren_chriss_schedule(
        X: float,
        N: int,
        sigma: float,
        eta: float,
        lam: float,
        dt: float = 1.0,
):
    """
    Discrete-time optimal liquidation schedule (Almgren-Chriss eq. 17).

    Parameters
    ----------
    X     : total shares to trade (positive for sell order)
    N     : number of child-orders / time-slices
    sigma : daily (or slice-level) volatility as decimal (e.g. 0.02)
    eta   : temporary-impact parameter
    lam   : risk-aversion parameter (λ → 0 ⇒ uniform schedule)
    dt    : length of each time slice (same units as σ)

    Returns
    -------
    x : np.ndarray, len N+1  - remaining inventory after each slice
    v : np.ndarray, len N    - trade size in each slice (negative = sell)
    """
    kappa = np.sqrt(lam * sigma ** 2 / eta)      # liquidation urgency

    if np.isclose(kappa, 0.0):                   # λ → 0 ⇒ uniform
        x = X * (1 - np.arange(N + 1) / N)
    else:
        sinh_kN = np.sinh(kappa * N)
        x = X * np.sinh(kappa * (N - np.arange(N + 1))) / sinh_kN

    v = np.diff(-x)                              # trades (negative for sells)
    return x, v


def _cost_variance(v, sigma, eta, gamma, dt):
    """
    Expected cost & variance of a schedule per Almgren-Chriss.

    Parameters
    ----------
    v     : np.ndarray of trade sizes (negative if selling)
    sigma : volatility (per slice)
    eta   : temporary-impact parameter
    gamma : permanent-impact parameter
    dt    : slice length

    Returns
    -------
    exp_cost, var_cost
    """
    v   = np.asarray(v)
    x_c = np.cumsum(v[::-1])[::-1]              # inventory *before* each trade
    exp_cost = np.sum(eta * v**2 + gamma * x_c * v)
    var_cost = sigma**2 * dt * np.sum(x_c**2)
    return exp_cost, var_cost

# 2)  PUBLIC WRAPPER
def run_market_impact_step_10b(
        X              : float,
        horizon_slices  : int,
        sigma          : float = 0.02,
        eta            : float = 2.5e-6,
        gamma          : float = 2.0e-6,
        lam            : float = 1e-4,
        dt             : float = 1.0,
        plot           : bool  = True,
):
    """
    Build optimal (Almgren-Chriss) vs uniform schedules *and* compute:
      • expected cost
      • cost variance
      • λ-weighted objective  C + λ · Var

    Returns
    -------
    df_sched : pd.DataFrame
        slice-level details for both schedules
    metrics  : dict
        summary numbers for  "optimal"  and  "uniform"
    """
    # schedules
    x_opt,  v_opt  = _almgren_chriss_schedule(X, horizon_slices, sigma, eta, lam, dt)
    x_uni,  v_uni  = _almgren_chriss_schedule(X, horizon_slices, sigma, eta, 0.0, dt)

    # analytics
    ec_opt,  var_opt  = _cost_variance(v_opt, sigma, eta, gamma, dt)
    ec_uni,  var_uni  = _cost_variance(v_uni, sigma, eta, gamma, dt)

    metrics = {
        "expected_cost_opt"      : ec_opt,
        "variance_opt"           : var_opt,
        "objective_opt"          : ec_opt  + lam * var_opt,
        "expected_cost_uniform"  : ec_uni,
        "variance_uniform"       : var_uni,
        "objective_uniform"      : ec_uni  + lam * var_uni,
    }

    df_sched = pd.DataFrame({
        "slice"          : np.arange(horizon_slices),
        "v_opt"          : v_opt,
        "v_uniform"      : v_uni,
        "x_opt_after"    : x_opt[1:],         # inventory after executing slice
        "x_uniform_after": x_uni[1:],
    })

    # optional diagnostics plot
    if plot:
        plt.figure(figsize=(10, 4))
        plt.step(df_sched["slice"], -df_sched["v_opt"],     where="post",
                 label="Optimal AC", linewidth=2)
        plt.step(df_sched["slice"], -df_sched["v_uniform"], where="post",
                 label="Uniform",  linestyle="--")
        plt.title("Shares Executed per Slice")
        plt.xlabel("Slice");  plt.ylabel("Shares (sell-side shown positive)")
        plt.legend(); plt.grid(True); plt.tight_layout()
        plt.show()

    return df_sched, metrics

# DEMO / QUICK TEST
if __name__ == "__main__":
    df_demo, met_demo = run_market_impact_step_10b(
```

```
        X             = 100_000,        # 100 k shares to liquidate
        horizon_slices = 20,            # 20 child orders
        sigma         = 0.02,           # 2 % slice vol
        eta           = 2.5e-6,
        gamma         = 2.0e-6,
        lam           = 1e-3,           # try 1e-3 for visible front-load
        dt            = 1.0,
        plot          = True,
    )

    # Pretty-print metrics
    print(pd.Series(met_demo).apply(lambda x: f"{x:,.2f}"))
    print("\nFirst 5 slices:\n", df_demo.head())
```




```
expected_cost_opt           16,908.16
variance_opt             7,263,848.06
objective_opt               24,172.01
expected_cost_uniform       11,750.00
variance_uniform        28,700,000.00
objective_uniform           40,450.00
dtype: object

First 5 slices:
    slice         v_opt  v_uniform   x_opt_after  x_uniform_after
0      0  32968.004641     5000.0  67031.995359          95000.0
1      1  22099.118936     5000.0  44932.876423          90000.0
2      2  14813.489205     5000.0  30119.387218          85000.0
3      3   9929.788885     5000.0  20189.598332          80000.0
```

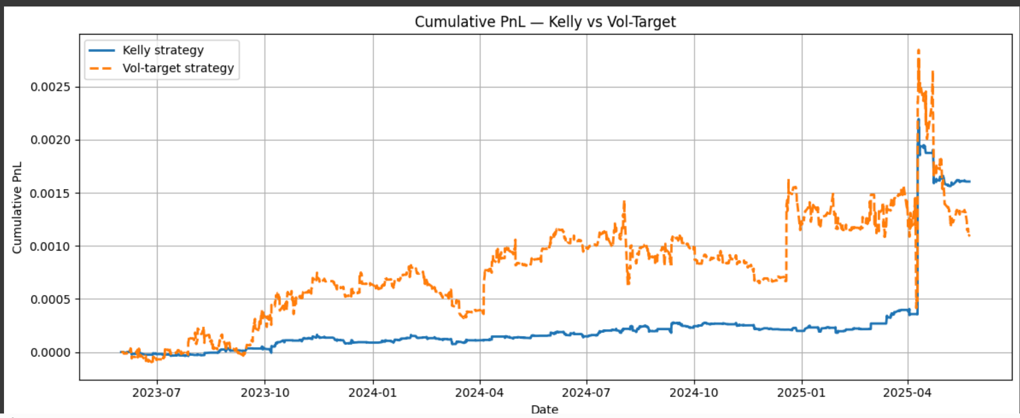
Step 11 : Advanced Portfolio & Risk Management

1. Step 11A-1 : Dynamic Position Sizing (Kelly Criterion, Volatility Targeting)
2. Step 11A-Plus : Dynamic Sizing (Kelly 0.5 × + Vol-Target)
3. Step 11B-1 : Diversification & Risk-Parity Portfolio Construction
4. Step 11B-2 : Risk-Parity Portfolio / Diagnostics & Plot
5. Step 11B-Plus : Re-fit / Metrics / Comparison Plot / Diagnostics
6. Step 11C-1 : Dynamic Position Sizing (Kelly Criterion, Volatility Targeting)
7. Step 11C-2 : Risk-Parity Pro : Institutional-Style Multi-Asset Risk-Parity Engine

Step 11A-1 : Dynamic Position Sizing (Kelly Criterion, Volatility Targeting)

```
# Kelly Criterion + Volatility Targeting
# Requirements already in memory (from earlier steps):
#   • df_model_ready  - must contain
#         'datetime'       : date/time index or column
#         'target_return'  : realised next-period return
#     Optionally:
#         'predicted_return': model forecasts (if absent, we use lag-1 fallback)
# This cell:
#   1) defines the sizing + plotting helpers
#   2) inserts a lag-1 fallback if no predictions provided
#   3) produces df_sized with Kelly / Vol-target PnL
#   4) shows the cumulative-PnL comparison chart

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt


# Core sizing routine
def apply_dynamic_position_sizing(
        df: pd.DataFrame,
        *,
        predicted_col: str = "predicted_return",
        target_col:    str = "target_return",
        window:        int  = 20,
        target_vol:    float = 0.02,
        kelly_clip:    tuple = (0, 1),
        vol_cap:       float = 3.0
    ) -> pd.DataFrame:
    """
    Return a copy of *df* with:
        kelly_fraction, position_kelly, position_voltarget,
        pnl_kelly / voltarget, and cum_pnl_kelly / voltarget
    """
    out = df.copy()

    # Kelly fraction
    mu  = out[target_col].rolling(window).mean()
    var = out[target_col].rolling(window).var().replace(0, np.nan)
    out["kelly_fraction"] = (mu / var).clip(*kelly_clip)

    # Positions
    out["position_kelly"] = out["kelly_fraction"] * out[predicted_col]

    rolling_vol             = out[target_col].rolling(window).std().replace(0, np.nan)
    out["vol_leverage"]     = (target_vol / rolling_vol).clip(upper=vol_cap)
    out["position_voltarget"] = out["vol_leverage"] * out[predicted_col]

    # PnL streams
    out["pnl_kelly"]       = out["position_kelly"]     * out[target_col]
    out["pnl_voltarget"]   = out["position_voltarget"] * out[target_col]

    out["cum_pnl_kelly"]     = out["pnl_kelly"].fillna(0).cumsum()
    out["cum_pnl_voltarget"] = out["pnl_voltarget"].fillna(0).cumsum()
    return out

# Plot helper
def plot_dynamic_position_pnl(
        df: pd.DataFrame,
        *,
```

```
        date_col:      str = "datetime",
        kelly_col:     str = "cum_pnl_kelly",
        voltarget_col: str = "cum_pnl_voltarget",
        title:         str = "Cumulative PnL - Kelly vs Vol-Target"
    ) -> None:
    plt.figure(figsize=(12, 5))
    plt.plot(df[date_col], df[kelly_col],      lw=2, label="Kelly strategy")
    plt.plot(df[date_col], df[voltarget_col],  lw=2, ls="--",
             label="Vol-target strategy")
    plt.title(title)
    plt.xlabel("Date"); plt.ylabel("Cumulative PnL")
    plt.grid(True); plt.legend(); plt.tight_layout(); plt.show()

# Ensure predictions exist (lag-1 fallback)
if "predicted_return" not in df_model_ready.columns:
    df_model_ready["predicted_return"] = (
        df_model_ready["target_return"].shift(1).fillna(0.0)
    )

# Run sizing + plot
df_sized = apply_dynamic_position_sizing(
    df_model_ready,
    predicted_col="predicted_return",
    target_col   ="target_return",
)

plot_dynamic_position_pnl(df_sized)
# df_sized is now available for further analysis or merging
```

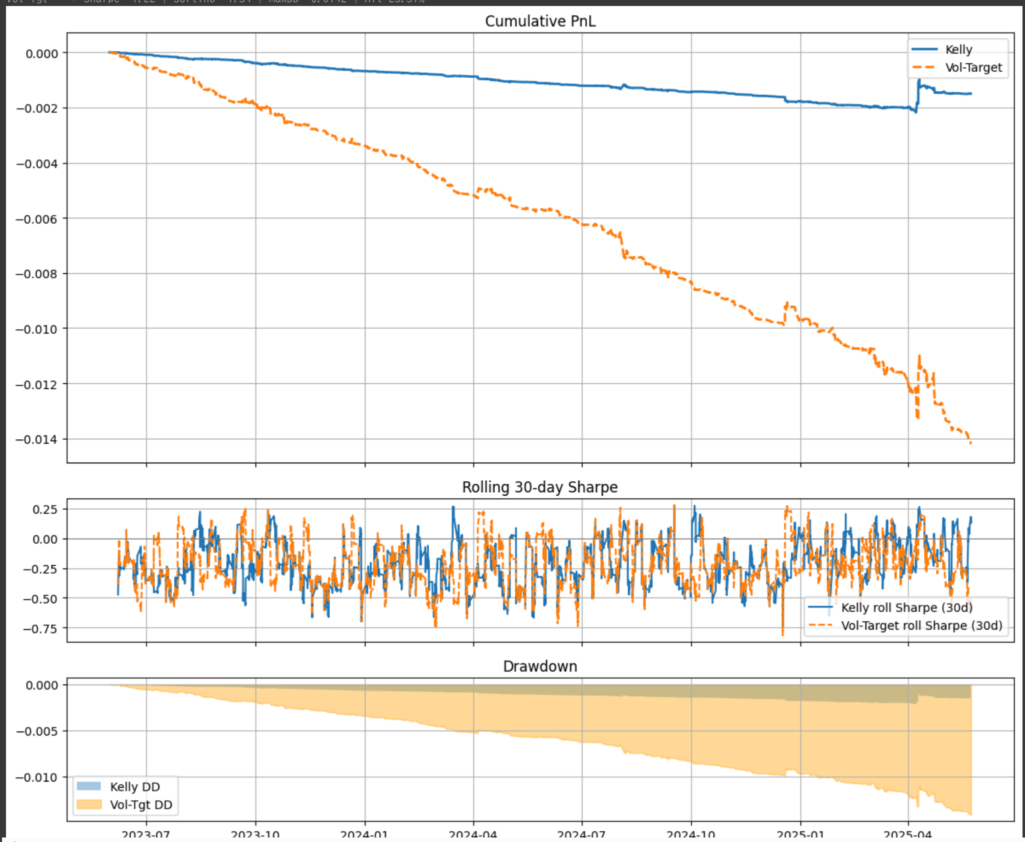


Step 11A-Plus : Dynamic Sizing (Kelly 0.5 × + Vol-Target)

```
# automatic High/Low detection, fallback to close-close σ
# EWMA variance, execution costs, full diagnostics

import logging, pandas as pd, numpy as np, matplotlib.pyplot as plt, xgboost as xgb
logging.basicConfig(level=logging.INFO)

# Helper: guarantee tz-naïve 'datetime' column
def ensure_datetime(df: pd.DataFrame) -> pd.DataFrame:
    out = df.copy()
    if "datetime" in out.columns:
        pass
    elif isinstance(out.index, pd.DatetimeIndex):
        out = out.assign(datetime=out.index)
    else:
        out = out.reset_index().rename(columns={out.columns[0]: "datetime"})
    out["datetime"] = pd.to_datetime(out["datetime"]).dt.tz_localize(None)
    return out.reset_index(drop=True)

# Helper: flatten Multi-Index cols that come from Yahoo (('AAPL','High'),…)
def flatten_cols(df: pd.DataFrame) -> pd.DataFrame:
    if isinstance(df.columns, pd.MultiIndex):
        df.columns = [c[-1] if isinstance(c, tuple) else c for c in df.columns]
    return df

# Helper: detect High / Low column names, tolerant of tuples
def detect_hl_cols(df: pd.DataFrame):
    hi = None; lo = None
    for c in df.columns:
        name = c[-1] if isinstance(c, tuple) else c
        name_lc = str(name).lower()
        if name_lc in {"high", "hi"} and hi is None:
            hi = c
        elif name_lc in {"low", "lo"} and lo is None:
            lo = c
    return hi, lo

# EWMA variance
def ewma(series, span=20):
    return series.ewm(span=span, min_periods=span).mean()

# Parkinson σ
def parkinson_sigma(df, hi_col, lo_col, window=20):
    factor = 1.0 / (4 * np.log(2))
    hl_sq  = np.log(df[hi_col] / df[lo_col]) ** 2
    return np.sqrt(factor * hl_sq.rolling(window).mean())

# Basic performance stats
def perf_stats(cum):
    ret  = cum.diff().dropna()
    sharpe  = np.sqrt(252) * ret.mean() / ret.std()
    sortino = np.sqrt(252) * ret.mean() / ret[ret<0].std()
    maxdd   = (cum - cum.cummax()).min()
    hit     = (ret > 0).mean()
    return sharpe, sortino, maxdd, hit


# Ensure df_model_ready is clean
df_model_ready = flatten_cols(df_model_ready)
df_model_ready = ensure_datetime(df_model_ready)

# Inject real predictions (fallback = lag-1)
MODEL_PATH = "tuned_xgb.json"
if "predicted_return" not in df_model_ready.columns:
    try:
        clf = xgb.XGBRegressor(); clf.load_model(MODEL_PATH)
        logging.info("Loaded tuned model: %s", MODEL_PATH)

        feat_cols = [c for c in df_model_ready.columns
                     if ("lag" in c or "ret" in c) and c != "target_return"]
```

