基于 LightGBM 的加密货币次频异常收益率预测

刘健乐[*]   胡锦程[†]   詹炫佑[‡]

2025 年 6 月 11 日

摘要

本报告使用了基于 LightGBM 的集成学习方法，用于预测 14 种加密货币的 15 分钟残差收益。通过特征工程和时序交叉验证策略，我们实现了最终加权相关系数 0.01929 的表现，对比竞赛 Leaderboard，我们能达到第 10 名，拿到了金牌的成绩。我们创新性地结合了技术指标计算、量价关系分析和滚动窗口训练策略，有效应对了金融时间序列的非平稳性以及分布偏移的问题。

1 背景介绍

近年来，全球加密货币市场交易活跃，每日交易额超过 400 亿美元。作为一种新兴的投资与投机资产，加密货币价格波动剧烈，既孕育了造富神话，也带来了巨大损失。如何预测这些价格波动，成为金融科技领域的重要课题。本项目旨在利用机器学习方法对 14 种主流加密货币的短期异常收益率进行预测。主办方提供了自 2018 年以来的 1min bar 的市场数据，我们在此基础上构建预测模型。需注意的是，加密货币市场存在高度非平稳性，价格信号往往转瞬即逝，且市场波动性与相关性结构随时间不断演变，模型易于过拟合，所以如何对抗过拟合是重中之重。

2 数据预处理

2.1 数据描述

本项目采用的研究数据为**次频加密货币市场数据**G-Research Crypto Forecasting 数据集，时间跨度覆盖 **2018 年 1 月 1 日至 2022 年 1 月 23 日**，数据粒度为 **1 分钟 Bar**。数据记录了 14 种主流加密货币在此期间的市场交易信息，总计包含数百万行观测，具体字段说明如下：

---

[*]刘健乐学号：202221060536, 负责数据清洗等预处理工作
[†]胡锦程学号：202221090040, 负责因子挖掘
[‡]詹炫佑学号：202221090208, 负责模型训练及最终汇总

- **timestamp**：该行数据对应的分钟时间戳；

- **Asset_ID**：加密资产的唯一标识代码；

- **Count**：该分钟内发生的成交笔数；

- **Open**：该分钟开始时的美元计价价格；

- **High**：该分钟内成交的最高美元价格；

- **Low**：该分钟内成交的最低美元价格；

- **Close**：该分钟结束时的美元计价价格；

- **Volume**：该分钟内成交的加密货币单位数量；

- **VWAP**：该分钟的成交量加权平均价格（Volume Weighted Average Price）；

- **Target**：**15 分钟残差收益率**，用于构建模型预测目标。具体计算方式详见官方文档中 "Prediction and Evaluation" 部分说明。

此外，数据集覆盖的加密资产包括：Binance Coin（BNB）、Bitcoin（BTC）、Bitcoin Cash（BCH）、Cardano（ADA）、Dogecoin（DOGE）、EOS.IO（EOS）、Ethereum（ETH）、Ethereum Classic（ETC）、IOTA（MIOTA）、Litecoin（LTC）、Maker（MKR）、Monero（XMR）、Stellar（XLM）和 TRON（TRX）。

2.2 数据清洗

采用以下预处理流程：

Algorithm 1 数据预处理流程

1: **for** 每个资产 ID $id \in [0, 13]$ **do**
2:     提取对应资产数据 $df \leftarrow df_{train}[Asset\_ID == id]$
3:     删除 Target 为空的记录
4:     按 60 秒频率重新索引并向前填充
5: **end for**
6: 合并所有资产数据并按时间排序

