

# Part 2 Model Training and Prediction

December 20, 2021

## 1 Predict Future Sales Part 2: Model Training and Prediction

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```
[101]: #load packages
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import copy

import os
import pickle
from tqdm import tqdm #progress bar
from itertools import product
import warnings
warnings.filterwarnings("ignore")
from IPython.display import clear_output

from sklearn.feature_extraction import text
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import KFold, StratifiedKFold
from sklearn.metrics import r2_score, mean_squared_error
from sklearn.preprocessing import StandardScaler
from sklearn.decomposition import PCA, TruncatedSVD, NMF
from sklearn.linear_model import LinearRegression, Ridge, Lasso, Lars,
↳ElasticNet
```

```
# from sklearn.externals import joblib
import joblib

import lightgbm as lgb
import xgboost as xgb
import catboost as cb
```

```
[2]: #load processed data
df1 = pd.read_csv('./data_processed/data.csv', index_col=0)
```

```
[103]: data_folder = "./data/"
test = pd.read_csv(os.path.join(data_folder, "test.csv")).set_index('ID')
```

```
[72]: cat_features = ['shop_id_target_enc', 'item_id_target_enc',
                    'city_code_target_enc', 'item_category_id_x_target_enc',
                    'type_code_target_enc', 'subtype_code_target_enc']
```

## 3 1. Model Training

We will implement the following models:

- **Linear Regression:** preproccing is required and we will use **StandardScaler**;
- **XGBoost / LightBGM:** no preproccesing as decision tree are capable of handling features with different scales.

### 3.1 1.1 Validation scheme

We choose **holdout** as out validation scheme: out training set runs from Jan.2013 to Sep.2015, validation set runs on Oct.2015. The test set runs on Nov.2015.

```
[4]: all_data = copy.copy(df1)

X_train = all_data[all_data['date_block_num'] < 33].drop(['item_cnt_month'],
    ↪axis=1)
Y_train = all_data[all_data['date_block_num'] < 33]['item_cnt_month']

X_valid = all_data[all_data['date_block_num'] == 33].drop(['item_cnt_month'],
    ↪axis=1)
Y_valid = all_data[all_data['date_block_num'] == 33]['item_cnt_month']

X_test = all_data[all_data['date_block_num'] == 34].drop(['item_cnt_month'],
    ↪axis=1)

print(X_train.shape)
print(Y_train.shape)
print(X_valid.shape)
print(Y_valid.shape)
print(X_test.shape)
```

```
(6186922, 38)
(6186922,)
(238172, 38)
(238172,)
(214200, 38)
```

```
[5]: X_test.head()
```

```
[5]:      date_block_num  date_avg_item_cnt_lag_1  \
6425094             34             0.2585
6425095             34             0.0000
6425096             34             0.2585
6425097             34             0.2585
6425098             34             0.0000

      date_item_avg_item_cnt_lag_1  date_item_avg_item_cnt_lag_2  \
6425094                0.5684                2.512
6425095                0.0000                0.000
6425096                0.9546                1.860
6425097                0.6360                1.116
6425098                0.0000                0.000

      date_item_avg_item_cnt_lag_3  date_item_avg_item_cnt_lag_6  \
6425094                2.834                1.978
6425095                0.000                0.000
6425096                3.572                1.613
6425097                1.548                0.000
6425098                0.000                0.000

      date_item_avg_item_cnt_lag_12  date_shop_avg_item_cnt_lag_1  \
6425094                1.3                0.1901
6425095                0.0                0.0000
6425096                0.0                0.1901
6425097                0.0                0.1901
6425098                0.0                0.0000

      date_shop_avg_item_cnt_lag_2  date_shop_avg_item_cnt_lag_3  ...  \
6425094                0.2059                0.2451  ...
6425095                0.0000                0.0000  ...
6425096                0.2059                0.2451  ...
6425097                0.2059                0.2451  ...
6425098                0.0000                0.0000  ...