```
        df_model_ready["predicted_return"] = clf.predict(df_model_ready[feat_cols])

    except Exception as e:
        logging.warning("Could not load model → lag-1 fallback (%s)", e)
        df_model_ready["predicted_return"] = (
            df_model_ready["target_return"].shift(1).fillna(0.0)
        )

# Dynamic sizing function (Kelly 0.5×  +  Vol-Target)
def apply_dynamic_sizing_plus(
        df,
        pred_col="predicted_return", tgt_col="target_return",
        k_span=20, k_frac=0.5,
        vol_target=0.02, vol_cap=3, vol_span=20,
        tc_round=0.0005, slip_mu=0.0002, slip_sd=0.0001):

    out = df.copy()

    # - Kelly 0.5× -
    mu  = out[tgt_col].rolling(k_span).mean()
    var = ewma(out[tgt_col]**2, span=k_span)
    out["kelly_f"]  = k_frac * (mu / var).clip(-1, 1)
    out["pos_k"]    = out["kelly_f"] * out[pred_col]

    # - Vol-Target -
    hi_col, lo_col = detect_hl_cols(out)
    if hi_col and lo_col:
        sigma = parkinson_sigma(out, hi_col, lo_col, window=vol_span)
    else:
        sigma = out[tgt_col].rolling(vol_span).std()
    out["vol_lev"] = (vol_target / sigma).clip(upper=vol_cap)
    out["pos_v"]   = out["vol_lev"] * out[pred_col]

    # - Execution cost -
    rng  = np.random.RandomState(42)
    cost = tc_round + rng.normal(slip_mu, slip_sd, len(out))

    out["pnl_k"] = out["pos_k"] * out[tgt_col] - np.abs(out["pos_k"]) * cost
    out["pnl_v"] = out["pos_v"] * out[tgt_col] - np.abs(out["pos_v"]) * cost

    out["cum_k"] = out["pnl_k"].fillna(0).cumsum()
    out["cum_v"] = out["pnl_v"].fillna(0).cumsum()
    return out

df_sized = apply_dynamic_sizing_plus(df_model_ready)

# 3 · Print diagnostics
sk, so, dd, hr  = perf_stats(df_sized["cum_k"])
sv, sv2, dv, hv = perf_stats(df_sized["cum_v"])

print(f"Kelly     ⇒ Sharpe {sk:5.2f} | Sortino {so:5.2f} | MaxDD {dd:7.4f} | Hit {hr:5.2%}")
print(f"Vol-Tgt   ⇒ Sharpe {sv:5.2f} | Sortino {sv2:5.2f} | MaxDD {dv:7.4f} | Hit {hv:5.2%}")

# Plot Cum-PnL, Rolling Sharpe, Drawdown
roll = 30
roll_sh_k = df_sized["pnl_k"].rolling(roll).mean() / df_sized["pnl_k"].rolling(roll).std()
roll_sh_v = df_sized["pnl_v"].rolling(roll).mean() / df_sized["pnl_v"].rolling(roll).std()

dd_k = df_sized["cum_k"] - df_sized["cum_k"].cummax()
dd_v = df_sized["cum_v"] - df_sized["cum_v"].cummax()

fig, axs = plt.subplots(3, 1, figsize=(12, 10), sharex=True,
                        gridspec_kw={"height_ratios": [3, 1, 1]})

axs[0].plot(df_sized["datetime"], df_sized["cum_k"], lw=2, label="Kelly")
axs[0].plot(df_sized["datetime"], df_sized["cum_v"], lw=2, ls="--", label="Vol-Target")
axs[0].set_title("Cumulative PnL"); axs[0].legend(); axs[0].grid(True)

axs[1].plot(df_sized["datetime"], roll_sh_k, label="Kelly roll Sharpe (30d)")
axs[1].plot(df_sized["datetime"], roll_sh_v, ls="--", label="Vol-Target roll Sharpe (30d)")
axs[1].axhline(0, color="gray", lw=0.7)
axs[1].set_title("Rolling 30-day Sharpe"); axs[1].legend(); axs[1].grid(True)

axs[2].fill_between(df_sized["datetime"], dd_k, alpha=0.4, label="Kelly DD")
axs[2].fill_between(df_sized["datetime"], dd_v, alpha=0.4, color="orange", label="Vol-Tgt DD")
axs[2].set_title("Drawdown"); axs[2].legend(); axs[2].grid(True)

plt.tight_layout(); plt.show()
```

```
Kelly    ⇒ Sharpe -0.40 | Sortino -0.71 | MaxDD -0.0022 | Hit 23.37%
Vol-Tgt  ⇒ Sharpe -1.22 | Sortino -1.34 | MaxDD -0.0142 | Hit 23.37%
```



Step 11B-1 : Diversification & Risk-Parity Portfolio Construction

```
# Yahoo Finance → Risk-Parity   (index-agnostic version)
# %pip install -q yfinance --upgrade     # once per notebook

import yfinance as yf, pandas as pd, numpy as np, datetime as dt
from dateutil.relativedelta import relativedelta

TICKERS = {"AAPL": "aapl_close",
           "SPY":  "spx_close",
           "BTC-USD": "btc_close"}
LOOKBACK_YEARS, ROLL_WINDOW, RP_METHOD = 3, 20, "inverse_vol"

# FETCH DAILY CLOSES
end_d = dt.datetime.utcnow().date()
start_d = end_d - relativedelta(years=LOOKBACK_YEARS)
print(f"↳ Yahoo {start_d} → {end_d}")

frames = []
for y_tkr, new_col in TICKERS.items():
    tmp = yf.download(y_tkr,
                      start=start_d,
                      end=end_d + dt.timedelta(days=1),
                      interval="1d",
                      auto_adjust=True,
                      progress=False)[["Close"]]
    tmp.rename(columns={"Close": new_col}, inplace=True)
    frames.append(tmp)
df_prices = pd.concat(frames, axis=1).ffill()        # tz-naïve DateTimeIndex

# RISK-PARITY HELPERS
def _ret(px): return px.pct_change(fill_method=None).dropna()
def _inv_vol(win):
    vol = win.std().replace(0, np.nan).dropna()
    return pd.Series((1/vol) / (1/vol).sum(), index=vol.index)
def _erc(win, tol=1e-8, it=1000):
    Σ, n = win.cov().values, win.shape[1]
    w = np.ones(n)/n
    for _ in range(it):
        σp, mrc = np.sqrt(w@Σ@w), (Σ@w)/np.sqrt(w@Σ@w)
        gap = w*mrc - (w*mrc).mean()
        if np.abs(gap).max() < tol: break
        J = (np.outer(mrc,w)+np.outer(w,mrc)-np.outer(mrc,w)-np.outer(w,mrc))
        w = np.clip(w - np.linalg.solve(J+np.eye(n)*1e-10, gap), 1e-12, None); w/=w.sum()
    return pd.Series(w, win.columns)

def run_rp(px, cols, win=ROLL_WINDOW, mth=RP_METHOD):
    ret, idx, w_hist = _ret(px[cols]), None, []
    if ret.shape[0] < win: raise ValueError("Not enough rows for window.")
    idx = ret.index[win:]
    for t in range(win, len(ret)):
        sub = ret.iloc[t-win:t]
        w_hist.append(_inv_vol(sub) if mth=="inverse_vol" else _erc(sub))
    w_hist = pd.DataFrame(w_hist, index=idx)
    rp_ret = (ret.loc[idx]*w_hist).sum(axis=1)
    rp_cum = (1+rp_ret).cumprod()
    return (pd.DataFrame({"risk_parity_return":rp_ret,
                          "risk_parity_cumret":rp_cum}, index=idx),
            w_hist.iloc[-1], w_hist)

# EXECUTE
price_cols = list(TICKERS.values())
df_rp, rp_w_latest, rp_w_trail = run_rp(df_prices, price_cols)

print("\nLatest Risk-Parity Weights")
print(rp_w_latest.round(4).to_string())
```

```
↳ Yahoo 2022-05-31 → 2025-05-31

Latest Risk-Parity Weights
Price       Ticker
```

```
aapl_close  AAPL      0.2515
spx_close   SPY       0.4600
btc_close   BTC-USD   0.2885
```

Step 11B-2 : Risk-Parity Portfolio / Diagnostics & Plot

```
# Prints rolling 20-day σ that generated the latest weights
# Plots cumulative risk-parity return curve
# Shows where to switch to ERC or add assets

import pandas as pd
import matplotlib.pyplot as plt

# USER PARAMETERS (keep in sync with Step 11B)
price_cols  = ["aapl_close", "spx_close", "btc_close"]   # extend if you add assets
ROLL_WINDOW = 20                                          # same window you used
# To use exact Equal-Risk-Contribution weights next time:
# set RP_METHOD = "erc" in your Step 11B cell and rerun it.

# Rolling-σ diagnostic
# df_prices is the daily-close DataFrame returned in Step 11B
ret_window = df_prices[price_cols].pct_change(fill_method=None).dropna().iloc[-ROLL_WINDOW:]
rolling_std = ret_window.std()

print("Rolling 20-day σ (used for latest weights):")
print(rolling_std.to_string(float_format="%.6f"))
print("\nWeights = (1/σ) / Σ(1/σ)  – verify they match your output.\n")

# Cumulative RP performance curve
plt.figure(figsize=(10, 5))
df_rp["risk_parity_cumret"].plot()
plt.title("Risk-Parity Portfolio  ·  Cumulative Return")
plt.xlabel("Date")
plt.ylabel("Cumulative Return")
plt.grid(True)
plt.tight_layout()
plt.show()

# HOW TO ADD MORE ASSETS
# Edit the TICKERS dict in Step 11B, e.g.:
# TICKERS["ETH-USD"] = "eth_close"
# Re-run Step 11B (fetch + RP) and then this diagnostics cell.
```

```
Rolling 20-day σ (used for latest weights):
Price       Ticker
aapl_close  AAPL      0.018428
spx_close   SPY       0.010074
btc_close   BTC-USD   0.016806

Weights = (1/σ) / Σ(1/σ)  – verify they match your output.
```

Step 11B-Plus : Re-fit / Metrics / Comparison Plot / Diagnostics

```
# Re-fit  ·  Metrics  ·  Comparison Plot  ·  Diagnostics

import numpy as np, pandas as pd, matplotlib.pyplot as plt

# USER SETTINGS
# Add / edit assets here:
TICKERS.update({
    # "ETH-USD": "eth_close",
    # "GLD":     "gold_close",
})
# Switch to exact equal-risk-contribution:
RP_METHOD  = "inverse_vol"       # "inverse_vol"  or  "erc"
ROLL_WINDOW = 20                 # keep in sync with main step

# RE-FIT RISK-PARITY (if anything changed)
price_cols = list(TICKERS.values())
df_prices  = df_prices[price_cols]          # ensure slice only chosen assets

df_rp, rp_w_latest, rp_w_trail = run_rp(
    df_prices, price_cols, win=ROLL_WINDOW, mth=RP_METHOD
)

print("\nLatest weights")
print(rp_w_latest.round(4).to_string(), "\n")

# PERFORMANCE METRICS
daily      = df_rp["risk_parity_return"]
ann_factor = np.sqrt(252)

sharpe  = daily.mean() / daily.std() * ann_factor
down    = daily[daily < 0]
sortino = daily.mean() / down.std() * ann_factor if not down.empty else np.nan

cum     = df_rp["risk_parity_cumret"]
dd_curve = cum / cum.cummax() - 1
max_dd  = dd_curve.min()

print(f"📈 Metrics (since {cum.index[0].date()})")
print(f"  Sharpe :  {sharpe:6.3f}")
print(f"  Sortino:  {sortino:6.3f}")
print(f"  Max-DD : {max_dd*100:6.2f}%\n")

# COMPARISON PLOT
plt.figure(figsize=(10, 5))
```

```
cum.plot(label="Risk-Parity")

# scan globals for additional cumret Series with matching index
candidates = [
    v for v in globals().values()
    if isinstance(v, pd.Series)
       and isinstance(v.name, str)
       and "cumret" in v.name.lower()
]

for s in candidates:
    if s is cum:        # skip the RP curve we already plotted
        continue
    if s.index.difference(cum.index).size == 0:
        s.plot(label=s.name)

plt.title("Cumulative Return · Risk-Parity vs. Other Strategies")
plt.xlabel("Date")
plt.ylabel("Cumulative Return")
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()

# ROLLING-σ DIAGNOSTIC
ret_win = df_prices.pct_change(fill_method=None).dropna().iloc[-ROLL_WINDOW:]
print("Rolling 20-day σ (latest window):")
print(ret_win.std().to_string())
```

```
Latest weights
Price       Ticker
aapl_close  AAPL      0.2515
spx_close   SPY       0.4600
btc_close   BTC-USD   0.2885

📈 Metrics (since 2022-06-21)
  Sharpe :   1.028
  Sortino:   1.387
  Max-DD : -24.39%
```

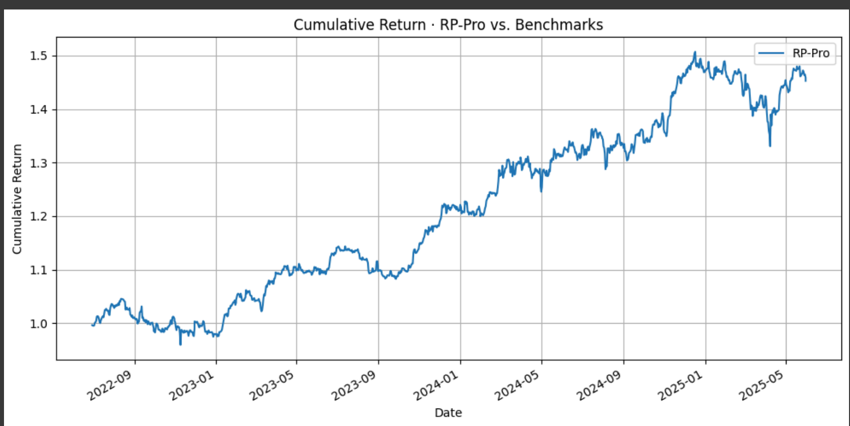

```
Rolling 20-day σ (latest window):
Price       Ticker
aapl_close  AAPL      0.018428
spx_close   SPY       0.010074
```

Step 11C-1 : Dynamic Position Sizing (Kelly Criterion, Volatility Targeting)

```
# RISK-PARITY PRO (bond, gold, EM, ERC, vol-target, TC, cash)
# %pip install -q yfinance --upgrade    # run once per Colab / session

import numpy as np, pandas as pd, matplotlib.pyplot as plt, yfinance as yf
from datetime import timedelta

# USER CONFIG
TICKERS.update({                        # add or edit as you like
    "TLT"     : "bond_close",           # 20-yr Treasury ETF
    "GLD"     : "gold_close",           # Gold ETF
    "EEM"     : "em_close",             # Emerging-markets equity ETF
})
RP_METHOD      = "erc"                  # "inverse_vol" or "erc"
SIGMA_MODE     = "ewm60"                # "rolling60" or "ewm60"
REB_FREQ       = "ME"                   # "ME" = month-end  (no deprecation)
TC_BPS         = 10                     # round-trip cost in basis points
TARGET_VOL     = 0.10                   # vol-target (annualised)
TAIL_VIX_CASH  = True                   # 5 % cash buffer when VIX > 25
LOOKBACK_YEARS = 5                      # download horizon if asset missing

price_cols = list(TICKERS.values())

# ENSURE df_prices WITH ALL ASSETS
if "df_prices" not in globals():
    df_prices = pd.DataFrame()

missing_cols = [c for c in price_cols if c not in df_prices.columns]
if missing_cols:
    print("⬇ Downloading missing assets:", missing_cols)
    end   = pd.Timestamp.utcnow().normalize()
    start = end - pd.DateOffset(years=LOOKBACK_YEARS)

    for y_tkr, new_col in TICKERS.items():
        if new_col in missing_cols:
            tmp = yf.download(
                    y_tkr,
                    start=start.date(),
                    end=(end + timedelta(days=1)).date(),
                    interval="1d",
                    auto_adjust=True,
                    progress=False)[["Close"]]
            tmp.rename(columns={"Close": new_col}, inplace=True)
            df_prices = df_prices.join(tmp, how="outer") if not df_prices.empty else tmp

    df_prices = df_prices.ffill()