---

3 特征工程

3.1 因子类别

- **均线系统因子**: 快慢线离差, 均线加速因子

- **动量类因子**: 标准化收益率, 量价配合动量, 自适应动量

- **突破类因子**: 布林带突破, 通道突破

- **波动结构因子**: 波动聚集, 日内波动模式

3.2 特征描述

特征名称	类型	中文描述与计算逻辑
Open/High/Low/Close	数值型	开盘价/最高价/最低价/收盘价
Volume	数值型	总交易量（单位: 标的物数量）, 负值表示数据异常
VWAP	数值型	成交量加权平均价: $\text{VWAP} = \frac{\sum(P_i \times V_i)}{\sum V_i}$
price_ema_ratio_[N]	数值型	价格与 N 期 EMA 比值: $\frac{\text{Close}}{\text{EMA}(N)}$ （N=5,10,20,50）
ma_cross_above_5_20	二值型	均线金叉信号: $\text{EMA}(5) > \text{EMA}(20)$且昨日 $\text{EMA}(5) \leq \text{EMA}(20)$
bollinger_break_upper_[N]	二值型	突破布林带上轨: $\text{Close} > \text{EMA}(N) + 2\sigma$
rsi_[N]	数值型	相对强弱指数: $100 - \frac{100}{1+\text{RS}}$, 其中 $\text{RS} = \frac{\text{平均涨幅}}{\text{平均跌幅}}$
doji_candle	二值型	十字星形态判定: $\frac{\|\text{Open}-\text{Close}\|}{\text{High}-\text{Low}} < 0.1$且影线长度 $> 2 \times$ 实体长度
volume_price_corr	数值型	成交量与价格的滚动相关系数（20 周期）
volatility_clustering	数值型	波动率聚集效应: $\frac{\sigma_t}{\sigma_{t-1}}$

3.3 描述性统计

	count	mean	std	min	25%	50%	75%	max
Asset_ID	28,459,123	6.503	4.070	0	3	7	10	13
Count	28,459,123	285.816	858.331	1	17	62	226	165,016
Open	28,459,123	1620.152	6928.539	0.001	0.286	18.141	284.135	68986.117
High	28,459,123	1623.700	6938.019	0.001	0.287	18.163	284.800	69024.200
Low	28,459,123	1617.117	6919.137	0.000	0.285	18.120	283.540	68,734
Close	28,459,123	1620.157	6928.541	0.001	0.286	18.141	284.131	68973.564
Volume	28,459,123	276510.736	2297080.037	-0.366	100	1073.908	24617.275	759755403.142
VWAP	28,459,123	1620.144	6928.474	-799.747	0.286	18.141	284.122	68894.052
Target	28,459,123	0.000	0.007	-0.509	-0.002	0	0.002	0.964
train_flg	28,459,123	0.037	0.188	0	0	0	0	1
intra_minute_range	28,459,123	0.006	0.014	0	0.001	0.002	0.005	2.954
close_open_ratio	28,459,123	1.000	0.002	0.759	1.000	1	1.000	1.975
price_vwap_premium	28,459,123	0.000	0.019	-56.597	-0.000	0	0.000	59.064
price_ema_ratio_5	28,459,123	1.000	0.002	0.597	0.999	1.000	1.001	1.498
price_ema_ratio_10	28,459,123	1.000	0.003	0.546	0.999	1.000	1.001	1.687
price_ema_ratio_20	28,459,123	1.000	0.004	0.519	0.999	1.000	1.001	1.818
price_ema_ratio_50	28,459,123	1.000	0.006	0.502	0.998	1.000	1.002	1.927
price_ema_diff_fast	28,459,123	-0.001	0.422	-1.000	-0.337	-0.000	0.340	1.000
price_ema_diff_slow	28,459,123	-0.007	0.653	-1.000	-0.651	-0.000	0.641	1.000
trend_accel_5	28,459,123	1.000	0.001	0.888	1.000	1	1.000	1.213
trend_accel_10	28,459,123	1.000	0.002	0.906	0.999	1.000	1.001	1.196
normalized_change_5	28,459,123	0.001	1.056	-309.645	-0.648	0	0.651	317.089
normalized_change_10	28,459,123	0.001	0.995	-5.504	-0.562	0	0.565	6.320
normalized_change_20	28,459,123	0.001	0.994	-4.713	-0.517	0	0.519	4.621
price_change_per_volume	28,459,123	-0.000	0.092	-16.120	-0.000	0	0.000	8.700
price_change_per_volume_ma_5	28,459,123	-0.000	0.090	-9.097	-0.000	0	0.000	6.572
price_change_per_volume_ma_10	28,459,123	-0.000	0.090	-9.097	-0.000	0	0.000	3.600
price_change_per_volume_ma_20	28,459,123	-0.000	0.089	-9.097	-0.000	0	0.000	3.600
abs_snr_5	28,459,123	0.003	0.537	-1	-0.374	0	0.382	1
abs_snr_10	28,459,123	0.004	0.396	-1	-0.245	0	0.252	1
abs_snr_20	28,459,123	0.005	0.290	-1	-0.165	0	0.172	1
abs_snr_50	28,459,123	0.004	0.191	-1	-0.099	0	0.105	1
volume_ratio_5	28,459,123	1.013	0.729	-0.032	0.532	0.899	1.272	5.000
volume_ratio_10	28,459,123	1.025	0.943	-0.015	0.460	0.820	1.243	10.000
volume_ratio_20	28,459,123	1.034	1.150	-0.015	0.414	0.764	1.211	20.000
volume_ratio_50	28,459,123	1.043	1.427	-0.014	0.371	0.710	1.175	49.992
volume_price_divergence	28,459,123	0.000	0.006	-1.244	-0.001	-0.000	0.001	1.438
ma_cross_above_5_20	28,459,123	0.034	0.181	0	0	0	0	1
bollinger_break_upper_10	28,459,123	0.031	0.173	0	0	0	0	1
bollinger_break_lower_10	28,459,123	0.031	0.175	0	0	0	0	1
bollinger_break_upper_20	28,459,123	0.049	0.215	0	0	0	0	1
bollinger_break_lower_20	28,459,123	0.049	0.217	0	0	0	0	1
strong_bull_candle	28,459,123	0.032	0.176	0	0	0	0	1
strong_bear_candle	28,459,123	0.028	0.166	0	0	0	0	1
doji_candle	28,459,123	0.415	0.493	0	0	0	1	1
rsi_5	28,459,123	53.123	31.761	0	28.179	52.426	79.959	100
rsi_10	28,459,123	52.553	23.317	0	36.903	51.148	67.063	100
rsi_20	28,459,123	52.230	17.813	0	41.463	50.669	60.945	100
rsi_50	28,459,123	51.960	13.387	0	44.947	50.364	56.416	100
volume_price_corr	28,459,123	-0.007	0.322	-1.000	-0.224	0	0.210	1
volatility_clustering	28,459,123	0.918	0.358	0	0.721	0.943	1.157	1.795