      tfidf_interaction_1  tfidf_interaction_2  tfidf_interaction_3  \
6425094            0.000000            0.033116            0.0
6425095            0.000395            0.034083            0.0
6425096            0.000000            0.032825            0.0
```

6425097	0.000000	0.033220	0.0
6425098	0.000000	0.032375	0.0

	tfidf_interaction_4	tfidf_interaction_5	tfidf_interaction_6	\
6425094	0.0	0.0	0.000134	
6425095	0.0	0.0	0.000464	
6425096	0.0	0.0	0.000014	
6425097	0.0	0.0	0.000251	
6425098	0.0	0.0	0.000000	

	tfidf_interaction_7	tfidf_interaction_8	tfidf_interaction_9	\
6425094	0.001819	0.000000	0.000000	
6425095	0.000000	0.001306	0.001373	
6425096	0.015599	0.000000	0.000000	
6425097	0.012365	0.000187	0.000000	
6425098	0.019344	0.000000	0.000000	

	tfidf_interaction_10
6425094	0.000046
6425095	0.000597
6425096	0.000000
6425097	0.000177
6425098	0.000000

[5 rows x 38 columns]

### 3.2 1.2 LightGBM Regressor

The correct metric to be used is **root mean squared error**

Our first model is regularized gradient boosting LightGBM.

```
[6]: lgb_train = lgb.Dataset(X_train, Y_train)
lgb_valid = lgb.Dataset(X_valid, Y_valid)

params = {
    'boosting_type': 'dart',
    'metric': 'l2_root', # RMSE
    'verbose': 1,
    'seed': 0,
    'max_depth': 8,
    'learning_rate': 0.1,
    'reg_lambda': 2.0,
    'reg_alpha': 2.0,
    'subsample': 0.7,
    'num_leaves': 20,
    'feature_fraction': 0.8,
    'drop_rate': 0.2
```

```

}

#next time, try to use GPU rather than CPU
model_lgbm = lgb.train(params, lgb_train, num_boost_round=1000,
    ↪valid_sets=lgb_valid,
        early_stopping_rounds=200,
    ↪categorical_feature=cat_features,
        verbose_eval=50)

```

[LightGBM] [Warning] Auto-choosing row-wise multi-threading, the overhead of testing was 0.141321 seconds.

You can set `force\_row\_wise=true` to remove the overhead.

And if memory is not enough, you can set `force\_col\_wise=true`.

[LightGBM] [Info] Total Bins 7654

[LightGBM] [Info] Number of data points in the train set: 6186922, number of used features: 38

[LightGBM] [Info] Start training from score 0.288849