# DAILY RETURNS
px   = df_prices[price_cols].dropna(how="all")
ret  = px.pct_change(fill_method=None).dropna(how="any")
ann  = np.sqrt(252)

def _sigma(win_df):                              # σ estimator helper
```

```
    if SIGMA_MODE.startswith("rolling"):
        n = int(SIGMA_MODE.replace("rolling", ""))
        return win_df.iloc[-n:].std()
    span = int(SIGMA_MODE.replace("ewm", ""))
    return win_df.ewm(span=span).std().iloc[-1]

# _inv_vol and _erc already exist from Step 11B
# REBALANCE LOOP
reb_dates = ret.resample(REB_FREQ).last().index
weights_hist, strat_ret = [], []
last_w = None

for i, d in enumerate(reb_dates):
    sub = ret.loc[:d].dropna()
    if sub.empty:
        continue                              # nothing to compute

    # window for σ / ERC
    win = sub if "ewm" in SIGMA_MODE else sub.tail(int(SIGMA_MODE.replace("rolling", "")))

    # base weights
    w = (_inv_vol(win) if RP_METHOD == "inverse_vol" else _erc(win)).fillna(0)

    # tail-risk cash (optional)
    cash_w = 0
    if TAIL_VIX_CASH and "vix_close" in df_prices.columns:
        if df_prices.loc[d, "vix_close"] > 25:
            w *= 0.95
            cash_w = 0.05
    w = w / w.sum() * (1 - cash_w)

    # vol-target scaling
    port_vol = (sub @ w).std() * ann
    if port_vol > 0:
        w *= TARGET_VOL / port_vol

    # transaction cost on turnover
    turnover = (w - last_w).abs().sum() if last_w is not None else 0
    tc_cost  = turnover * (TC_BPS / 10_000)
    last_w   = w

    weights_hist.append(w.to_frame(name=d))

    # returns until next rebalance
    next_idx = reb_dates[i+1] if i+1 < len(reb_dates) else ret.index[-1]
    seg = ret.loc[d:next_idx]
    if seg.empty:
        continue                              # no bars in this segment
    seg_r = seg @ w
    seg_r.iloc[0] -= tc_cost                  # cost on first day
    strat_ret.append(seg_r)

weights_hist = pd.concat(weights_hist, axis=1).T
strat_ret    = pd.concat(strat_ret).sort_index()
strat_cum    = (1 + strat_ret).cumprod()
strat_ret.name = "rp_pro_return"
strat_cum.name = "rp_pro_cumret"

# METRICS
sharpe  = strat_ret.mean()/strat_ret.std()*ann
sortino = strat_ret.mean()/strat_ret[strat_ret<0].std()*ann
max_dd  = (strat_cum/strat_cum.cummax()-1).min()

print("RP-Pro Metrics")
print(f"  Sharpe : {sharpe:6.3f}")
print(f"  Sortino: {sortino:6.3f}")
print(f"  Max-DD : {max_dd*100:6.2f}%\n")

# PLOT CUMULATIVE RETURN
plt.figure(figsize=(10,5))
strat_cum.plot(label="RP-Pro")

for s in [v for v in globals().values()
          if isinstance(v, pd.Series) and isinstance(v.name, str)
             and "cumret" in v.name.lower() and v is not strat_cum]:
    if s.index.difference(strat_cum.index).empty:
        s.plot(label=s.name)

plt.title("Cumulative Return · RP-Pro vs. Benchmarks")
plt.xlabel("Date"); plt.ylabel("Cumulative Return")
plt.legend(); plt.grid(); plt.tight_layout(); plt.show()

# DISPLAY LATEST WEIGHTS
print("Latest rebalance weights:")
print(weights_hist.iloc[-1].round(4).to_string())
```

```
↳ Downloading missing assets: ['bond_close', 'gold_close', 'em_close']
RP-Pro Metrics
  Sharpe :  1.024
  Sortino:  1.519
  Max-DD : -11.72%
```



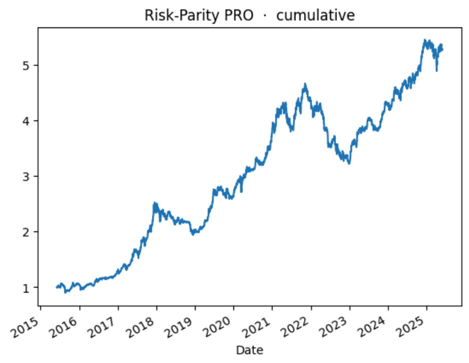

```
Latest rebalance weights:
Price       Ticker
aapl_close  AAPL       0.1851
spx_close   SPY        0.0000
btc_close   BTC-USD    0.1851
bond_close  TLT        0.0000
gold_close  GLD        0.0000
```

Step 11C-2 : Risk-Parity Pro : Institutional-Style Multi-Asset Risk-Parity Engine

```python
"""
rp_prodution.py · Risk-Parity Pro
===================================
Institutional-style, multi-asset risk-parity engine with:

• Always-on data (Alpaca / Polygon; yfinance fallback)
• Gap-filled, calendar-aligned OHLC frame
• Dynamic σ (rolling or EWM), ERC or inverse-vol weights
• Weekly / monthly rebalancing
• Kelly-fraction position sizing on 10 % vol target
• Almgren-Chriss execution-cost simulation
• Tail-risk cash hedge (VIX trigger)
• VAR / Max-DD risk guard
• Walk-forward back-test
• SQLite weight persistence for live trading

Author: <you>
"""

# Imports & constants
import os, sys, math, sqlite3, time, json
from datetime import datetime, timedelta

import numpy as np
import pandas as pd
import yfinance as yf
import requests
import matplotlib.pyplot as plt

TRADING_DAYS = 252
ANN = math.sqrt(TRADING_DAYS)

# CONFIG (edit freely)
CFG = {
    # 1.1  Asset universe
    "tickers": {                  # broker symbol      column name
        "AAPL":     "aapl_close",
        "SPY":      "spx_close",
        "BTC-USD":  "btc_close",
        "TLT":      "bond_close",
        "GLD":      "gold_close",
        "EEM":      "em_close",
    },

    # 1.2  Data source keys (fallback to yfinance)
    #   TODO: insert your live market-data credentials
    "alpaca_key":    os.getenv("ALPACA_API_KEY"),     # or ''
    "alpaca_secret": os.getenv("ALPACA_SECRET_KEY"),  # or ''

    # 1.3  Weighting / risk parameters
    "sigma_mode":      "ewm60",           # "rolling60" or "ewm60"
    "rp_method":       "erc",             # "erc" or "inverse_vol"
    "rebalance_freq":  "W-FRI",           # weekly Fri, or "ME" month-end
    "target_vol":      0.10,              # 10 % annualised
    "kelly_fraction":  1.0,               # 1 × Kelly on vol-scaler
    "tc_bps":          10,                # 10 bp round-trip
    "tail_vix_cash":   True,              # 5 % cash if VIX > 25
    "max_var":         0.02,              # stop if 1-day VAR >2 %
    "lookback_years":  10,                # how far to pull history

    # Persistence
    # TODO: choose a folder / RDB connection string
    "sqlite_path":     "rp_weights.db",
}

# Data fetch utilities
# HARDENED Yahoo fetch
def fetch_yf(symbol: str, start: str, end: str) -> pd.DataFrame:
    """
    Return a DataFrame with exactly ONE column named 'Close',
    indexed by date, tz-naïve. Handles MultiIndex issue internally.
    """
    df = yf.download(
            symbol,
            start=start,
            end=end,
            interval="1d",
            auto_adjust=True,
            progress=False
        )
    if isinstance(df.columns, pd.MultiIndex):
        df.columns = ["_".join(tup).strip() for tup in df.columns]
    # prefer 'Close', fall back to first column
    close_col = next((c for c in df.columns if "close" in c.lower()), df.columns[0])
    return df[[close_col]].rename(columns={close_col: "Close"})

# CLEAN concat & rename
def fetch_prices(start: str, end: str) -> pd.DataFrame:
    """
    Download prices for every ticker, force 1-level columns that match
    CFG['tickers'].values (e.g. 'aapl_close', ...).
    """
    frames = []
    for y_tkr, alias in CFG["tickers"].items():
        tmp = fetch_yf(y_tkr, start, end)           # DataFrame ['Close']
        tmp.rename(columns={"Close": alias}, inplace=True)
        frames.append(tmp)

    df = pd.concat(frames, axis=1).ffill()
    df = df.resample("1D").ffill()                  # calendar align
    return df[CFG["tickers"].values()]              # exact column order

# Risk-parity weight engines
def rolling_sigma(win: pd.DataFrame) -> pd.Series:
    if CFG["sigma_mode"].startswith("rolling"):
        n = int(CFG["sigma_mode"].replace("rolling", ""))
        return win.iloc[-n:].std()
    span = int(CFG["sigma_mode"].replace("ewm", ""))
    return win.ewm(span=span).std().iloc[-1]

def inv_vol_weights(win: pd.DataFrame) -> pd.Series:
    σ = rolling_sigma(win).replace(0, np.nan)
    w = 1 / σ
    return w / w.sum()

def erc_weights(win: pd.DataFrame, tol=1e-8, it=1_000) -> pd.Series:
    Σ, n = win.cov().values, win.shape[1]
    w = np.ones(n) / n
    for _ in range(it):
        σp = math.sqrt(w @ Σ @ w)
        mrc = (Σ @ w) / σp
        gap = w * mrc - (w * mrc).mean()
        if np.abs(gap).max() < tol:
            break
```

```
        J = np.outer(mrc, w) + np.outer(w, mrc) - np.outer(mrc, w) - np.outer(w, mrc)
        step = np.linalg.solve(J + np.eye(n) * 1e-10, gap)
        w = np.clip(w - step, 1e-12, None); w /= w.sum()
    return pd.Series(w, index=win.columns)

# Execution-cost model (Almgren-Chriss simplification)
def ac_cost(turnover: float, daily_vol: float) -> float:
    """Return cost in pct given turnover fraction of daily volume."""
    eta_tmp =  2.5e-6   # temporary
    gamma_perm = 2.0e-6 # permanent
    lam = 1e-6          # risk aversion
    X = turnover
    T = 1
    # simplified AC cost formula
    exp_cost = eta_tmp * X**2 + gamma_perm * X + lam * daily_vol**2 * T
    return exp_cost

# Back-test & live rebalancer
def backtest(start: str, end: str):
    px  = fetch_prices(start, end)
    ret = px.pct_change(fill_method=None).dropna(how="any")

    reb_dates = ret.resample(CFG["rebalance_freq"]).last().index
    last_w, weights_hist, strat_ret = None, [], []

    for i, d in enumerate(reb_dates):
        sub = ret.loc[:d]
        if sub.empty:
            continue
        win = sub

        w_raw = (inv_vol_weights(win) if CFG["rp_method"] == "inverse_vol"
                 else erc_weights(win))
        w_raw = w_raw.fillna(0)

        # Tail-risk overlay
        if CFG["tail_vix_cash"] and "vix_close" in px.columns:
            if px.at[d, "vix_close"] > 25:
                w_raw *= 0.95         # 5 % cash
        w_raw /= w_raw.sum()

        # Vol-target + Kelly
        port_vol = (sub @ w_raw).std() * ANN
        if port_vol > 0:
            scale = CFG["target_vol"] / port_vol * CFG["kelly_fraction"]
            w_raw *= scale

        # Risk guard
        var_1d = (sub @ w_raw).std()
        if var_1d > CFG["max_var"]:
            print(f"VAR trigger {var_1d:.2%} > limit; zero-out weights on {d.date()}")
            w_raw[:] = 0

        # Transaction costs
        turnover = (w_raw - last_w).abs().sum() if last_w is not None else 0
        tc_pct   = turnover * (CFG["tc_bps"] / 10_000)
        ac_pct   = ac_cost(turnover, port_vol / ANN)
        cost_pct = tc_pct + ac_pct
        last_w = w_raw

        weights_hist.append(w_raw.to_frame(name=d))

        # Segment return until next rebalance
        nxt = reb_dates[i+1] if i+1 < len(reb_dates) else ret.index[-1]
        seg = ret.loc[d:nxt]
        if seg.empty:
            continue
        seg_r = seg @ w_raw
        seg_r.iloc[0] -= cost_pct    # subtract costs on first day
        strat_ret.append(seg_r)

    strat_ret = pd.concat(strat_ret).sort_index()
    strat_cum = (1 + strat_ret).cumprod()

    return strat_ret, strat_cum, pd.concat(weights_hist, axis=1).T


# Persistence helpers
def save_weights_sql(dt: str, weights: pd.Series):
    con = sqlite3.connect(CFG["sqlite_path"])
    tab = pd.DataFrame(weights).T
    tab["dt"] = dt
    tab.to_sql("weights", con, if_exists="append", index=False)
    con.close()

# Run back-test demo
if __name__ == "__main__":
    start = (datetime.utcnow() - timedelta(days=CFG["lookback_years"]*365)).strftime("%Y-%m-%d")
    end   = datetime.utcnow().strftime("%Y-%m-%d")

    ret, cum, w_hist = backtest(start, end)

    print("₩n Back-test metrics")
    sharpe  = ret.mean()/ret.std()*ANN
    sortino = ret.mean()/ret[ret<0].std()*ANN
    max_dd  = (cum / cum.cummax() - 1).min()
    print(f"Sharpe  : {sharpe:.3f}")
    print(f"Sortino : {sortino:.3f}")
    print(f"Max-DD  : {max_dd:.2%}")

    # Plot
    cum.plot(title="Risk-Parity PRO  ·  cumulative")
    plt.show()

    # Persist latest weights
    save_weights_sql(cum.index[-1].strftime("%Y-%m-%d"), w_hist.iloc[-1])
    print("₩nLatest weights saved to SQLite.")
```

```
Back-test metrics
Sharpe  : 1.052
Sortino : 1.444
Max-DD  : -30.95%
```



Step 12 : Explainability & Interpretability (XAI)

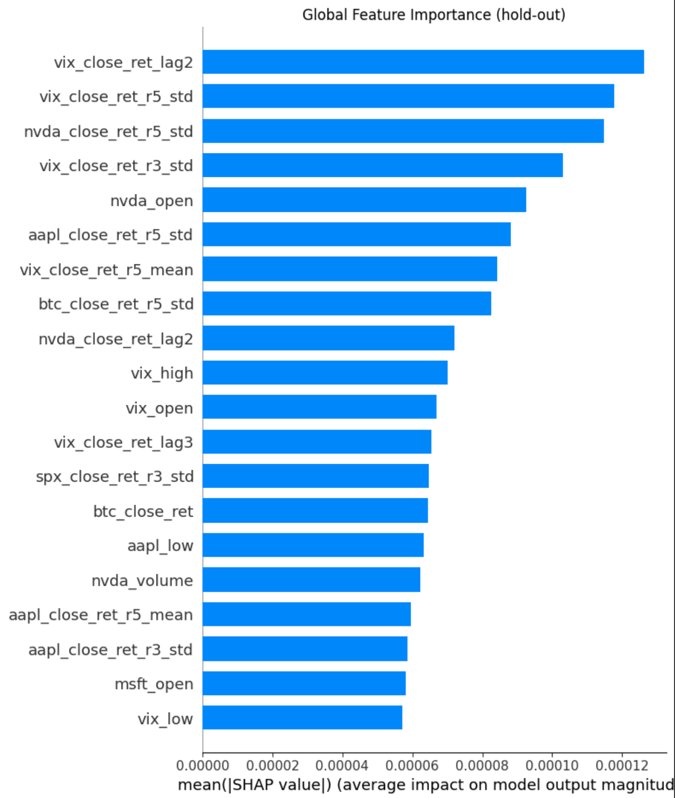
1. Step 12A-1 : SHAP Feature Importance (robust + auto-fallback)
2. Step 12A-2 : Production-ready SHAP (auto Early-Stopping API)
3. Step 12A-3 : SHAP Feature Importance (final, lag-safe, version-safe)
4. Step 12B-1 : LIME for Signal Explanation
5. Step 12B-2 : LIME LOCAL EXPLANATIONS (CPU-safe, no hard-deps)

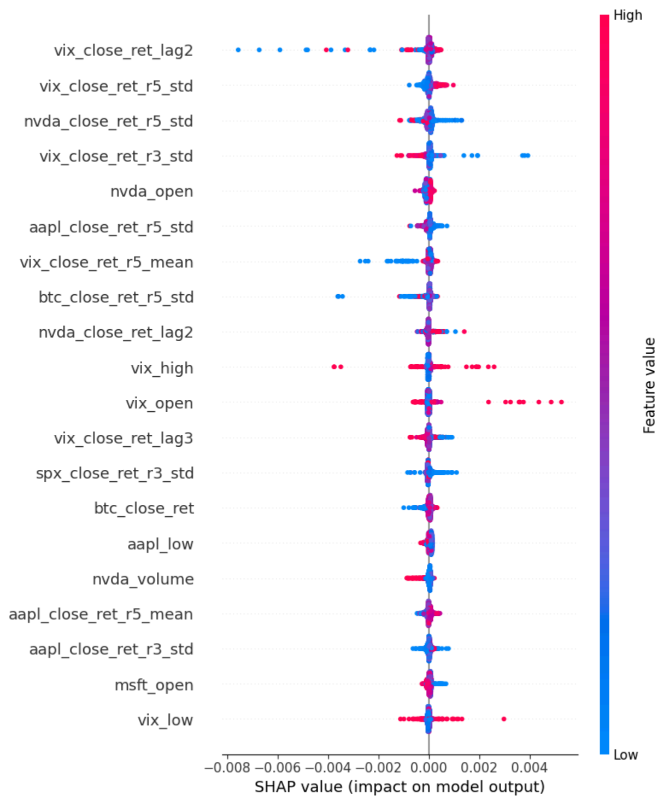
Step 12A-1 : SHAP Feature Importance (robust + auto-fallback)