4 实验流程

首先我们将 2021-06-01 之后的数据划分为测试集, 将前面的数据进行五折时间序列交叉验证, 找到最优参数配置如下:

```
{
    "objective": "regression",
    "metric": "rmse",
    "boosting_type": "gbdt",
    "learning_rate": 0.01,
    "num_leaves": 31,
    "max_depth": -1,
    "min_child_samples": 200,
    "reg_alpha": 1.0,
    "reg_lambda": 5.0,
    "feature_fraction": 0.5,
    "bagging_fraction": 0.5,
    "bagging_freq": 1,
    "verbose": -1,
    "bagging_seed": 42,
    "n_estimators": 500,
    "device_type": "gpu",
    "gpu_platform_id": 0,
    "gpu_device_id": 0,
    "max_bin": 127,
    "seed": 42
}
```

Listing 1: LightGBM 超参数配置

4.1 tricks

- **embargo**: 训练集验证集间保留 3750min 隔离

- **硬件加速**: 启用 GPU 训练

- **特征分桶限制**: 加速实验

- **正则化组合**: L1+L2 双重正则化防止过拟合

- **特征, 样本采样**: 每轮训练随机使用 50% 特征以及 50% 样本, 对抗过拟合

5   实验结果

5.1   模型表现

标的	5 个 fold 验证集平均相关系数	权重
Binance Coin (BNB)	0.22751	4.30407
Bitcoin (BTC)	0.11425	6.77992
Bitcoin Cash (BCH)	0.27705	2.39790
Cardano (ADA)	0.10083	4.40672
Dogecoin (DOGE)	0.18548	3.55535
EOS.IO (EOS)	0.13863	1.38629
Ethereum (ETH)	0.10747	5.89440
Ethereum Classic (ETC)	0.14271	2.07944
IOTA (MIOTA)	0.13030	1.09861
Litecoin (LTC)	0.10333	2.39790
Maker (MKR)	0.96698	1.09861
Monero (XMR)	0.18920	1.60944
Stellar (XLM)	0.22306	2.07944
TRON (TRX)	0.15675	1.79176