```

[50]    valid_0's rmse: 0.99683
[100]   valid_0's rmse: 0.972024
[150]   valid_0's rmse: 0.968635
[200]   valid_0's rmse: 0.964639
[250]   valid_0's rmse: 0.964203
[300]   valid_0's rmse: 0.959738
[350]   valid_0's rmse: 0.957481
[400]   valid_0's rmse: 0.956257
[450]   valid_0's rmse: 0.954682
[500]   valid_0's rmse: 0.954533
[550]   valid_0's rmse: 0.957562
[600]   valid_0's rmse: 0.955514
[650]   valid_0's rmse: 0.954121
[700]   valid_0's rmse: 0.957515
[750]   valid_0's rmse: 0.956778
[800]   valid_0's rmse: 0.956383
[850]   valid_0's rmse: 0.956392
[900]   valid_0's rmse: 0.957082
[950]   valid_0's rmse: 0.954556
[1000]  valid_0's rmse: 0.952658

```

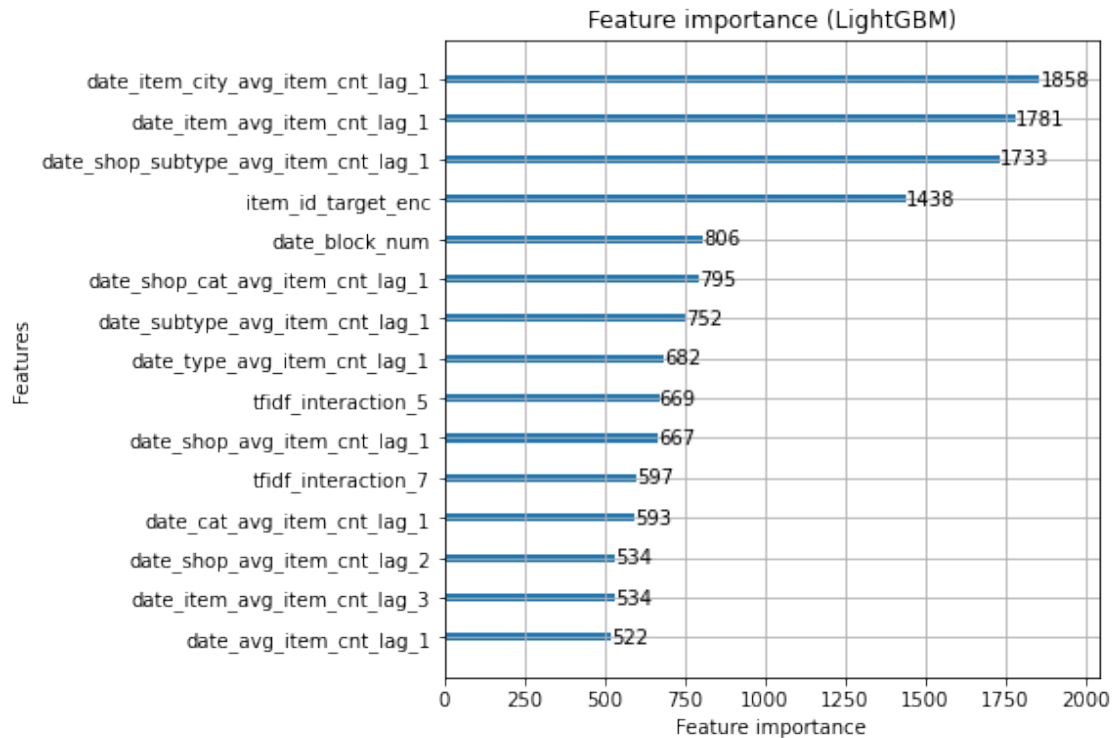
```
[7]: print(np.sqrt(mean_squared_error(Y_valid, model_lgbm.predict(X_valid))))
```

0.9526578913079428

```

[8]: lgb.plot_importance(model_lgbm, max_num_features=15, figsize=(6,6),
    ↪title='Feature importance (LightGBM)')
plt.show()

```



```
[9]: joblib.dump(model_lgbm, 'models/model1_lgbm.pkl');
```

```
[10]: model_lgbm = joblib.load('models/model1_lgbm.pkl') #how to save and check the
      ↪ parameters when load???
```

```
[ ]: # model_lgbm.save_model('models/model1_lgbm_txt.txt') #save
      # model_lgbm_txt = lgb.Booster(model_file='models/model1_lgbm_txt.txt') #load
```

### 3.3 1.3 XGBoost Regressor

Now we try XGBoost library.

```
[13]: model_xgb = xgb.XGBRegressor(max_depth=8, n_estimators=1000,
      ↪ min_child_weight=300,
      colsample_bytree=0.8, subsample=0.8, eta=0.2,
      ↪ seed=42,
      reg_alpha=0.2, reg_lambda=2.0)

model_xgb.fit(X_train, Y_train, eval_metric='rmse', eval_set=[(X_valid,
      ↪ Y_valid)],
      verbose=True, early_stopping_rounds=1000) #start:10:29pm, end 1:
      ↪ 23am
```

[0] validation\_0-rmse:1.08661  
[1] validation\_0-rmse:1.04106  
[2] validation\_0-rmse:1.00700  
[3] validation\_0-rmse:0.98522  
[4] validation\_0-rmse:0.96973  
[5] validation\_0-rmse:0.96625  
[6] validation\_0-rmse:0.96619  
[7] validation\_0-rmse:0.96430  
[8] validation\_0-rmse:0.95899  
[9] validation\_0-rmse:0.95977  
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[13]: XGBRegressor(base\_score=0.5, booster='gbtree', colsample\_bylevel=1,  
                  colsample\_bynode=1, colsample\_bytree=0.8, enable\_categorical=False,  
                  eta=0.2, gamma=0, gpu\_id=-1, importance\_type=None,  
                  interaction\_constraints='', learning\_rate=0.200000003,  
                  max\_delta\_step=0, max\_depth=8, min\_child\_weight=300, missing=nan,  
                  monotone\_constraints='()', n\_estimators=1000, n\_jobs=16,