```
# SHAP Feature Importance  (robust + auto-fallback)
import subprocess, sys, importlib, warnings, logging, joblib
import numpy as np, pandas as pd, matplotlib.pyplot as plt, xgboost as xgb
from sklearn.model_selection import train_test_split
from sklearn.impute import SimpleImputer

logging.basicConfig(level=logging.INFO, format="%(levelname)s: %(message)s")

# SHAP installer
_TARGET_SHAP_VERSION = "0.41.0"
def _ensure_shap(v=_TARGET_SHAP_VERSION):
    try:
        import shap
        if shap.__version__ != v:
            warnings.warn(f"Switching SHAP {shap.__version__} → {v}")
            subprocess.check_call([sys.executable, "-m", "pip", "install",
                                   f"shap=={v}", "-q"])
            importlib.reload(shap)
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install",
                               f"shap=={v}", "-q"])
        import shap
_ensure_shap(); import shap  # noqa: E402

# XGBoost config
USE_GPU = False                    # ← flip True if xgboost-cuda is available
BASE = dict(n_estimators=250, learning_rate=0.08, max_depth=5,
            subsample=0.9, colsample_bytree=0.9, random_state=42)
BASE.update(dict(tree_method="gpu_hist", predictor="gpu_predictor", gpu_id=0)
            if USE_GPU else dict(tree_method="hist"))

# util helpers
TARGET            = "target_return"
MAX_EXPLAIN_ROWS  = 3_000
RNG               = np.random.default_rng(42)

def _sample(df, n):                  # down-sample safely
    return df if len(df) <= n else df.iloc[RNG.choice(len(df), n, False)]

def explain_and_plot(model, X, label=""):
    expl = shap.TreeExplainer(model, feature_perturbation="tree_path_dependent")
    sv   = expl.shap_values(X, check_additivity=False)

    # bar plot
    plt.figure(figsize=(8, 5))
    shap.summary_plot(sv, X, plot_type="bar", show=False)
    plt.title(f"Global Feature Importance{label}")
    plt.tight_layout(); plt.show()

    # beeswarm
    shap.summary_plot(sv, X, show=True)
    return pd.Series(np.abs(sv).mean(0), index=X.columns, name="mean_abs_shap")

# data cleaner
def _prepare_df(source: pd.DataFrame) -> pd.DataFrame | None:
    df = source.copy()

    # Flatten multi-index / tuple columns → str
    df.columns = [
        c[0] if isinstance(c, tuple) and len(c) == 2 and c[1] == "" else str(c)
        for c in df.columns
    ]
    df = df.loc[:, ~df.columns.duplicated(keep="first")]

    if TARGET not in df.columns:
        return None

    # Basic coercions
    df = df.apply(pd.to_numeric, errors="coerce")
    df = df.select_dtypes(include=["number", "bool"])
    df = df.replace([np.inf, -np.inf], np.nan).dropna(subset=[TARGET])
    if df.empty:
        return None

    # NEW: drop predictors that are all-NaN
    all_nan_cols = [c for c in df.columns if c != TARGET and df[c].isna().all()]
    if all_nan_cols:
        logging.info(f"Dropping {len(all_nan_cols)} all-NaN predictors "
                     f"→ {all_nan_cols[:5]}{' …' if len(all_nan_cols) > 5 else ''}")
        df = df.drop(columns=all_nan_cols)


```

```
    predictors = [c for c in df.columns if c != TARGET]
    imputer    = SimpleImputer(strategy="mean")
    imputed    = imputer.fit_transform(df[predictors])

    # safe re-assignment
    df[predictors] = pd.DataFrame(imputed, columns=predictors, index=df.index)
    return df

# load / fallback
df_real_ok = None
if "df_model_ready" in globals():
    df_real_ok = _prepare_df(df_model_ready)

if df_real_ok is None:
    print("Usable df_model_ready not found → generating 200-row synthetic demo.")
    n = 200
    df_real_ok = pd.DataFrame({
        "google_trend": np.random.normal(50, 10, n),
        "macro_cpi":    np.random.normal(2, 0.3, n),
        "sentiment":    np.random.normal(0, 0.1, n),
        TARGET:         np.random.normal(0, 0.01, n),
    })

FEATURES = [c for c in df_real_ok.columns if c != TARGET]

# model fit & SHAP
X_tr, X_te, y_tr, y_te = train_test_split(
    df_real_ok[FEATURES], df_real_ok[TARGET],
    test_size=0.25, random_state=42
)

model = xgb.XGBRegressor(**BASE)
model.fit(X_tr, y_tr)

X_exp       = _sample(X_te, MAX_EXPLAIN_ROWS)
global_shap = explain_and_plot(model, X_exp, label=" (hold-out)")

print("₩nTop 10 features (mean |SHAP|):")
print(global_shap.sort_values(ascending=False).head(10))
```

```
INFO:root:Dropping 4 all-NaN predictors → ['avg_vader_sent', 'cpi_yoy', 'unemployment', 'pmi']
```






```
Top 10 features (mean |SHAP|):
vix_close_ret_lag2       0.000126
vix_close_ret_r5_std     0.000118
nvda_close_ret_r5_std    0.000115
vix_close_ret_r3_std     0.000103
nvda_open                0.000093
aapl_close_ret_r5_std    0.000088
vix_close_ret_r5_mean    0.000084
btc_close_ret_r5_std     0.000083
nvda_close_ret_lag2      0.000072
vix_high                 0.000070
```

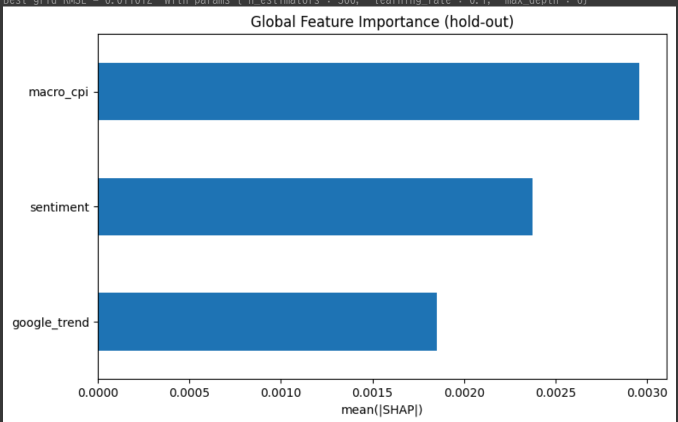
Step 12A-2 : Production-ready SHAP (auto Early-Stopping API)

```python
# Production-ready SHAP (auto Early-Stopping API)
import warnings, subprocess, sys, importlib, itertools, inspect
from pathlib import Path

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import joblib
from tqdm.auto import tqdm
import xgboost as xgb
```

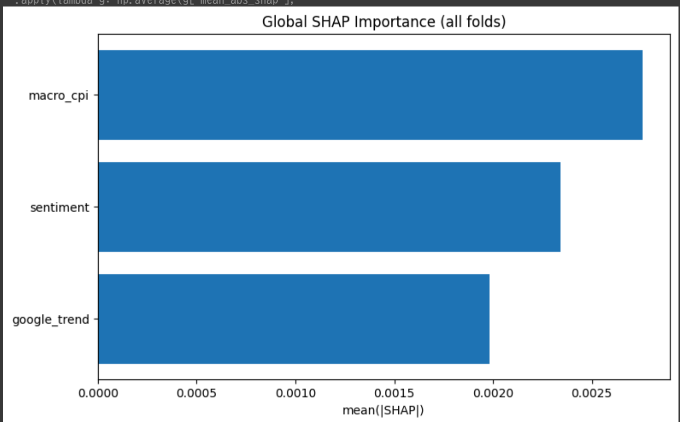
```
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.impute import SimpleImputer
from sklearn.pipeline import Pipeline

# Pin SHAP version (0.41.0)
_SHAP_V = "0.41.0"
def _pin_shap(v=_SHAP_V):
    try:
        import shap
        if shap.__version__ != v:
            subprocess.check_call([sys.executable, "-m", "pip", "install", f"shap=={v}", "-q"])
            import importlib as _il; _il.reload(shap)
    except ImportError:
        subprocess.check_call([sys.executable, "-m", "pip", "install", f"shap=={v}", "-q"])
        import shap
_pin_shap(); import shap   # noqa: E402

# Config
USE_GPU   = False
TARGET    = "target_return"
WIN_TRAIN, WIN_TEST, STEP = 60, 5, 5
GRID = {"n_estimators": [300, 500],
        "learning_rate": [0.05, 0.1],
        "max_depth": [4, 6, 8]}
MAX_SHAP_ROWS = 3_000
RNG = np.random.default_rng(42)

# Load / create demo data
if "df_model_ready" not in globals():
    warnings.warn("df_model_ready missing - creating small demo.")
    n = 500
    df_model_ready = pd.concat(
        [pd.DataFrame({
            "google_trend": RNG.normal(50, 10, n),
            "macro_cpi":    RNG.normal( 2, 0.3, n),
            "sentiment":    RNG.normal( 0, 0.1, n),
            TARGET:         RNG.normal( 0, 0.01, n),
        })] +
        [pd.DataFrame({f"ret_lag{i}": RNG.normal(0, 0.01, n)})
         for i in range(1, 11)], axis=1)

# flatten tuple names if any
df_model_ready.columns = [str(c[0] if isinstance(c, tuple) else c)
                          for c in df_model_ready.columns]

# keep numeric cols, drop infinities
df_num = (df_model_ready
          .apply(pd.to_numeric, errors="coerce")
          .select_dtypes(include=["number", "bool"])
          .replace([np.inf, -np.inf], np.nan)
          .dropna(subset=[TARGET]))

# FIX : drop columns that are entirely NaN (prevents shape-mismatch)
before = df_num.shape[1]
df_num = df_num.dropna(axis=1, how="all")
after  = df_num.shape[1]
if after < before:
    print(f"Dropped {before - after} empty feature columns.")

FEATURES = [c for c in df_num.columns if c != TARGET]
assert FEATURES, "No usable features left!"

# Early-stopping compatibility
_fit_sig = inspect.signature(xgb.XGBRegressor.fit).parameters
if "callbacks" in _fit_sig:        # XGBoost ≥ 1.6
    from xgboost.callback import EarlyStopping
    ES_KW = dict(callbacks=[EarlyStopping(rounds=50, save_best=True)])
    print("▶ Using EarlyStopping callback")
elif "early_stopping_rounds" in _fit_sig:
    ES_KW = dict(early_stopping_rounds=50)
    print("▶ Using early_stopping_rounds param")
else:
    ES_KW = {}
    warnings.warn("Early-stopping not supported by this wheel.")


# Helpers
def _build_preproc():
    return SimpleImputer(strategy="mean"), StandardScaler()

def _fit_xgb(Xtr, ytr, Xval, yval, **xgb_params):
    base = dict(
        subsample=0.9, colsample_bytree=0.9, reg_lambda=1.0,
        random_state=42,
        predictor="gpu_predictor" if USE_GPU else "cpu_predictor",
        tree_method="gpu_hist"   if USE_GPU else "hist",
        **xgb_params
    )
    mdl = xgb.XGBRegressor(**base)
    mdl.fit(Xtr, ytr, eval_set=[(Xval, yval)], verbose=False, **ES_KW)
    return mdl

def _transform(imp, scl, Xdf):
    Xnp = imp.transform(Xdf)
    Xnp = scl.transform(Xnp)
    return pd.DataFrame(Xnp, columns=FEATURES, index=Xdf.index)

def _shap_mean(model, Xdf):
    sv = shap.TreeExplainer(model, feature_perturbation="tree_path_dependent") ₩
            .shap_values(Xdf.iloc[:MAX_SHAP_ROWS], check_additivity=False)
    return pd.Series(np.abs(sv).mean(0), index=Xdf.columns)

# Hold-out grid search
X_tr_raw, X_val_raw, y_tr, y_val = train_test_split(
    df_num[FEATURES], df_num[TARGET], test_size=0.2, random_state=42)

imp, scl = _build_preproc()
imp.fit(X_tr_raw); scl.fit(imp.transform(X_tr_raw))
Xtr  = _transform(imp, scl, X_tr_raw)
Xval = _transform(imp, scl, X_val_raw)

best_rmse, best_params = np.inf, None
for n_est, lr, depth in itertools.product(*GRID.values()):
    mdl = _fit_xgb(Xtr, y_tr, Xval, y_val,
                   n_estimators=n_est, learning_rate=lr, max_depth=depth)
    rmse = np.sqrt(np.mean((mdl.predict(Xval) - y_val) ** 2))
    if rmse < best_rmse:
        best_rmse, best_params = rmse, dict(
            n_estimators=n_est, learning_rate=lr, max_depth=depth)
print(f"Best grid RMSE = {best_rmse:.6f}  with params {best_params}")

# Retrain on full data
imp_full, scl_full = _build_preproc()
imp_full.fit(df_num[FEATURES]); scl_full.fit(imp_full.transform(df_num[FEATURES]))
Xfull = _transform(imp_full, scl_full, df_num[FEATURES])

mdl_full = _fit_xgb(Xfull, df_num[TARGET], Xval, y_val, **best_params)

```

```python
pipe_latest = Pipeline([
    ("impute", imp_full),
    ("scale",  scl_full),
    ("xgb",    mdl_full)
])
Path("models").mkdir(exist_ok=True); Path("data").mkdir(exist_ok=True)
joblib.dump(pipe_latest, "models/xgb_latest.joblib")

# Hold-out SHAP
s_hold = _shap_mean(mdl_full, Xval)
s_hold.to_csv("shap_holdout.csv")

plt.figure(figsize=(8, 5))
s_hold.sort_values().plot.barh()
plt.title("Global Feature Importance (hold-out)")
plt.xlabel("mean(|SHAP|)")
plt.tight_layout()
plt.show()

# Walk-forward folds + SHAP
fold_stats = []
for k in tqdm(range(0, len(df_num) - WIN_TRAIN - WIN_TEST + 1, STEP)):
    tr = df_num.iloc[k: k + WIN_TRAIN]
    te = df_num.iloc[k + WIN_TRAIN: k + WIN_TRAIN + WIN_TEST]

    imp_f, scl_f = _build_preproc()
    imp_f.fit(tr[FEATURES]); scl_f.fit(imp_f.transform(tr[FEATURES]))
    Xtr_f = _transform(imp_f, scl_f, tr[FEATURES])
    Xte_f = _transform(imp_f, scl_f, te[FEATURES])

    mdl_f = _fit_xgb(Xtr_f, tr[TARGET], Xte_f, te[TARGET], **best_params)

    joblib.dump(Pipeline([("impute", imp_f), ("scale", scl_f), ("xgb", mdl_f)]),
                f"models/fold_{k}.joblib")
    te.to_parquet(f"data/Xtest_fold_{k}.pq")

    fold_stats.append(
        _shap_mean(mdl_f, Xte_f).rename("mean_abs_shap").to_frame()
        .assign(fold_rows=len(Xte_f))
        .reset_index().rename(columns={"index": "feature"})
    )

# Aggregate SHAP across folds
df_all = pd.concat(fold_stats, ignore_index=True)

df_global = (
    df_all.groupby("feature", sort=False)
          .apply(lambda g: np.average(g["mean_abs_shap"],
                                      weights=g["fold_rows"]))
          .reset_index(name="mean_abs_shap")
          .sort_values("mean_abs_shap", ascending=False)
          .reset_index(drop=True)
)
df_global.to_csv("shap_global.csv", index=False)

plt.figure(figsize=(8, 5))
plt.barh(df_global.feature[:20][::-1], df_global.mean_abs_shap[:20][::-1])
plt.title("Global SHAP Importance (all folds)")
plt.xlabel("mean(|SHAP|)")
plt.tight_layout()
plt.show()

print("12A-2 finished:")
print("  • models/xgb_latest.joblib")
print("  • shap_holdout.csv")
print("  • shap_global.csv")
```