表 1: 各资产模型表现及对应权重

5.2   测试集评估

采用加权 Pearson 相关系数, 不同品种一起计算:

$$\text{Score} = \frac{\sum w_a \cdot \text{cov}(\hat{y}_a, y_a)}{\sqrt{\sum w_a \cdot \text{var}(\hat{y}_a) \cdot \sum w_a \cdot \text{var}(y_a)}} \tag{1}$$

最终得分:0.01929

5.3   有效特征分析

- 量价关系特征占据 Top 特征的大部分
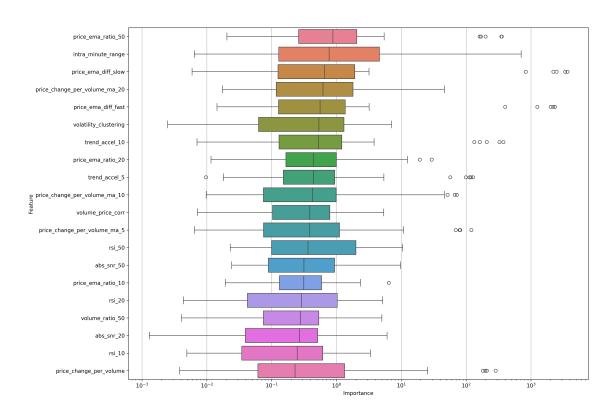
- 长期技术指标 (20-50 周期) 比短期指标更有效

- 包含更长时序信息的因子更有效

图 1: Top 20 特征重要性 (基于信息增益)