```
num_parallel_tree=1, predictor='auto', random_state=42,
reg_alpha=0.2, reg_lambda=2.0, scale_pos_weight=1, seed=42,
subsample=0.8, tree_method='approx', validate_parameters=1,
verbosity=None)
```

```
[15]: print(np.sqrt(mean_squared_error(Y_valid, model_xgb.predict(X_valid))))
```

```
0.9589862849643996
```

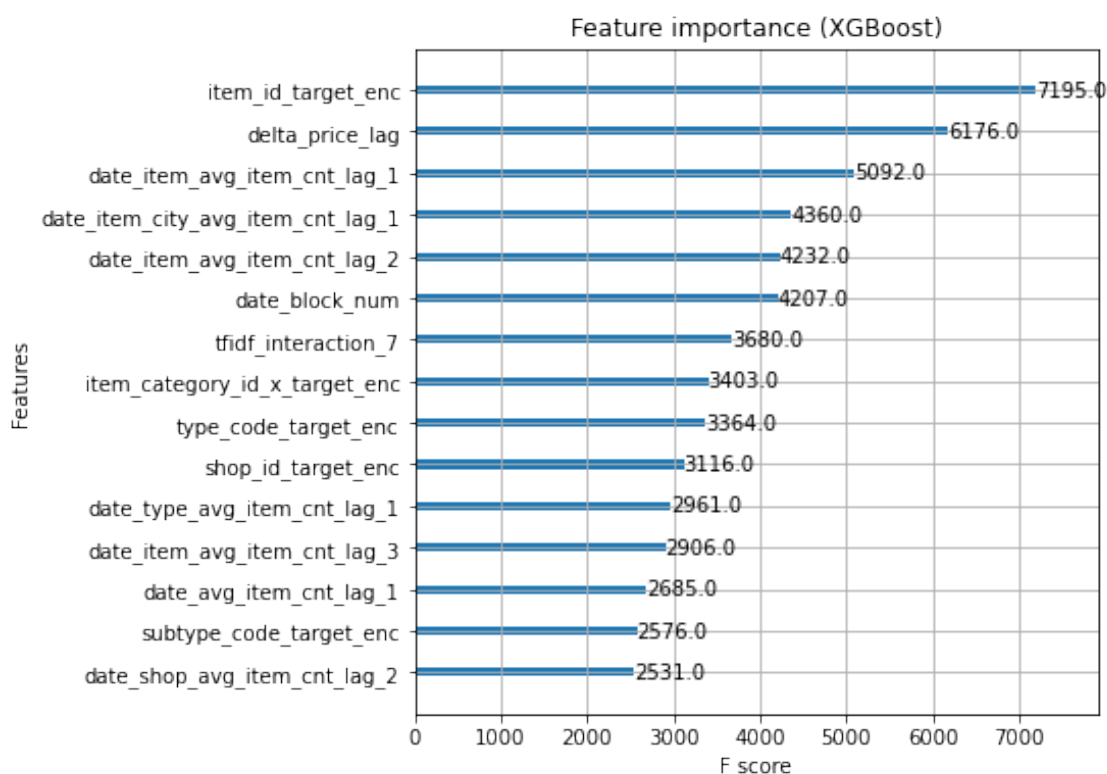
```
[16]: joblib.dump(model_xgb, 'models/model2_xgb.pkl');
```

```
[17]: model_xgb = joblib.load('models/model2_xgb.pkl')
```

```
[18]: print(model_xgb.best_iteration)
```

```
8
```

```
[19]: fig, ax = plt.subplots(figsize=(6,6))
xgb.plot_importance(model_xgb, max_num_features=15, title='Feature importance_
→(XGBoost)', ax=ax)
plt.show()
```



### 3.3.1 1.3.1 Training XGBoost Regressor on GPU