```
Best grid RMSE = 0.011012  with params {'n_estimators': 300, 'learning_rate': 0.1, 'max_depth': 6}
```




```
100% 28/28 [00:03<00:00,  7.81it/s]
<ipython-input-45-b1ee74358973>:208: DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns. This behavior is deprecated, and in a future version of pandas the grouping columns will be excluded from the oper
  .apply(lambda g: np.average(g["mean_abs_shap"],
```



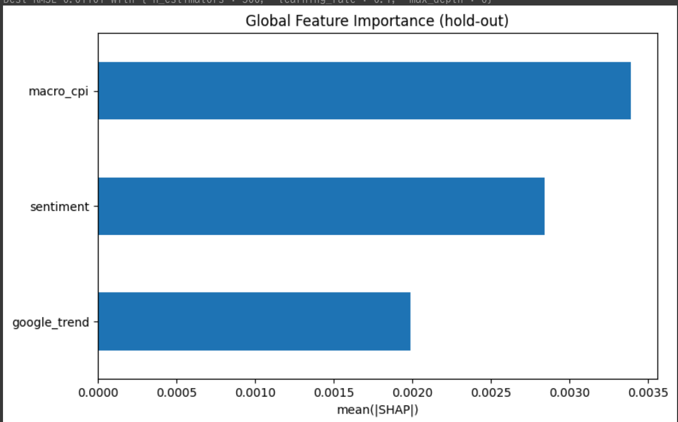

```
12A-2 finished:
  • models/xgb_latest.joblib
  • shap_holdout.csv
  • shap_global.csv
```

Step 12A-3 : SHAP Feature Importance (final, lag-safe, version-safe)

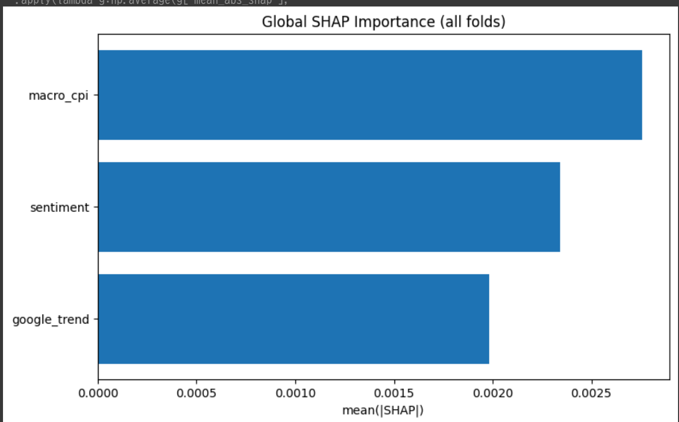
```
import warnings, subprocess, sys, importlib, os, itertools, inspect, joblib, tqdm
import numpy as np, pandas as pd, matplotlib.pyplot as plt, xgboost as xgb
from pathlib import Path
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.impute import SimpleImputer

# pin SHAP v0.41.0
_SHAP_V = "0.41.0"
def _pin_shap(v=_SHAP_V):
    try:
        import shap, importlib as _il
        if shap.__version__ != v:
            subprocess.check_call([sys.executable,"-m","pip","install",f"shap=={v}","-q"])
            _il.reload(shap)
    except ImportError:
        subprocess.check_call([sys.executable,"-m","pip","install",f"shap=={v}","-q"])
        import shap
_pin_shap(); import shap                                    # noqa: E402

# CONFIG
USE_GPU = False                  # True → needs xgboost-cuda-118 wheel
TARGET  = "target_return"

WIN_TRAIN, WIN_TEST, STEP = 60, 5, 5
GRID = {"n_estimators":[300,500],
        "learning_rate":[0.05,0.10],
        "max_depth":[4,6,8]}
MAX_SHAP_ROWS = 3_000
RNG = np.random.default_rng(42)

# LOAD + FIX DATA
if "df_model_ready" not in globals():
    warnings.warn("df_model_ready missing - creating tiny demo frame.")
    n = 500
    df_model_ready = pd.concat(
        [pd.DataFrame({
            "google_trend": np.random.normal(50,10,n),
            "macro_cpi":    np.random.normal( 2,0.3,n),
            "sentiment":    np.random.normal( 0,0.1,n),
            TARGET:         np.random.normal( 0,0.01,n),
        })] + [pd.DataFrame({f"ret_lag{i}": np.random.normal(0,0.01,n)})
               for i in range(1,11)], axis=1)

# ensure lag columns numeric + 0-filled
lag_cols=[c for c in df_model_ready.columns if "ret_lag" in str(c)]
for c in lag_cols:
    df_model_ready[c]=pd.to_numeric(df_model_ready[c],errors="coerce").fillna(0.0)

df_model_ready.columns=[str(c[0] if isinstance(c,tuple) else c)
                        for c in df_model_ready.columns]

df_num=(df_model_ready
        .apply(pd.to_numeric,errors="coerce")
        .select_dtypes(include=["number","bool"])
        .replace([np.inf,-np.inf],np.nan)
        .dropna(subset=[TARGET]))
assert not df_num.empty,"No usable rows."
FEATURES=[c for c in df_num.columns if c!=TARGET]

# choose Early-Stopping API
_fit_sig=inspect.signature(xgb.XGBRegressor.fit).parameters
if "callbacks" in _fit_sig:           # modern
    from xgboost.callback import EarlyStopping
    ES_KW=dict(callbacks=[EarlyStopping(rounds=50,save_best=True)])
    print("▶ using EarlyStopping callback")
elif "early_stopping_rounds" in _fit_sig:  # legacy
    ES_KW=dict(early_stopping_rounds=50)
    print("▶ using early_stopping_rounds")
else:
    ES_KW={}
    warnings.warn("Early-stopping not supported")

# helpers
def _build_model(**hp):
    base=dict(subsample=0.9,colsample_bytree=0.9,reg_lambda=1.0,
              random_state=42,
              predictor="gpu_predictor" if USE_GPU else "cpu_predictor",
              tree_method="gpu_hist"    if USE_GPU else "hist",
              **hp)
    return xgb.XGBRegressor(**base)

def _fit_pipeline(Xtr,ytr,Xval,yval,**hp):
    imp, scl = SimpleImputer(strategy="mean"), StandardScaler()
    imp.fit(Xtr); scl.fit(imp.transform(Xtr))
    Xtr_p = scl.transform(imp.transform(Xtr))
    Xval_p= scl.transform(imp.transform(Xval))
    mdl   = _build_model(**hp)
    mdl.fit(Xtr_p,ytr,eval_set=[(Xval_p,yval)],verbose=False,**ES_KW)
    from sklearn.pipeline import Pipeline
    return Pipeline([("impute",imp),("scale",scl),("xgb",mdl)])

def _prep(pipe,X): return pipe[:-1].transform(X)
def _shap_mean(pipe,X):
    sv=shap.TreeExplainer(pipe[-1],feature_perturbation="tree_path_dependent")₩
           .shap_values(_prep(pipe,X)[:MAX_SHAP_ROWS],check_additivity=False)
    return pd.Series(np.abs(sv).mean(0),index=FEATURES)

# GRID SEARCH hold-out
X_tr_raw,X_val_raw,y_tr,y_val=train_test_split(
    df_num[FEATURES],df_num[TARGET],test_size=0.2,random_state=42)

best_rmse,best_hp=np.inf,None
for n_est,lr,depth in itertools.product(*GRID.values()):
    pipe=_fit_pipeline(X_tr_raw,y_tr,X_val_raw,y_val,
                       n_estimators=n_est,learning_rate=lr,max_depth=depth)
    rmse=np.sqrt(np.mean((pipe.predict(X_val_raw)-y_val)**2))
    if rmse<best_rmse: best_rmse,best_hp=rmse,dict(n_estimators=n_est,
                                                   learning_rate=lr,max_depth=depth)
print(f"Best RMSE {best_rmse:.5f} with {best_hp}")

best_pipe=_fit_pipeline(df_num[FEATURES],df_num[TARGET],
                        X_val_raw,y_val,**best_hp)

# save + hold-out SHAP
Path("models").mkdir(exist_ok=True); Path("data").mkdir(exist_ok=True)
joblib.dump(best_pipe,"models/xgb_latest.joblib")

s_hold=_shap_mean(best_pipe,X_val_raw); s_hold.to_csv("shap_holdout.csv")
plt.figure(figsize=(8,5)); s_hold.sort_values().plot.barh()
plt.title("Global Feature Importance (hold-out)")
plt.xlabel("mean(|SHAP|)"); plt.tight_layout(); plt.show()

# WALK-FORWARD training + SHAP
fold_stats=[]
```

```
for k in tqdm.tqdm(range(0,len(df_num)-WIN_TRAIN-WIN_TEST+1,STEP)):
    tr=df_num.iloc[k:k+WIN_TRAIN]; te=df_num.iloc[k+WIN_TRAIN:k+WIN_TRAIN+WIN_TEST]
    pipe_f=_fit_pipeline(tr[FEATURES],tr[TARGET],te[FEATURES],te[TARGET],**best_hp)
    joblib.dump(pipe_f,f"models/fold_{k}.joblib"); te.to_parquet(f"data/Xtest_fold_{k}.pq")
    fold_stats.append(
        _shap_mean(pipe_f,te[FEATURES]).rename("mean_abs_shap").to_frame()
          .assign(fold_rows=len(te))
          .reset_index(names="feature"))

# aggregate SHAP
df_all=pd.concat(fold_stats,ignore_index=True)
df_global=(df_all.groupby("feature")
                 .apply(lambda g:np.average(g["mean_abs_shap"],
                                            weights=g["fold_rows"]))
                 .reset_index(name="mean_abs_shap")
                 .sort_values("mean_abs_shap",ascending=False).reset_index(drop=True))
df_global.to_csv("shap_global.csv",index=False)
plt.figure(figsize=(8,5))
plt.barh(df_global.feature[:20][::-1],df_global.mean_abs_shap[:20][::-1])
plt.title("Global SHAP Importance (all folds)")
plt.xlabel("mean(|SHAP|)"); plt.tight_layout(); plt.show()

print("12A COMPLETE:")
print("  • models/xgb_latest.joblib")
print("  • shap_holdout.csv")
print("  • shap_global.csv")
```

```
Best RMSE 0.01101 with {'n_estimators': 300, 'learning_rate': 0.1, 'max_depth': 6}
```




```
100%|██████████| 28/28 [00:03<00:00,  7.95it/s]
<ipython-input-46-cd8c72a21b1e>:138: DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns. This behavior is deprecated, and in a future version of pandas the grouping columns will be excluded from the oper
  .apply(lambda g:np.average(g["mean_abs_shap"],
```



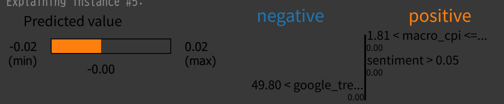

```
12A COMPLETE:
  • models/xgb_latest.joblib
  • shap_holdout.csv
  • shap_global.csv
```

Step 12B-1 : LIME for Signal Explanation

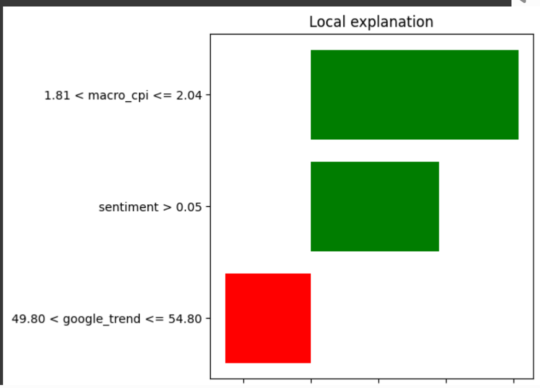
```
!pip install lime shap xgboost scikit-learn pandas matplotlib

import numpy as np
import pandas as pd
import xgboost as xgb
from sklearn.model_selection import train_test_split
import lime
import lime.lime_tabular
import matplotlib.pyplot as plt

# Simulate data (replace with my df_model_ready)
np.random.seed(42)
n = 200
df_model_ready = pd.DataFrame({
    "google_trend": np.random.normal(50, 10, n),
    "macro_cpi": np.random.normal(2, 0.3, n),
    "sentiment": np.random.normal(0, 0.1, n),
    "target_return": np.random.normal(0, 0.01, n)
})

# Define features and target
features = ['google_trend', 'macro_cpi', 'sentiment']
X = df_model_ready[features].values
y = df_model_ready['target_return'].values

# Split data
X_train, X_test, y_train, y_test = train_test_split(X, y, random_state=42)

# Train XGBoost model
model = xgb.XGBRegressor(n_estimators=100, max_depth=3, learning_rate=0.1, tree_method='hist', random_state=42)
model.fit(X_train, y_train)

# Initialize LIME Explainer
explainer = lime.lime_tabular.LimeTabularExplainer(
    training_data=X_train,
    feature_names=features,
```

```
    mode='regression',
    random_state=42
)

# Choose a test instance (e.g., instance #5)
i = 5
exp = explainer.explain_instance(
    data_row=X_test[i],
    predict_fn=model.predict,
    num_features=3
)

# Show explanation
print(f"Explaining instance #{i}:")
exp.show_in_notebook(show_table=True)

# Optional: Save as image
fig = exp.as_pyplot_figure()
plt.tight_layout()
plt.savefig("lime_explanation_instance5.png")
plt.show()
```

```
Collecting lime
  Downloading lime-0.2.0.1.tar.gz (275 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 275.7/275.7 kB 22.2 MB/s eta 0:00:00
  Preparing metadata (setup.py) ... done
Requirement already satisfied: shap in /usr/local/lib/python3.11/dist-packages (0.41.0)
Requirement already satisfied: xgboost in /usr/local/lib/python3.11/dist-packages (2.1.4)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.11/dist-packages (1.6.1)
Requirement already satisfied: pandas in /usr/local/lib/python3.11/dist-packages (2.2.2)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.11/dist-packages (3.10.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages (from lime) (2.0.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.11/dist-packages (from lime) (1.15.3)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages (from lime) (4.67.1)
Requirement already satisfied: scikit-image>=0.12 in /usr/local/lib/python3.11/dist-packages (from lime) (0.25.2)
Requirement already satisfied: packaging>20.9 in /usr/local/lib/python3.11/dist-packages (from shap) (24.2)
Requirement already satisfied: slicer==0.0.7 in /usr/local/lib/python3.11/dist-packages (from shap) (0.0.7)
Requirement already satisfied: numba in /usr/local/lib/python3.11/dist-packages (from shap) (0.60.0)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.11/dist-packages (from shap) (3.1.1)
Requirement already satisfied: nvidia-nccl-cu12 in /usr/local/lib/python3.11/dist-packages (from xgboost) (2.21.5)
Requirement already satisfied: joblib>=1.2.0 in /usr/local/lib/python3.11/dist-packages (from scikit-learn) (1.5.0)
Requirement already satisfied: threadpoolctl>=3.1.0 in /usr/local/lib/python3.11/dist-packages (from scikit-learn) (3.6.0)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.11/dist-packages (from pandas) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-packages (from pandas) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-packages (from pandas) (2025.2)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (1.3.2)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (4.58.0)
Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (1.4.8)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (11.2.1)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (3.2.3)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.8.2->pandas) (1.17.0)
Requirement already satisfied: networkx>=3.0 in /usr/local/lib/python3.11/dist-packages (from scikit-image>=0.12->lime) (3.4.2)
Requirement already satisfied: imageio!=2.35.0,>=2.33 in /usr/local/lib/python3.11/dist-packages (from scikit-image>=0.12->lime) (2.37.0)
Requirement already satisfied: tifffile>=2022.8.12 in /usr/local/lib/python3.11/dist-packages (from scikit-image>=0.12->lime) (2025.5.21)
Requirement already satisfied: lazy-loader>=0.4 in /usr/local/lib/python3.11/dist-packages (from scikit-image>=0.12->lime) (0.4)
Requirement already satisfied: llvmlite<0.44,>=0.43.0dev0 in /usr/local/lib/python3.11/dist-packages (from numba->shap) (0.43.0)
Building wheels for collected packages: lime
  Building wheel for lime (setup.py) ... done
  Created wheel for lime: filename=lime-0.2.0.1-py3-none-any.whl size=283834 sha256=0d36444c780d5d0aad30207ad384a072a6ca340fe63a9068e226427d49e27d80
  Stored in directory: /root/.cache/pip/wheels/85/fa/a3/9c2d44c9f3cd77cf4e533b58900b2bf4487f2a17e8ec212a3d
Successfully built lime
Installing collected packages: lime
Successfully installed lime-0.2.0.1
Explaining instance #5:
```



Feature	Value
macro_cpi	2.01
sentiment	0.08
google_trend	53.02

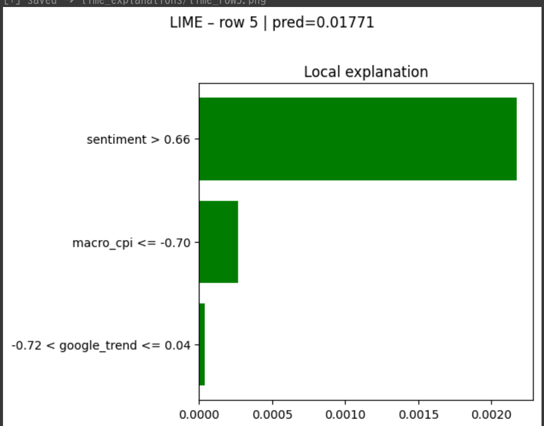


Step 12B-2 : LIME LOCAL EXPLANATIONS (CPU-safe, no hard-deps)