6 结论

6.1 核心总结

本方案通过 LightGBM 实现了加密货币异常收益率预测，关键成功因素包括：

- 精细的 1min bar 特征工程

- 不同资产独立建模

- 稳健的时序交叉验证策略

- 严格的 train valid embargo, 保证没有静态信息泄露

6.2 改进方向

- 我们目前仅采用了时序因子, 后续还可以加入截面因子提供信息

- 我们目前仅采用了 lgbm 这种 tabular 类模型, 后续可以尝试 lstm, transformer 等时序类模型

- 有了模型预测值我们可以通过归一化不同品种预测值作为权重完成一个截面多空策略, 但限于工作量问题, 目前暂未实现

A 队伍分工

刘健乐负责下载数据, 数据清洗等预处理工作, 胡锦程负责因子挖掘, 詹炫佑负责模型训练以及最终汇总

B 模型训练日志

```
Training model for Binance Coin (ID=0 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00927982
    Model saved to /mnt/T0/zxy/result/kaggle/model/Binance Coin/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
```

```
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00746596
    Model saved to /mnt/T0/zxy/result/kaggle/model/Binance Coin/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00661043
    Model saved to /mnt/T0/zxy/result/kaggle/model/Binance Coin/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.0060335
    Model saved to /mnt/T0/zxy/result/kaggle/model/Binance Coin/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00558635
    Model saved to /mnt/T0/zxy/result/kaggle/model/Binance Coin/fold_4.pkl
  valid corr score of Binance Coin (ID=0) is 0.22751. (Weight: 4.30407)
  test corr score of Binance Coin (ID=0) is 0.01500. (Weight: 4.30407)
Training model for Bitcoin     (ID=1 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00191199
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00187972
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00194922
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
```

```
[500]  valid_0's rmse: 0.00190762
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00182028
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin/fold_4.pkl
  valid corr score of Bitcoin (ID=1) is 0.11425. (Weight: 6.77992)
  test corr score of Bitcoin (ID=1) is 0.01992. (Weight: 6.77992)
Training model for Bitcoin Cash (ID=2 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00488626
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin Cash/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.0107588
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin Cash/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00907468
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin Cash/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00804903
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin Cash/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00726878
    Model saved to /mnt/T0/zxy/result/kaggle/model/Bitcoin Cash/fold_4.pkl
  valid corr score of Bitcoin Cash (ID=2) is 0.27705. (Weight: 2.39790)
  test corr score of Bitcoin Cash (ID=2) is 0.00222. (Weight: 2.39790)
Training model for Cardano     (ID=3 )
Fold 0
```

```
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00468671
    Model saved to /mnt/T0/zxy/result/kaggle/model/Cardano/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00464408
    Model saved to /mnt/T0/zxy/result/kaggle/model/Cardano/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00468699
    Model saved to /mnt/T0/zxy/result/kaggle/model/Cardano/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00451126
    Model saved to /mnt/T0/zxy/result/kaggle/model/Cardano/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00433217
    Model saved to /mnt/T0/zxy/result/kaggle/model/Cardano/fold_4.pkl
  valid corr score of Cardano (ID=3) is 0.10083. (Weight: 4.40672)
  test corr score of Cardano (ID=3) is 0.02869. (Weight: 4.40672)
Training model for Dogecoin    (ID=4 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00550366
    Model saved to /mnt/T0/zxy/result/kaggle/model/Dogecoin/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00468526
    Model saved to /mnt/T0/zxy/result/kaggle/model/Dogecoin/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
```

```
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00498716
    Model saved to /mnt/T0/zxy/result/kaggle/model/Dogecoin/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00515174
    Model saved to /mnt/T0/zxy/result/kaggle/model/Dogecoin/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00553004
    Model saved to /mnt/T0/zxy/result/kaggle/model/Dogecoin/fold_4.pkl
  valid corr score of Dogecoin (ID=4) is 0.18548. (Weight: 3.55535)
  test corr score of Dogecoin (ID=4) is 0.00359. (Weight: 3.55535)
Training model for EOS.IO     (ID=5 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00778288
    Model saved to /mnt/T0/zxy/result/kaggle/model/EOS.IO/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00640718
    Model saved to /mnt/T0/zxy/result/kaggle/model/EOS.IO/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00578302
    Model saved to /mnt/T0/zxy/result/kaggle/model/EOS.IO/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00524241
    Model saved to /mnt/T0/zxy/result/kaggle/model/EOS.IO/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
```

```
[500]  valid_0's rmse: 0.00480502
    Model saved to /mnt/T0/zxy/result/kaggle/model/EOS.IO/fold_4.pkl
  valid corr score of EOS.IO (ID=5) is 0.13863. (Weight: 1.38629)
  test corr score of EOS.IO (ID=5) is 0.00781. (Weight: 1.38629)
Training model for Ethereum    (ID=6 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00249987
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00268517
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00258959
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00246786
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00236951
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum/fold_4.pkl
  valid corr score of Ethereum (ID=6) is 0.10747. (Weight: 5.89440)
  test corr score of Ethereum (ID=6) is -0.01012. (Weight: 5.89440)
Training model for Ethereum Classic (ID=7 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00752527
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum Classic/fold_0.pkl
Fold 1
```