```
[107]: model_xgb = xgb.XGBRegressor(max_depth=8, n_estimators=1000,␣
    ↪min_child_weight=300,
    ↪colsample_bytree=0.8, subsample=0.8, eta=0.2,␣
    ↪seed=42,
    ↪reg_alpha=0.2, reg_lambda=2.0,␣
    ↪tree_method='gpu_hist')
model_xgb.fit(X_train, Y_train, eval_metric='rmse', eval_set=[(X_valid,␣
    ↪Y_valid)],
    ↪verbose=True, early_stopping_rounds=1000) #start:10:29pm, end 1:
    ↪23am
```

```
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[992] validation\_0-rmse:1.08553  
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```
[994] validation_0-rmse:1.08544
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[996] validation_0-rmse:1.08537
[997] validation_0-rmse:1.08527
[998] validation_0-rmse:1.08529
[999] validation_0-rmse:1.08529
```

```
[107]: XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
                  colsample_bynode=1, colsample_bytree=0.8, enable_categorical=False,
                  eta=0.2, gamma=0, gpu_id=0, importance_type=None,
                  interaction_constraints='', learning_rate=0.200000003,
                  max_delta_step=0, max_depth=8, min_child_weight=300, missing=nan,
                  monotone_constraints='()', n_estimators=1000, n_jobs=16,
                  num_parallel_tree=1, predictor='auto', random_state=42,
                  reg_alpha=0.2, reg_lambda=2.0, scale_pos_weight=1, seed=42,
                  subsample=0.8, tree_method='gpu_hist', validate_parameters=1,
                  verbosity=None)
```

The XGBoost method ran on CPU cost 1h 23 min, ran on GPU only cost 57 seconds.

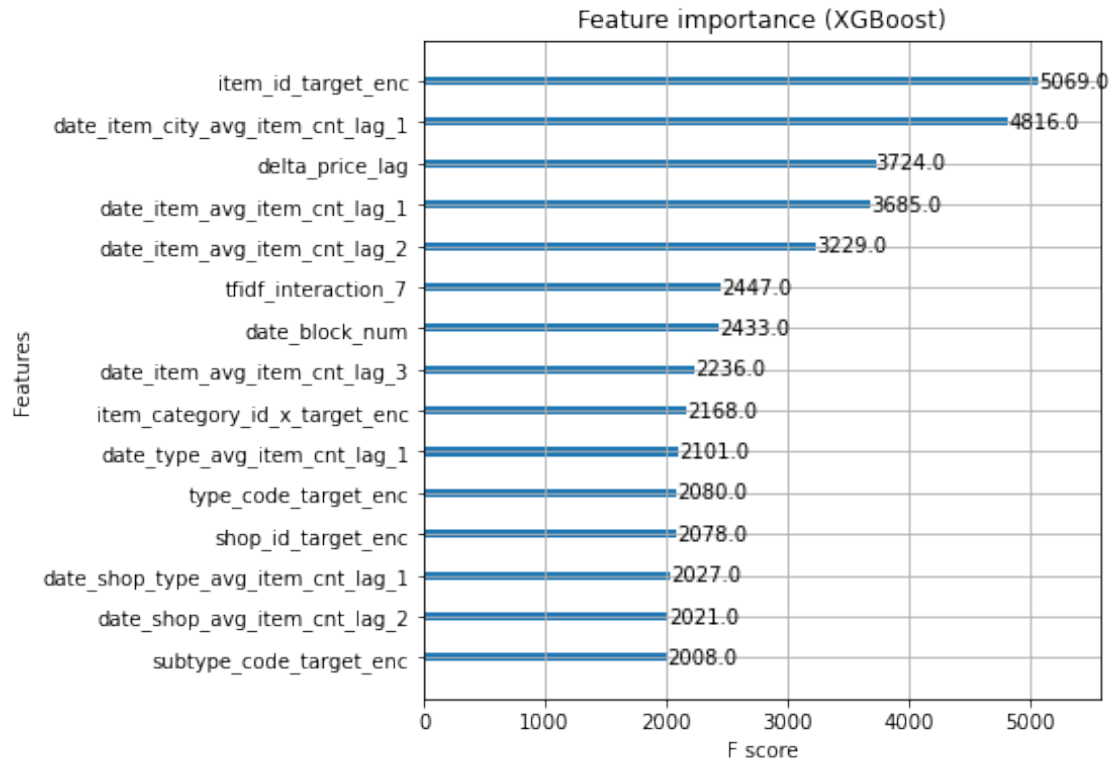
```
[108]: print(np.sqrt(mean_squared_error(Y_valid, model_xgb.predict(X_valid))))