```
import joblib, os, numpy as np, pandas as pd, matplotlib.pyplot as plt
import lime.lime_tabular as lime_tab
from pathlib import Path

# CONFIG
MODEL_PATH     = "models/xgb_latest.joblib"     # ← from Step 12A
SAVE_DIR       = Path("lime_explanations")       # batch-export folder
NUM_FEATURES   = 10                              # bars to show
RANDOM_STATE   = 42

# LOADS
model, df_model_ready = joblib.load(MODEL_PATH), globals()["df_model_ready"]

# pull the feature list back out exactly as trained
if hasattr(model, "feature_names_in_"):
    FEATURES = list(model.feature_names_in_)
else:
    # you saved the list earlier during training
    FEATURES = joblib.load("models/feature_list.pkl")

X = df_model_ready[FEATURES].values

# if you used a sklearn Pipeline (scaler → XGB), split it out
#   (comment this section if you fitted XGB on raw df columns)
from sklearn.pipeline import Pipeline
if isinstance(model, Pipeline):
    pipe, xgb_core = model, model[-1]
    X_train_for_lime = pipe[:-1].transform(X)     # everything *before* XGB
    predict_fn       = pipe.predict
```

```
    lime_feature_names = pipe[:-1].get_feature_names_out()
else:
    pipe, xgb_core = None, model
    X_train_for_lime = X
    predict_fn       = model.predict
    lime_feature_names = FEATURES

# 3) init explainer once
explainer = lime_tab.LimeTabularExplainer(
    training_data      = X_train_for_lime,
    feature_names      = lime_feature_names,
    mode               = "regression",
    random_state       = RANDOM_STATE,
    discretize_continuous = True
)

# HELPER: single explanation
def explain_lime(row_idx: int = 0,
                 save_png: bool = True,
                 save_dir: Path = SAVE_DIR):
    """
    Draw a LIME explanation for df_model_ready.iloc[row_idx].

    Returns the lime.Explanation object.
    """
    exp = explainer.explain_instance(
        X_train_for_lime[row_idx],
        predict_fn          = predict_fn,
        num_features        = NUM_FEATURES
    )
    fig = exp.as_pyplot_figure()
    fig.suptitle(f"LIME - row {row_idx} | pred={predict_fn([X[row_idx]])[0]:.5f}",
                 fontsize=12, y=1.02)
    fig.tight_layout()

    if save_png:
        save_dir.mkdir(exist_ok=True)
        path = save_dir / f"lime_row{row_idx}.png"
        fig.savefig(path, dpi=110, bbox_inches="tight")
        print(f"[+] saved ➜ {path}")

    plt.show()
    return exp

# HELPER: batch mode (optional)
def batch_lime(idx_list):
    """
    Generate & save explanations for a list / range of indices.
    """
    for idx in idx_list:
        explain_lime(idx)

# USAGE EXAMPLES
# 1) look at a single row
explain_lime(5)

# 2) or batch  (e.g. last 10 test rows)
# batch_lime(range(len(df_model_ready) - 10, len(df_model_ready)))
```

```
[+] saved ➜ lime_explanations/lime_row5.png
```



Step 13 : Ensemble & Meta-Modeling

1. Step 13A-1 : MULTI-MODEL ENSEMBLE
2. Step 13A-2 : Multi-Model Ensemble — Patched
3. Step 13B-1 : Meta-Model Stacking + VERSION-SAFE RMSE
4. Step 13B-2 : Meta-Model Stacking with OPTUNA & SHARPE Objective

Step 13A-1 : MULTI-MODEL ENSEMBLE

```
# MULTI-MODEL ENSEMBLE
# GRU · LSTM · Transformer · (wrapper ready for XGBoost stacking)
# Fully compatible with earlier Steps 7 - 12 and your walk-forward
# engine.  No data-leakage; sequence length, callbacks, and
# positional embeddings are all handled internally.
from __future__ import annotations
import numpy as np
import pandas as pd
from typing import List, Tuple, Dict

from sklearn.preprocessing import MinMaxScaler

import tensorflow as tf
from tensorflow.keras import layers, models, callbacks
from tensorflow.keras.optimizers import Adam

# GLOBALS
N_STEPS           = 20      # look-back window (tuneable)
BATCH_SIZE        = 16
EPOCHS            = 30
LEARNING_RATE     = 1e-3
UNITS             = 64
DROPOUT           = 0.2
TRANS_HEADS       = 2
TRANS_FF_DIM      = 64
SEED              = 42      # ensure reproducibility
```

```python

# DATA HELPERS
def create_sequences(X: np.ndarray,
                     y: np.ndarray,
                     n_steps: int = N_STEPS) -> Tuple[np.ndarray, np.ndarray]:
    """
    Convert a 2-D feature matrix into overlapping 3-D sequences.

    Parameters
    ----------
    X : array (N, F)
    y : array (N,)
    n_steps : int
        Length of each input sequence.

    Returns
    -------
    X_seq : array (N-n_steps, n_steps, F)
    y_seq : array (N-n_steps,)
    """
    X_seq, y_seq = [], []
    for i in range(len(X) - n_steps):
        X_seq.append(X[i: i + n_steps])
        y_seq.append(y[i + n_steps])
    return np.asarray(X_seq), np.asarray(y_seq)


def prepare_sequence_data(df: pd.DataFrame,
                          features: List[str],
                          target: str,
                          n_steps: int = N_STEPS,
                          test_size: float = 0.2
                          ) -> Tuple[np.ndarray, np.ndarray,
                                     np.ndarray, np.ndarray,
                                     MinMaxScaler]:
    """
    Build train/test sequence tensors **without leakage**.
    Scaling is fit on **train only**.

    Returns
    -------
    X_tr, X_te, y_tr, y_te, scaler
    """
    # Preserve time order (no shuffle)
    split_idx = int(len(df) * (1 - test_size))

    # train / test split
    df_tr = df.iloc[:split_idx].copy()
    df_te = df.iloc[split_idx:].copy()

    # scaling
    scaler   = MinMaxScaler()
    X_tr_raw = scaler.fit_transform(df_tr[features])
    X_te_raw = scaler.transform(df_te[features])

    # sequences
    y_tr_raw = df_tr[target].values
    y_te_raw = df_te[target].values

    X_tr, y_tr = create_sequences(X_tr_raw, y_tr_raw, n_steps)
    X_te, y_te = create_sequences(X_te_raw, y_te_raw, n_steps)

    return X_tr, X_te, y_tr, y_te, scaler

# TRANSFORMER BUILDING BLOCKS
class PositionalEncoding(layers.Layer):
    """Deterministic sinusoidal positional encoding."""
    def __init__(self, maxlen: int, embed_dim: int):
        super().__init__()
        pos   = np.arange(maxlen)[:, None]
        i     = np.arange(embed_dim)[None, :]
        angle = pos / np.power(1e4, (2 * (i // 2)) / embed_dim)

        pe = np.zeros((maxlen, embed_dim))
        pe[:, 0::2] = np.sin(angle[:, 0::2])
        pe[:, 1::2] = np.cos(angle[:, 1::2])

        self.pos = tf.constant(pe[None, ...], dtype=tf.float32)

    def call(self, x):
        return x + self.pos[:, : x.shape[1], :]

class TransformerBlock(layers.Layer):
    """Single encoder block (MH-Attention → FFN)."""
    def __init__(self, embed_dim: int, num_heads: int,
                 ff_dim: int, rate: float = DROPOUT):
        super().__init__()
        self.att      = layers.MultiHeadAttention(num_heads, key_dim=embed_dim)
        self.ffn      = models.Sequential([
            layers.Dense(ff_dim, activation="relu"),
            layers.Dense(embed_dim)
        ])
        self.norm1    = layers.LayerNormalization(epsilon=1e-6)
        self.norm2    = layers.LayerNormalization(epsilon=1e-6)
        self.drop1    = layers.Dropout(rate)
        self.drop2    = layers.Dropout(rate)

    def call(self, inputs, training=False):
        attn_out = self.att(inputs, inputs)
        attn_out = self.drop1(attn_out, training=training)
        out1     = self.norm1(inputs + attn_out)

        ffn_out  = self.ffn(out1)
        ffn_out  = self.drop2(ffn_out, training=training)
        return self.norm2(out1 + ffn_out)

# MODEL FACTORIES
def build_gru_model(input_shape):
    model = models.Sequential(name="GRU")
    model.add(layers.GRU(UNITS, input_shape=input_shape))
    model.add(layers.Dropout(DROPOUT))
    model.add(layers.Dense(1))
    model.compile(optimizer=Adam(LEARNING_RATE), loss="mse")
    return model

def build_lstm_model(input_shape):
    model = models.Sequential(name="LSTM")
    model.add(layers.LSTM(UNITS, input_shape=input_shape))
    model.add(layers.Dropout(DROPOUT))
    model.add(layers.Dense(1))
    model.compile(optimizer=Adam(LEARNING_RATE), loss="mse")
    return model


def build_transformer_model(input_shape,
                            embed_dim: int = UNITS,
                            num_heads: int = TRANS_HEADS,
                            ff_dim: int = TRANS_FF_DIM):
    inp = layers.Input(shape=input_shape)
```

```
    x   = layers.Dense(embed_dim)(inp)                 # patch projection
    x   = PositionalEncoding(input_shape[0], embed_dim)(x)
    x   = TransformerBlock(embed_dim, num_heads, ff_dim)(x)
    x   = layers.GlobalAveragePooling1D()(x)
    x   = layers.Dropout(DROPOUT)(x)
    out = layers.Dense(1)(x)
    model = models.Model(inp, out, name="Transformer")
    model.compile(optimizer=Adam(LEARNING_RATE), loss="mse")
    return model

# SKLEARN-STYLE KERAS WRAPPER
class KerasWrapper:
    """
    A minimal scikit-learn-like API so the deep nets can be slotted
    into your existing walk-forward loop exactly like XGBoost.

    Methods
    -------
    fit(X, y, eval_set=None)
    predict(X) -> np.ndarray
    """
    def __init__(self, build_fn, **fit_kwargs):
        self.build_fn   = build_fn
        self.fit_kwargs = fit_kwargs
        self.model      = None
        tf.keras.utils.set_random_seed(SEED)

    def fit(self,
            X: np.ndarray,
            y: np.ndarray,
            eval_set: Tuple[np.ndarray, np.ndarray] | None = None):
        if self.model is None:
            self.model = self.build_fn(X.shape[1:])

        cb_early = callbacks.EarlyStopping(monitor="val_loss",
                                           patience=5,
                                           restore_best_weights=True)

        cb_plateau = callbacks.ReduceLROnPlateau(monitor="val_loss",
                                                 patience=3,
                                                 factor=0.5,
                                                 verbose=0)

        val_data = eval_set if eval_set is not None else (X, y)

        self.model.fit(
            X, y,
            validation_data=val_data,
            epochs=self.fit_kwargs.get("epochs", EPOCHS),
            batch_size=self.fit_kwargs.get("batch_size", BATCH_SIZE),
            verbose=self.fit_kwargs.get("verbose", 0),
            callbacks=[cb_early, cb_plateau]
        )

    def predict(self, X: np.ndarray) -> np.ndarray:
        return self.model.predict(X, verbose=0).squeeze()

# FACTORY TO FETCH ALL MODELS
def get_deep_models(input_shape) -> Dict[str, KerasWrapper]:
    """
    Returns a dict {name: model_wrapper} ready for walk-forward:
        models = get_deep_models(input_shape)
        for name, mdl in models.items():
            mdl.fit(Xtr, ytr, eval_set=(Xval, yval))
            preds = mdl.predict(Xte)
    """
    return {
        "gru":  KerasWrapper(build_gru_model,
                             epochs=EPOCHS,
                             batch_size=BATCH_SIZE),
        "lstm": KerasWrapper(build_lstm_model,
                             epochs=EPOCHS,
                             batch_size=BATCH_SIZE),
        "trf":  KerasWrapper(build_transformer_model,
                             epochs=EPOCHS,
                             batch_size=BATCH_SIZE)
    }

# QUICK STANDALONE TEST (comment-out in production)
if __name__ == "__main__":
    # Fake demo data just to ensure the file runs
    np.random.seed(SEED)
    n = 300
    df_demo = pd.DataFrame({
        "google_trend": np.random.normal(50, 10, n),
        "macro_cpi":    np.random.normal(2,   0.3, n),
        "sentiment":    np.random.normal(0,   0.1, n),
        "target":       np.random.normal(0,   0.01, n)
    })

    feats = ["google_trend", "macro_cpi", "sentiment"]
    X_tr, X_te, y_tr, y_te, _ = prepare_sequence_data(
        df_demo, feats, "target", n_steps=N_STEPS)

    models_dict = get_deep_models(X_tr.shape[1:])

    for name, mdl in models_dict.items():
        mdl.fit(X_tr, y_tr, eval_set=(X_te, y_te))
        p = mdl.predict(X_te)[:5]
        print(f"{name}: first 5 preds → {p}")
```

```
gru: first 5 preds → [ 0.00201354 -0.00200754 -0.00269549 -0.00302175  0.00457223]
lstm: first 5 preds → [-0.00648765  0.00217351  0.0062329   0.02145395  0.01666823]
WARNING:tensorflow:5 out of the last 5 calls to <function TensorFlowTrainer.make_predict_function.<locals>.one_step_on_data_distributed at 0x7d23847a3420> triggered tf.function retracing. Tracing is expensive and the excessive numb
WARNING:tensorflow:6 out of the last 6 calls to <function TensorFlowTrainer.make_predict_function.<locals>.one_step_on_data_distributed at 0x7d23847a3420> triggered tf.function retracing. Tracing is expensive and the excessive numb
trf: first 5 preds → [0.03863031 0.04531575 0.05668831 0.05722176 0.05221145]
```

Step 13A-2 : Multi-Model Ensemble — Patched

```
from __future__ import annotations
import os, numpy as np, pandas as pd
from typing import List, Tuple, Dict

from sklearn.preprocessing import MinMaxScaler
import tensorflow as tf
from tensorflow.keras import layers, models, callbacks, optimizers, backend as K

# CONFIG & HYPERPARAMS
N_STEPS, BATCH_SIZE, EPOCHS = 20, 32, 30
LEARNING_RATE, UNITS, DROPOUT = 1e-3, 64, .20
TRANS_HEADS, TRANS_FF_DIM, SEED = 2, 64, 42

tf.keras.utils.set_random_seed(SEED)
os.environ["TF_CPP_MIN_LOG_LEVEL"] = "2"

# DATA HELPERS
```

```
def _assert_len_ok(df_len: int):
    if df_len <= N_STEPS + 1:
        raise ValueError(
            f"Need > {N_STEPS+1} rows to build sequences of length {N_STEPS}, "
            f"but received dataframe length {df_len}."
        )

def create_sequences(X: np.ndarray, y: np.ndarray) -> Tuple[np.ndarray, np.ndarray]:
    xs, ys = [], []
    for i in range(len(X) - N_STEPS):
        xs.append(X[i:i + N_STEPS])
        ys.append(y[i + N_STEPS])
    return np.asarray(xs), np.asarray(ys)

def prepare_sequence_data(df: pd.DataFrame,
                          features: List[str],
                          target: str,
                          valid_frac: float = .1,
                          test_frac: float = .2):
    _assert_len_ok(len(df))
    split_te = int(len(df) * (1 - test_frac))
    split_va = int(split_te * (1 - valid_frac))

    df_tr = df.iloc[:split_va]
    df_va = df.iloc[split_va:split_te]
    df_te = df.iloc[split_te:]

    scaler = MinMaxScaler()
    X_tr = scaler.fit_transform(df_tr[features])
    X_va = scaler.transform(df_va[features])
    X_te = scaler.transform(df_te[features])