13

```
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00690242
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum Classic/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00770886
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum Classic/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00712523
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum Classic/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00953153
    Model saved to /mnt/T0/zxy/result/kaggle/model/Ethereum Classic/fold_4.pkl
  valid corr score of Ethereum Classic (ID=7) is 0.14271. (Weight: 2.07944)
  test corr score of Ethereum Classic (ID=7) is 0.01490. (Weight: 2.07944)
Training model for IOTA        (ID=8 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00670181
    Model saved to /mnt/T0/zxy/result/kaggle/model/IOTA/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00812304
    Model saved to /mnt/T0/zxy/result/kaggle/model/IOTA/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00715497
    Model saved to /mnt/T0/zxy/result/kaggle/model/IOTA/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
```

```
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00704122
    Model saved to /mnt/T0/zxy/result/kaggle/model/IOTA/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00673385
    Model saved to /mnt/T0/zxy/result/kaggle/model/IOTA/fold_4.pkl
  valid corr score of IOTA (ID=8) is 0.13030. (Weight: 1.09861)
  test corr score of IOTA (ID=8) is 0.02497. (Weight: 1.09861)
Training model for Litecoin    (ID=9 )
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00340946
    Model saved to /mnt/T0/zxy/result/kaggle/model/Litecoin/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00381752
    Model saved to /mnt/T0/zxy/result/kaggle/model/Litecoin/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.0038117
    Model saved to /mnt/T0/zxy/result/kaggle/model/Litecoin/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00362208
    Model saved to /mnt/T0/zxy/result/kaggle/model/Litecoin/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00338117
    Model saved to /mnt/T0/zxy/result/kaggle/model/Litecoin/fold_4.pkl
  valid corr score of Litecoin (ID=9) is 0.10333. (Weight: 2.39790)
  test corr score of Litecoin (ID=9) is 0.00717. (Weight: 2.39790)
Training model for Maker       (ID=10)
```

```
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00264249
    Model saved to /mnt/T0/zxy/result/kaggle/model/Maker/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00476994
    Model saved to /mnt/T0/zxy/result/kaggle/model/Maker/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00476036
    Model saved to /mnt/T0/zxy/result/kaggle/model/Maker/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00637472
    Model saved to /mnt/T0/zxy/result/kaggle/model/Maker/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00621094
    Model saved to /mnt/T0/zxy/result/kaggle/model/Maker/fold_4.pkl
 valid corr score of Maker (ID=10) is 0.96698. (Weight: 1.09861)
  test corr score of Maker (ID=10) is -0.00090. (Weight: 1.09861)
Training model for Monero     (ID=11)
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00790532
    Model saved to /mnt/T0/zxy/result/kaggle/model/Monero/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]  valid_0's rmse: 0.00927056
    Model saved to /mnt/T0/zxy/result/kaggle/model/Monero/fold_1.pkl
Fold 2
```

```
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00840323
    Model saved to /mnt/T0/zxy/result/kaggle/model/Monero/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00786313
    Model saved to /mnt/T0/zxy/result/kaggle/model/Monero/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00725583
    Model saved to /mnt/T0/zxy/result/kaggle/model/Monero/fold_4.pkl
  valid corr score of Monero (ID=11) is 0.18920. (Weight: 1.60944)
  test corr score of Monero (ID=11) is -0.00089. (Weight: 1.60944)
Training model for Stellar    (ID=12)
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00809302
    Model saved to /mnt/T0/zxy/result/kaggle/model/Stellar/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00703348
    Model saved to /mnt/T0/zxy/result/kaggle/model/Stellar/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00622549
    Model saved to /mnt/T0/zxy/result/kaggle/model/Stellar/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00577043
    Model saved to /mnt/T0/zxy/result/kaggle/model/Stellar/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
```

```
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00544478
    Model saved to /mnt/T0/zxy/result/kaggle/model/Stellar/fold_4.pkl
  valid corr score of Stellar (ID=12) is 0.22306. (Weight: 2.07944)
  test corr score of Stellar (ID=12) is -0.00960. (Weight: 2.07944)
Training model for TRON        (ID=13)
Fold 0
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00766575
    Model saved to /mnt/T0/zxy/result/kaggle/model/TRON/fold_0.pkl
Fold 1
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00654021
    Model saved to /mnt/T0/zxy/result/kaggle/model/TRON/fold_1.pkl
Fold 2
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00588524
    Model saved to /mnt/T0/zxy/result/kaggle/model/TRON/fold_2.pkl
Fold 3
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00537031
    Model saved to /mnt/T0/zxy/result/kaggle/model/TRON/fold_3.pkl
Fold 4
Training until validation scores don't improve for 5 rounds
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 0.00512775
    Model saved to /mnt/T0/zxy/result/kaggle/model/TRON/fold_4.pkl
  valid corr score of TRON (ID=13) is 0.15675. (Weight: 1.79176)
  test corr score of TRON (ID=13) is -0.02148. (Weight: 1.79176)
        weighted OOF corr score: 0.54749
        FINAL TEST weighted corr score: 0.00617
    Feature importance plot saved to model/feature_importance.png

[Full Training] for Binance Coin (ID=0) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
```

```
        pkl


[Full Training] for Bitcoin (ID=1) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Bitcoin Cash (ID=2) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Cardano (ID=3) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Dogecoin (ID=4) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for EOS.IO (ID=5) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Ethereum (ID=6) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Ethereum Classic (ID=7) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for IOTA (ID=8) using entire training set...
```

```
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Litecoin (ID=9) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Maker (ID=10) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Monero (ID=11) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for Stellar (ID=12) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl


[Full Training] for TRON (ID=13) using entire training set...
    [Full Training] Final model saved to /mnt/T0/zxy/result/kaggle/model/TRON/final_model.
        pkl

FINAL TEST score: 0.01929
```