0.9800386356080234
```

```
[109]: print(model_xgb.best_iteration)

5
```

```
[110]: fig, ax = plt.subplots(figsize=(6,6))
      xgb.plot_importance(model_xgb, max_num_features=15, title='Feature importance_
      ↳(XGBoost)', ax=ax)
      plt.show()
```



### 3.4 1.4 Linear regression

We implement linear models `LinearRegression`, `Ridge`, `Lasso` as benchmarks. We need to implement *feature scaling* before fitting on the dataset.

**LinearRegression** model:

```
[73]: scaler = StandardScaler().fit(X_train)
      X_train_std = scaler.transform(X_train)
      X_valid_std = scaler.transform(X_valid)
```

```
[74]: model_linreg = LinearRegression(fit_intercept=True)
      model_linreg.fit(X_train_std, Y_train)
```

```
[74]: LinearRegression()
```

```
[75]: print(np.sqrt(mean_squared_error(Y_valid, model_linreg.predict(X_valid_std))))
```

0.9900095967566781

```
[76]: joblib.dump(model_linreg, 'models/model3_linreg.pkl');
```

**Ridge** model:

```
[77]: model_ridge = Ridge(alpha=4.0, fit_intercept=True, max_iter=1000, solver='saga')
model_ridge.fit(X_train_std, Y_train)
```

```
[77]: Ridge(alpha=4.0, max_iter=1000, solver='saga')
```

```
[78]: print(np.sqrt(mean_squared_error(Y_valid, model_ridge.predict(X_valid_std))))

0.9900082805056044
```

```
[79]: joblib.dump(model_ridge, 'models/model4_ridge.pkl');
```

Lasso model:

```
[80]: model_lasso = Lasso(alpha=10.0, fit_intercept=True, max_iter=1000)
model_lasso.fit(X_train_std, Y_train)
```

```
[80]: Lasso(alpha=10.0)
```

```
[81]: print(np.sqrt(mean_squared_error(Y_valid, model_lasso.predict(X_valid_std))))

1.1365538511881084
```

```
[82]: joblib.dump(model_lasso, 'models/model5_lasso.pkl');
```

## 4 2. Ensembling Method

### 4.1 2.1 Ensembling: LightGBM + Linear Regression

We will implement the KFold scheme time series implemented in the previous assignment.

1. Split the train data into chunks of duration T, select first M chunks.
2. Fit N diverse models on those M chunks and predict for the chunk M+1. Then fit those models on first M+1 chunks and predict for chunk M+2 and so on, until the end. After that, use all train data to fit models and get predictions for test. Now we will have meta-features for the chunks starting from M+1 and meta-features for test.
3. Now we can use meta-features from first K chunks [M+1, M+2, ..., M+K] to fit level 2 models and validate them on chunk M+K+1. Essentially we are back to step 1 with lesser amount of chunks and meta-features instead of features.

We start with **1st generation features**:

```
[85]: model_lgbm = joblib.load('models/model1_lgbm.pkl')
model_linreg = joblib.load('models/model3_linreg.pkl')
```

```
[86]: Y_valid_lgbm = model_lgbm.predict(X_valid)
Y_valid_lreg = model_linreg.predict(X_valid_std)
X_valid_level2 = np.c_[Y_valid_lgbm, Y_valid_lreg]
X_valid_level2[:10,:]
```

```
[86]: array([[ 0.02086253, -0.06266107],
           [ 0.11747867, -0.04090796],
           [ 0.11699397,  0.11597089],
           [ 0.23048892,  0.40084696],
           [ 0.01993154,  0.00991157],
           [ 0.00094701, -0.08366587],
           [ 0.01659449, -0.09086691],
           [ 0.02121464, -0.10312856],
           [ 0.02121464, -0.10569445],
           [ 0.01867623, -0.09369751]])
```

Then 2nd generation feature:

```
[87]: X_train = all_data[all_data['date_block_num']<=32].drop(['item_cnt_month'],
    ↪axis=1)
Y_train = all_data[all_data['date_block_num']<=32]['item_cnt_month']
X_valid = all_data[all_data['date_block_num']==33].drop(['item_cnt_month'],
    ↪axis=1)
Y_valid = all_data[all_data['date_block_num']==33]['item_cnt_month']
```

```
[88]: dates = all_data['date_block_num']
last_block = dates.max()
print('Test date_block_num is ',last_block)
dates_train = dates[dates < last_block]
dates_test = dates[dates == last_block]
```

Test date\_block\_num is 34

```
[89]: periods = np.arange(26, 33, 1)
periods
```

```
[89]: array([26, 27, 28, 29, 30, 31, 32])
```

```
[90]: dates_train_level2 = dates_train[dates_train.isin(periods)]
Y_train_level2 = Y_train[dates_train.isin(periods)]
X_train_level2 = np.zeros([Y_train_level2.shape[0], 2])
```

```
[91]: Y_train[dates_train.isin(periods)].shape == dates_train_level2.shape
```

```
[91]: True
```

```
[ ]: # cur_block_num = 26
# x = all_data[all_data['date_block_num'] < cur_block_num].
    ↪drop(['item_cnt_month'], axis=1)
# y = all_data[all_data['date_block_num'] < cur_block_num]['item_cnt_month'].
    ↪values
# x_test = all_data[all_data['date_block_num'] == cur_block_num].
    ↪drop(['item_cnt_month'], axis=1)
```

```
# y = all_data[all_data['date_block_num'] == cur_block_num]['item_cnt_month'].
↳values
```

[92]: *#Now fill 'X\_train\_level2' with metafeatures*

```
#params for lightGBM
params = {
    'boosting_type': 'dart',
    'metric': 'l2_root', # RMSE
    'verbose': 1,
    'seed': 0,
    'max_depth': 8,
    'learning_rate': 0.1,
    'reg_lambda': 2.0,
    'reg_alpha': 2.0,
    'subsample': 0.7,
    'num_leaves': 20,
    'feature_fraction': 0.8,
    'drop_rate': 0.2
}

for cur_block_num in periods:

    print('cur_block_num:', cur_block_num)

    # 1. split X_train into parts
    x = all_data[all_data['date_block_num'] < cur_block_num].
↳drop(['item_cnt_month'], axis=1)
    y = all_data[all_data['date_block_num'] < cur_block_num]['item_cnt_month'].
↳values
    x_test = all_data[all_data['date_block_num'] == cur_block_num].
↳drop(['item_cnt_month'], axis=1)
    y_test = all_data[all_data['date_block_num'] ==
↳cur_block_num]['item_cnt_month'].values

    #2. Fit Linear regression
    print('Fitting Linear Regression:')
    lr = LinearRegression(fit_intercept=True, normalize=True)
    scaler = StandardScaler().fit(x)
    x_std = scaler.transform(x)
    x_test_std = scaler.transform(x_test)
    lr.fit(x_std, y)
    Y_test_1 = lr.predict(x_test_std)

    # 3. Fit LightGBM and prediction
    print('LightGBM:')
    n_trees = 500
```

```

lgb_train = lgb.Dataset(x, y)
lgb_valid = lgb.Dataset(x_test, y_test)
model_lgbm = lgb.train(params, lgb_train, num_boost_round=n_trees,
↳valid_sets=lgb_valid,
                                early_stopping_rounds=50, verbose_eval=50)
Y_test_2 = model_lgbm.predict(x_test)

# 4. Store predictions from 2 & 3 to 'X_train_level2'
X_train_level2[dates_train_level2 == cur_block_num] = np.c_[Y_test_1,
↳Y_test_2]
clear_output()

print(X_train_level2.mean(axis=0))