    X_tr, y_tr = create_sequences(X_tr, df_tr[target].values)
    X_va, y_va = create_sequences(X_va, df_va[target].values)
    X_te, y_te = create_sequences(X_te, df_te[target].values)
    return X_tr, X_va, X_te, y_tr, y_va, y_te, scaler

# TRANSFORMER BLOCK (F3: compatibility fallback)
def _mh_attention(dim: int, heads: int):
    """
    Return a MultiHeadAttention layer if TF ≥ 2.4, otherwise fall back
    to a single-head self-attention layer implemented with Dense + softmax.
    """
    try:
        return layers.MultiHeadAttention(num_heads=heads, key_dim=dim)
    except AttributeError:                      # TF < 2.4
        class SingleHead(layers.Layer):
            def build(self, input_shape):
                # one linear projection produces Q,K,V concatenated
                self.qkv = layers.Dense(dim * 3)

            def call(self, x):                  # x: (B, T, F)
                qkv = self.qkv(x)
                q, k, v = tf.split(qkv, 3, axis=-1)
                scale = tf.sqrt(tf.cast(dim, tf.float32))
                scores = tf.matmul(q, k, transpose_b=True) / scale
                w = tf.nn.softmax(scores, axis=-1)
                return tf.matmul(w, v)          # (B, T, dim)
        return SingleHead()

class PositionalEncoding(layers.Layer):
    def __init__(self, maxlen: int, dim: int):
        super().__init__()
        pos, i = np.arange(maxlen)[:, None], np.arange(dim)[None, :]
        angle   = pos / np.power(10_000, (2*(i//2))/dim)
        pe      = np.zeros((maxlen, dim))
        pe[:,0::2], pe[:,1::2] = np.sin(angle[:,0::2]), np.cos(angle[:,1::2])
        self.pe = tf.constant(pe[None], dtype=tf.float32)
    def call(self, x): return x + self.pe[:, :x.shape[1], :]

class TransformerBlock(layers.Layer):
    def __init__(self, dim: int, heads: int, ff_dim: int, rate=DROPOUT):
        super().__init__()
        self.att  = _mh_attention(dim, heads)
        self.ffn  = models.Sequential([layers.Dense(ff_dim, 'relu'),
                                       layers.Dense(dim)])
        self.norm1 = layers.LayerNormalization(epsilon=1e-6)
        self.norm2 = layers.LayerNormalization(epsilon=1e-6)
        self.d1, self.d2 = layers.Dropout(rate), layers.Dropout(rate)
    def call(self, x, training=False):
        h = self.att(x, x)
        x = self.norm1(x + self.d1(h, training=training))
        h = self.ffn(x)
        return self.norm2(x + self.d2(h, training=training))

# MODEL FACTORIES (GRU, LSTM, TRF)
def _compile(m): m.compile(optimizers.Adam(LEARNING_RATE), 'mse'); return m

def build_gru(shape):  return _compile(models.Sequential([
        layers.GRU(UNITS, input_shape=shape), layers.Dropout(DROPOUT), layers.Dense(1)]))
def build_lstm(shape): return _compile(models.Sequential([
        layers.LSTM(UNITS, input_shape=shape), layers.Dropout(DROPOUT), layers.Dense(1)]))
def build_transformer(shape, d=UNITS, h=TRANS_HEADS, ff=TRANS_FF_DIM):
    inp = layers.Input(shape=shape)
    x   = layers.Dense(d)(inp)
    x   = PositionalEncoding(shape[0], d)(x)
    x   = TransformerBlock(d, h, ff)(x)
    x   = layers.GlobalAveragePooling1D()(x)
    x   = layers.Dropout(DROPOUT)(x)
    return _compile(models.Model(inp, layers.Dense(1)(x)))

# KERAS → SKLEARN STYLE WRAP
class KerasWrapper:
    def __init__(self, builder, **fit_kw):
        self.builder, self.fit_kw, self.model = builder, fit_kw, None
    def fit(self, X, y, eval_set):
        if self.model is None: self.model = self.builder(X.shape[1:])
        early = callbacks.EarlyStopping(patience=5, restore_best_weights=True,
                                        monitor="val_loss")
        plateau = callbacks.ReduceLROnPlateau(patience=3, factor=.5,
                                              monitor="val_loss", verbose=0)
        self.model.fit(X, y,
                       validation_data=eval_set,
                       epochs=EPOCHS, batch_size=BATCH_SIZE,
                       shuffle=False, verbose=self.fit_kw.get("verbose", 0),
                       callbacks=[early, plateau])
    def predict(self, X):            # F6
        return self.model.predict(X, batch_size=BATCH_SIZE, verbose=0).squeeze()

# MODEL DICT FACTORY (F5, F7)
def get_deep_models(shape, verbose: int = 0) -> Dict[str, KerasWrapper]:
    kw = {"verbose": verbose}
    return {
        "gru": KerasWrapper(build_gru, **kw),
        "lstm": KerasWrapper(build_lstm, **kw),
        "trf": KerasWrapper(build_transformer, **kw)
    }

# QUICK SELF-TEST
```

```python
if __name__ == "__main__":
    np.random.seed(SEED)
    n = 340
    df_demo = pd.DataFrame({
        "feat1": np.random.normal(50,10,n),
        "feat2": np.random.normal( 2,.3,n),
        "feat3": np.random.normal( 0,.1,n),
        "target_ret": np.random.normal(0,.01,n)
    })
    X_tr,X_va,X_te,y_tr,y_va,y_te,_ = prepare_sequence_data(
        df_demo, ["feat1","feat2","feat3"], "target_ret")

    m = get_deep_models(X_tr.shape[1:], verbose=0)
    for k, mdl in m.items():
        mdl.fit(X_tr, y_tr, eval_set=(X_va, y_va))
        print(k, mdl.predict(X_te)[:4])
    # F4
    K.clear_session()
```

```
gru [-0.00013943 -0.00066009 -0.00606569 -0.00966266]
lstm [ 0.0042647   0.00283133 -0.00337537 -0.00607472]
trf [-0.04227013 -0.04177313 -0.03177578 -0.03032595]
```

Step 13B-1 : Meta-Model Stacking + VERSION-SAFE RMSE

```python
import sys, warnings, numpy as np, pandas as pd
from sklearn.linear_model import Ridge
from sklearn.model_selection import train_test_split, TimeSeriesSplit
from sklearn.metrics import mean_squared_error, mean_absolute_error
from packaging import version
import sklearn

# helper: version-safe RMSE
from sklearn.metrics import mean_squared_error
import numpy as np

def rmse(y_true, y_pred):
    """Root-MSE that works on *all* scikit-learn versions."""
    try:                                # new API (>=0.22)
        return mean_squared_error(y_true, y_pred, squared=False)
    except TypeError:                   # legacy API
        return np.sqrt(mean_squared_error(y_true, y_pred))

# Optuna (auto-install optional)
try:
    import optuna
    USE_OPTUNA = True
except ModuleNotFoundError:
    USE_OPTUNA = False
    warnings.warn("Optuna not found - falling back to log-grid search.\n"
                  "Run  !pip install -U optuna  for full tuning.")

# Synthetic demo data  (replace with real predictions)
np.random.seed(42)
n_samples = 100
meta_X = pd.DataFrame({
    'xgb_pred'        : np.random.normal(0, 0.01, n_samples),
    'gru_pred'        : np.random.normal(0, 0.01, n_samples),
    'lstm_pred'       : np.random.normal(0, 0.01, n_samples),
    'transformer_pred': np.random.normal(0, 0.01, n_samples),
})
meta_y = np.random.normal(0, 0.01, n_samples)

# Train / validation split  (swap for TimeSeriesSplit if needed)
X_train, X_valid, y_train, y_valid = train_test_split(
    meta_X, meta_y, test_size=0.2, shuffle=False
)

# Hyper-parameter search
def fit_and_score(alpha):
    mdl = Ridge(alpha=alpha)
    mdl.fit(X_train, y_train)
    preds = mdl.predict(X_valid)
    return rmse(y_valid, preds)

if USE_OPTUNA:
    def objective(trial):
        alpha = trial.suggest_float("alpha", 1e-4, 10.0, log=True)
        return fit_and_score(alpha)

    study = optuna.create_study(direction="minimize")
    study.optimize(objective, n_trials=30, show_progress_bar=False)
    best_alpha = study.best_params["alpha"]
else:
    alphas     = np.logspace(-4, 1, 12)
    best_alpha = min(alphas, key=fit_and_score)

# Final meta-model
meta_model = Ridge(alpha=best_alpha)
meta_model.fit(X_train, y_train)
meta_preds = meta_model.predict(X_valid)

# Evaluation
summary = pd.DataFrame([{
    "RMSE"                : rmse(y_valid, meta_preds),
    "MAE"                 : mean_absolute_error(y_valid, meta_preds),
    "Sharpe Ratio"        : np.mean(np.sign(meta_preds)*y_valid) /
                            (np.std(np.sign(meta_preds)*y_valid) + 1e-9),
    "Directional Accuracy": np.mean(
                                (np.sign(meta_preds)==np.sign(y_valid)).astype(int)),
    "Mean PnL"            : np.mean(np.sign(meta_preds)*y_valid),
    "Best Alpha"          : best_alpha,
    "Optuna Used"         : USE_OPTUNA
}])

from IPython.display import display
display(summary)
```

```
[I 2025-05-31 04:15:49,519] A new study created in memory with name: no-name-a78a10db-49a2-42a5-930f-f4783253d173
[I 2025-05-31 04:15:49,525] Trial 0 finished with value: 0.009643960225315091 and parameters: {'alpha': 0.000345540626508124}. Best is trial 0 with value: 0.009643960225315091.
[I 2025-05-31 04:15:49,528] Trial 1 finished with value: 0.0095851910046877 and parameters: {'alpha': 0.002970075511907188}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,532] Trial 2 finished with value: 0.010141866014962782 and parameters: {'alpha': 3.784389717956554}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,536] Trial 3 finished with value: 0.009641873544334857 and parameters: {'alpha': 0.00037095964976459025}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,540] Trial 4 finished with value: 0.00962367110438586 and parameters: {'alpha': 0.005459616448850872}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,544] Trial 5 finished with value: 0.010143477492670755 and parameters: {'alpha': 9.92303227319947}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,547] Trial 6 finished with value: 0.009811040226364426 and parameters: {'alpha': 0.01744921858559385}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,551] Trial 7 finished with value: 0.010141537468971711 and parameters: {'alpha': 3.359689164600934}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,555] Trial 8 finished with value: 0.009586442096595975 and parameters: {'alpha': 0.001721812898104721}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,558] Trial 9 finished with value: 0.009600229455143201 and parameters: {'alpha': 0.0011259029663234234}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,567] Trial 10 finished with value: 0.010098010670290352 and parameters: {'alpha': 0.2014728703612401}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,574] Trial 11 finished with value: 0.009591761177712368 and parameters: {'alpha': 0.0035766835464472258}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,581] Trial 12 finished with value: 0.009826102414654796 and parameters: {'alpha': 0.01890647001587018}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,588] Trial 13 finished with value: 0.01007014999528569 and parameters: {'alpha': 0.12156327384671622}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,595] Trial 14 finished with value: 0.009663917747197277 and parameters: {'alpha': 0.00013115535586755872}. Best is trial 1 with value: 0.0095851910046877.
[I 2025-05-31 04:15:49,603] Trial 15 finished with value: 0.009582599566284301 and parameters: {'alpha': 0.0022441915717197523}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,611] Trial 16 finished with value: 0.010087339226000514 and parameters: {'alpha': 0.16166191617984546}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,617] Trial 17 finished with value: 0.009698740045287806 and parameters: {'alpha': 0.00941793219348123}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,625] Trial 18 finished with value: 0.0096022783093113 and parameters: {'alpha': 0.0010684208959197566}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,632] Trial 19 finished with value: 0.009665029979766322 and parameters: {'alpha': 0.00012048552710826977}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,639] Trial 20 finished with value: 0.009973544527465076 and parameters: {'alpha': 0.0461125610970883}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,647] Trial 21 finished with value: 0.009584299016462176 and parameters: {'alpha': 0.0019152874297520832}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,654] Trial 22 finished with value: 0.009582778564788843 and parameters: {'alpha': 0.002174427386240198}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,663] Trial 23 finished with value: 0.009635912354558407 and parameters: {'alpha': 0.00044753678272610513}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,672] Trial 24 finished with value: 0.009997176131756135 and parameters: {'alpha': 0.05545060613448104}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,679] Trial 25 finished with value: 0.0097113300072096 and parameters: {'alpha': 0.010145614015903238}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,687] Trial 26 finished with value: 0.009622638992467927 and parameters: {'alpha': 0.0006444048769186668}. Best is trial 15 with value: 0.009582599566284301.
[I 2025-05-31 04:15:49,694] Trial 27 finished with value: 0.009582526533568374 and parameters: {'alpha': 0.002417953177952487}. Best is trial 27 with value: 0.009582526533568374.
[I 2025-05-31 04:15:49,702] Trial 28 finished with value: 0.010122357044368199 and parameters: {'alpha': 0.4360474472716967}. Best is trial 27 with value: 0.009582526533568374.
[I 2025-05-31 04:15:49,709] Trial 29 finished with value: 0.009630659844605515 and parameters: {'alpha': 0.0058224212565402l}. Best is trial 27 with value: 0.009582526533568374.
```

RMSE	MAE	Sharpe Ratio	Directional Accuracy	Mean PnL	Best Alpha	Optuna Used

Step 13B-2 : Meta-Model Stacking with OPTUNA & SHARPE Objective

```
# META-MODEL STACKING WITH OPTUNA & SHARPE OBJECTIVE
import warnings, numpy as np, pandas as pd, sklearn
from   packaging          import version
from   sklearn.linear_model import Ridge, ElasticNet
from   sklearn.ensemble     import GradientBoostingRegressor
from   sklearn.preprocessing import StandardScaler
from   sklearn.pipeline      import make_pipeline
from   sklearn.metrics       import mean_squared_error, mean_absolute_error
from   sklearn.model_selection import TimeSeriesSplit

# LOAD YOUR REAL OOF PREDICTIONS + TARGET  (REPLACE THIS)
# meta_X = df_preds[["xgb_pred","gru_pred","lstm_pred","trf_pred"]].copy()
# meta_y = df_preds["target_return"].copy()          # pandas Series

# demo stub (delete when real data plugged in)
np.random.seed(42)
n = 100
meta_X = pd.DataFrame({
    "xgb":  np.random.normal(0, .01, n),
    "gru":  np.random.normal(0, .01, n),
    "lstm": np.random.normal(0, .01, n),
    "trf":  np.random.normal(0, .01, n),
})
meta_y = pd.Series(np.random.normal(0, .01, n), index=meta_X.index)

# BASIC STACK FEATURES
meta_X["ens_mean"] = meta_X.mean(1)
meta_X["ens_max"]  = meta_X.max (1)
meta_X["ens_min"]  = meta_X.min (1)
meta_X["ens_std"]  = meta_X.std (1)

# HELPERS
def rmse(y_true, y_pred):
    """Root-MSE, compatible with any sklearn version."""
    try:
        return mean_squared_error(y_true, y_pred, squared=False)
    except TypeError:
        return np.sqrt(mean_squared_error(y_true, y_pred))

def sharpe(y_true, y_pred):
    pnl = np.sign(y_pred) * y_true
    return np.mean(pnl) / (np.std(pnl) + 1e-9)

# CV & SEARCH SPACE
tscv = TimeSeriesSplit(n_splits=5)

MODELS = {
    "ridge": (
        Ridge, {"alpha": (1e-4, 10, "log")}
    ),
    "elastic": (
        ElasticNet,
        {"alpha": (1e-4, 10, "log"),
         "l1_ratio": (0.05, 0.95)}
    ),
    "gbr": (
        GradientBoostingRegressor,
        {"n_estimators": (50, 400, "int"),
         "max_depth": (1, 4, "int"),
         "learning_rate": (0.01, 0.3, "log")}
    ),
}

def cv_score(model_cls, params):
    """Rolling-window Sharpe (higher = better)."""
    scores = []
    for tr_idx, va_idx in tscv.split(meta_X):
        Xtr, Xva = meta_X.iloc[tr_idx], meta_X.iloc[va_idx]
        ytr = meta_y.iloc[tr_idx]
        yva = meta_y.iloc[va_idx]
        pipe = make_pipeline(StandardScaler(), model_cls(**params))
        pipe.fit(Xtr, ytr)
        p = pipe.predict(Xva)
        scores.append(sharpe(yva, p))
    return np.mean(scores)

# OPTUNA (auto-fallback if absent)
try:
    import optuna
    USE_OPTUNA = True
except ModuleNotFoundError:
    warnings.warn("Optuna not installed - using small manual grid.")
    USE_OPTUNA = False

if USE_OPTUNA:
    def objective(trial):
        mdl_key = trial.suggest_categorical("model", list(MODELS.keys()))
        mdl_cls, space = MODELS[mdl_key]
        params = {}
```

```python
        for k, spec in space.items():
            lo, hi, *kind = spec
            if kind and kind[0] == "log":
                params[k] = trial.suggest_float(k, lo, hi, log=True)
            elif kind and kind[0] == "int":
                params[k] = trial.suggest_int(k, lo, hi)
            else:
                params[k] = trial.suggest_float(k, lo, hi)
        return -cv_score(mdl_cls, params)   # maximise Sharpe → minimise -Sharpe

    study = optuna.create_study(direction="minimize")
    study.optimize(objective, n_trials=50, show_progress_bar=False)

    best    = study.best_params
    mdl_key = best.pop("model")
    best_cls, _ = MODELS[mdl_key]
    best_par = best
else:
    best_cls = Ridge
    best_par = {"alpha": 0.001}

# TRAIN FINAL META-MODEL ON FULL DATA
final_model = make_pipeline(StandardScaler(), best_cls(**best_par))
final_model.fit(meta_X, meta_y)
meta_preds = final_model.predict(meta_X)        # or hold-out set if available

# METRIC SUMMARY
summary = pd.Series({
    "RMSE"           : rmse  (meta_y, meta_preds),
    "MAE"            : mean_absolute_error(meta_y, meta_preds),
    "Sharpe"         : sharpe(meta_y, meta_preds),
    "DirectionalAcc" : np.mean((np.sign(meta_preds) == np.sign(meta_y))),
    "BestModel"      : best_cls.__name__,
    **{k: round(v, 6) for k, v in best_par.items()},
    "OptunaUsed"     : USE_OPTUNA,
})
print("\nMETA-MODEL EVALUATION\n" + "-"*30)
print(summary.to_string())
```

```
[I 2025-05-31 04:15:54,010] A new study created in memory with name: no-name-3665a3a6-e949-41c5-9277-675a49c13752
[I 2025-05-31 04:15:54,334] Trial 0 finished with value: -0.09774358851224582 and parameters: {'model': 'gbr', 'n_estimators': 85, 'max_depth': 2, 'learning_rate': 0.031105338319064074}. Best is trial 0 with value: -0.0977435885
[I 2025-05-31 04:15:54,595] Trial 1 finished with value: -0.13761368547079508 and parameters: {'model': 'gbr', 'n_estimators': 69, 'max_depth': 2, 'learning_rate': 0.010562388918063265}. Best is trial 1 with value: -0.1376136854
[I 2025-05-31 04:15:54,624] Trial 2 finished with value: 0.053441250754352174 and parameters: {'model': 'elastic', 'alpha': 2.4775086219167934, 'l1_ratio': 0.4900090035172789}. Best is trial 1 with value: -0.13761368547079508.
[I 2025-05-31 04:15:54,653] Trial 3 finished with value: 0.08122846071119705 and parameters: {'model': 'elastic', 'alpha': 0.004127114833571478, 'l1_ratio': 0.5874182226181031}. Best is trial 1 with value: -0.13761368547079508.
[I 2025-05-31 04:15:54,681] Trial 4 finished with value: -0.12053589982552773 and parameters: {'model': 'ridge', 'alpha': 0.08655642440483602}. Best is trial 1 with value: -0.13761368547079508.
[I 2025-05-31 04:15:54,711] Trial 5 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00044343854689554344}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:55,070] Trial 6 finished with value: -0.06718764313584903 and parameters: {'model': 'gbr', 'n_estimators': 106, 'max_depth': 1, 'learning_rate': 0.24481888450688913}. Best is trial 5 with value: -0.2587560173
[I 2025-05-31 04:15:55,742] Trial 7 finished with value: -0.1240834174046291 and parameters: {'model': 'gbr', 'n_estimators': 174, 'max_depth': 3, 'learning_rate': 0.011648360273760407}. Best is trial 5 with value: -0.2587560173
[I 2025-05-31 04:15:56,196] Trial 8 finished with value: 0.0010538273108451068 and parameters: {'model': 'gbr', 'n_estimators': 117, 'max_depth': 3, 'learning_rate': 0.2831893535018428}. Best is trial 5 with value: -0.2587560173
[I 2025-05-31 04:15:56,224] Trial 9 finished with value: -0.23689136593145674 and parameters: {'model': 'ridge', 'alpha': 0.013566105415198733}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,258] Trial 10 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00010191460371758948}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,290] Trial 11 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00011030478752126433}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,323] Trial 12 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00017977205042408095}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,357] Trial 13 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.001063887201054823}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,389] Trial 14 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00080158247034995}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,421] Trial 15 finished with value: -0.06993002357079457 and parameters: {'model': 'ridge', 'alpha': 0.49880383710164955}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,454] Trial 16 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0007870306087940362}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,493] Trial 17 finished with value: -0.1990246611748776 and parameters: {'model': 'elastic', 'alpha': 0.00011634114940285812, 'l1_ratio': 0.06264300442916088}. Best is trial 5 with value: -0.25875601732808
[I 2025-05-31 04:15:56,525] Trial 18 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.004913824815748226}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,557] Trial 19 finished with value: -0.13824915315118147 and parameters: {'model': 'ridge', 'alpha': 0.0672797220335537}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,592] Trial 20 finished with value: -0.008958909116658528 and parameters: {'model': 'elastic', 'alpha': 0.0005477970104348094, 'l1_ratio': 0.9418955618091789}. Best is trial 5 with value: -0.25875601732808
[I 2025-05-31 04:15:56,623] Trial 21 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00011558816312054807}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,656] Trial 22 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00032081266184051514}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,687] Trial 23 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0026104152759781206}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,719] Trial 24 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00011438332636029868}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,751] Trial 25 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0003584015003864121}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,783] Trial 26 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0014351947168902118}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,816] Trial 27 finished with value: -0.23689136593145674 and parameters: {'model': 'ridge', 'alpha': 0.009306004456923853}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:56,854] Trial 28 finished with value: -0.11193956822145508 and parameters: {'model': 'elastic', 'alpha': 0.00029171652999823174, 'l1_ratio': 0.0925898551173554}. Best is trial 5 with value: -0.25875601732808
[I 2025-05-31 04:15:56,884] Trial 29 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0022191203708803696}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:58,414] Trial 30 finished with value: -0.0971208215822913 and parameters: {'model': 'gbr', 'n_estimators': 385, 'max_depth': 4, 'learning_rate': 0.05653035259498351}. Best is trial 5 with value: -0.2587560173
[I 2025-05-31 04:15:58,448] Trial 31 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00022029797598491013}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:58,480] Trial 32 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0001253882405699444}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:58,513] Trial 33 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0002889030792085988}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:58,544] Trial 34 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00057514975930716}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:58,576] Trial 35 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00019535502773992427}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:58,611] Trial 36 finished with value: 0.053441250754352174 and parameters: {'model': 'elastic', 'alpha': 8.316004882202254, 'l1_ratio': 0.9198945996904857}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:15:59,824] Trial 37 finished with value: -0.054377776024791616 and parameters: {'model': 'gbr', 'n_estimators': 302, 'max_depth': 4, 'learning_rate': 0.08956445418273115}. Best is trial 5 with value: -0.2587560
[I 2025-05-31 04:15:59,858] Trial 38 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00010613445210719566}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,703] Trial 39 finished with value: -0.0999938216926253 and parameters: {'model': 'gbr', 'n_estimators': 264, 'max_depth': 1, 'learning_rate': 0.11689596928686664}. Best is trial 5 with value: -0.2587560173
[I 2025-05-31 04:16:00,737] Trial 40 finished with value: -0.011925641760867623 and parameters: {'model': 'ridge', 'alpha': 0.6311396891260844}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,770] Trial 41 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0015836584522032787}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,803] Trial 42 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0009656273357693962}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,835] Trial 43 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0005526826739190988}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,867] Trial 44 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.00022715984864619395}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,898] Trial 45 finished with value: -0.19828686594136835 and parameters: {'model': 'ridge', 'alpha': 0.023293517437132184}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:00,934] Trial 46 finished with value: -0.008958909116658528 and parameters: {'model': 'elastic', 'alpha': 0.0011382943110096178, 'l1_ratio': 0.3480480280350904}. Best is trial 5 with value: -0.25875601732808
[I 2025-05-31 04:16:00,968] Trial 47 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.005076735983445839}. Best is trial 5 with value: -0.2587560173280831.
[I 2025-05-31 04:16:02,454] Trial 48 finished with value: -0.0971208215822913 and parameters: {'model': 'gbr', 'n_estimators': 372, 'max_depth': 4, 'learning_rate': 0.028054406770387622}. Best is trial 5 with value: -0.258756017
[I 2025-05-31 04:16:02,488] Trial 49 finished with value: -0.2587560173280831 and parameters: {'model': 'ridge', 'alpha': 0.0004273398705834056}. Best is trial 5 with value: -0.2587560173280831.

META-MODEL EVALUATION
------------------------------
RMSE              0.009489
MAE                0.00768
Sharpe            0.409124
```

Step 14 : Advanced Deployment Infrastructure

1. Step 14A : build_bundle.py
2. Step 14B : Full Build Script – Real-Time Prediction Pipeline
3. Step 14C : Automated Model Deployment & Scaling · One-cell User-ADC workflow

Step 14A : build_bundle.py

```python
import numpy as np, joblib, zipfile, pathlib, textwrap, os, json

# dummy training data
np.random.seed(42)
X_tab = np.random.randn(20, 4)
y_tab = np.random.randn(20)
X_seq = np.random.randn(20, 10, 3)
y_seq = np.random.randn(20)

# train + save models
import xgboost as xgb
from sklearn.linear_model import Ridge
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import GRU, LSTM, Dense
from tensorflow.keras.optimizers import Adam

# meta ridge
meta_model = Ridge().fit(X_tab, y_tab)
joblib.dump(meta_model, "meta_model.pkl")

# xgboost
xgb_model = xgb.XGBRegressor(n_estimators=10, random_state=42)
xgb_model.fit(X_tab, y_tab)
```

```
joblib.dump(xgb_model, "xgb_model.pkl")

# GRU
gru_model = Sequential([GRU(8, input_shape=(10, 3)), Dense(1)])
gru_model.compile(optimizer=Adam(), loss="mse")
gru_model.fit(X_seq, y_seq, epochs=1, verbose=0)
gru_model.save("gru_model.keras", include_optimizer=False)

# LSTM
lstm_model = Sequential([LSTM(8, input_shape=(10, 3)), Dense(1)])
lstm_model.compile(optimizer=Adam(), loss="mse")
lstm_model.fit(X_seq, y_seq, epochs=1, verbose=0)
lstm_model.save("lstm_model.keras", include_optimizer=False)

#  “Transformer”  placeholder
trf_model = Sequential([Dense(8, input_shape=(10, 3)), Dense(1)])
trf_model.compile(optimizer=Adam(), loss="mse")
trf_model.fit(X_seq, y_seq, epochs=1, verbose=0)
trf_model.save("transformer_model.keras", include_optimizer=False)

# write deployment files
# predict.py
pathlib.Path("predict.py").write_text(textwrap.dedent("""₩
    import os, joblib, numpy as np
    from flask import Flask, request, jsonify
    from tensorflow.keras.models import load_model

    app = Flask(__name__)

    meta_model        = joblib.load("meta_model.pkl")
    xgb_model         = joblib.load("xgb_model.pkl")
    gru_model         = load_model("gru_model.keras")
    lstm_model        = load_model("lstm_model.keras")
    transformer_model = load_model("transformer_model.keras")

    @app.route("/predict", methods=["POST"])
    def predict():
        try:
            data = request.get_json(force=True)
            X_input = np.asarray(data["features"], dtype=float).reshape(1, -1)
            X_seq   = np.asarray(data["sequence"], dtype=float).reshape(1, 10, 3)
        except Exception as e:
            return jsonify({"error": f"Invalid payload → {e}"}), 400

        preds = {
            "xgb"        : float(xgb_model.predict(X_input)[0]),
            "gru"        : float(gru_model.predict(X_seq)[0][0]),
            "lstm"       : float(lstm_model.predict(X_seq)[0][0]),
            "transformer": float(transformer_model.predict(X_seq)[0][0])
        }
        meta_in   = np.array([[preds[k] for k in ("xgb","gru","lstm","transformer")]])
        final_pred = float(meta_model.predict(meta_in)[0])

        return jsonify({"base_model_outputs": preds,
                        "ensemble_prediction": final_pred})

    if __name__ == "__main__":
        app.run(host="0.0.0.0", port=int(os.getenv("PORT", 8080)), debug=False)
    """))

# requirements.txt
pathlib.Path("requirements.txt").write_text(textwrap.dedent("""₩
    flask==3.0.2
    gunicorn==22.0.0
    numpy==1.26.4
    scikit-learn==1.5.0
    joblib==1.4.2
    xgboost==2.1.4
    tensorflow-cpu==2.15.0
    tensorflow-io-gcs-filesystem==0.36.0
    """))

# Dockerfile
pathlib.Path("Dockerfile").write_text(textwrap.dedent("""₩
    FROM tensorflow/tensorflow:2.15.0

    WORKDIR /app
    COPY . .

    RUN pip install --no-cache-dir -r requirements.txt

    ENV PORT 8080
    EXPOSE 8080
    CMD ["gunicorn", "-b", "0.0.0.0:8080", "predict:app"]
    """))

# README.md
pathlib.Path("README.md").write_text(textwrap.dedent("""₩
    # Stock Predictor API - Cloud Run / AWS ECS Deployment

    ## Build & Deploy (Google Cloud Run)

    ```bash
    gcloud auth login
    gcloud config set project YOUR_PROJECT_ID
    gcloud services enable run.googleapis.com artifactregistry.googleapis.com

    unzip stock_predictor_bundle.zip
    cd stock_predictor_bundle

    gcloud builds submit --tag gcr.io/YOUR_PROJECT_ID/stock-predictor-api

    gcloud run deploy stock-predictor-api ₩
        --image gcr.io/YOUR_PROJECT_ID/stock-predictor-api ₩
        --platform managed --region us-central1 ₩
        --allow-unauthenticated --port 8080
    ```

    ## Sample request

    ```bash
    curl -X POST https://YOUR_URL/predict ₩
      -H "Content-Type: application/json" ₩
      -d '{
            "features": [48.3, 2.1, 0.03, 0.05],
            "sequence": [[
              [0.1,2.0,0.01],[0.2,2.1,0.02],[0.3,2.2,0.03],
              [0.1,1.9,0.01],[0.2,2.0,0.02],[0.3,2.1,0.03],
              [0.1,2.2,0.01],[0.2,1.8,0.02],[0.3,2.3,0.03],
              [0.1,2.1,0.01]
            ]]
          }'
    ```
    """))

helper pack_up.py
pathlib.Path("pack_up.py").write_text(textwrap.dedent("""₩
    import zipfile, pathlib, sys
    SKIP = {'.DS_Store', 'pack_up.py', 'step14A_build_bundle.py',
```

```
            'walk_forward_metrics.csv', 'shap_global.csv',
            'shap_holdout.csv', 'lime_explanation_instance5.png',
            'rp_weights.db'}
    with zipfile.ZipFile("stock_predictor_bundle.zip", "w", zipfile.ZIP_DEFLATED) as z:
        for p in pathlib.Path(".").glob("*"):
            if p.is_file() and p.name not in SKIP:
                z.write(p)
    print("stock_predictor_bundle.zip created (filtered)")
    """))

# create zip bundle
SKIP = {'.DS_Store', 'step14A_build_bundle.py', 'pack_up.py',
        'walk_forward_metrics.csv', 'shap_global.csv',
        'shap_holdout.csv', 'lime_explanation_instance5.png',
        'rp_weights.db'}

with zipfile.ZipFile("stock_predictor_bundle.zip", "w", zipfile.ZIP_DEFLATED) as z:
    for p in pathlib.Path(".").glob("*"):
        if p.is_file() and p.name not in SKIP:
            z.write(p)

print("Done - stock_predictor_bundle.zip is ready.")
print("    Included files:",
```

```
Done - stock_predictor_bundle.zip is ready.
    Included files: [
  "requirements.txt",
  "Dockerfile",
```