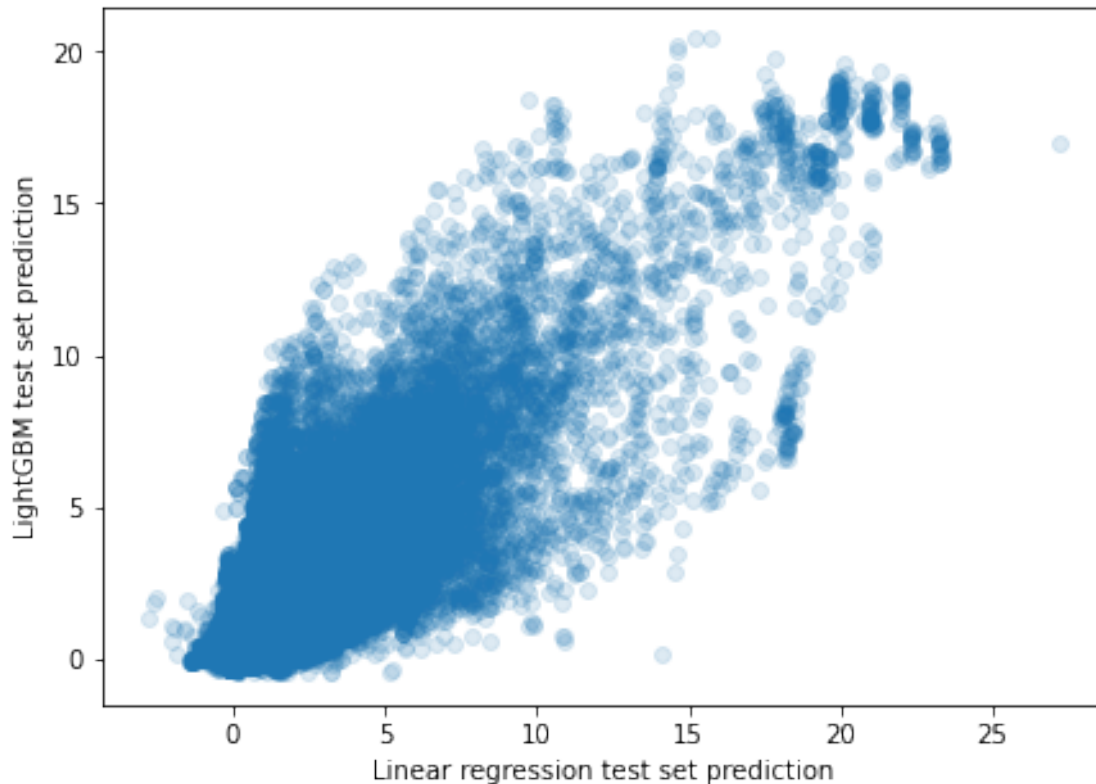
```

[0.31901372 0.27264671]

```
[95]: np.savez('./data_processed/X_train_level2.npz',X_train_level2=X_train_level2)
```

```
[94]: plt.figure(figsize=(7,5))
plt.scatter(X_train_level2[:,0], X_train_level2[:,1], marker='o', alpha=0.15)
plt.xlabel('Linear regression test set prediction')
plt.ylabel('LightGBM test set prediction')
plt.show()

```



Now we can do **stacking**.

```
[96]: Y_train_level2 = Y_train[dates_train.isin(periods)]
lr_stack = LinearRegression().fit(X_train_level2, Y_train_level2)
```

```
[97]: train_preds = lr_stack.predict(X_train_level2)
rmse_train = np.sqrt(mean_squared_error(Y_train_level2, train_preds))

valid_preds = lr_stack.predict(X_valid_level2)
rmse_valid = np.sqrt(mean_squared_error(Y_valid, valid_preds))

print('RMSE train: ', rmse_train)
print('RMSE test: ', rmse_valid)
```

```
RMSE train:  0.8091817048380416
RMSE test:   0.9788412024508074
```

## 5 3. Predictions

```
[98]: X_test = all_data[all_data['date_block_num']==34].drop(['item_cnt_month'],
    ↪axis=1)
```

```
Y_test_lgbm = model_lgbm.predict(X_test).clip(0, 20)
Y_test_xgbm = model_xgb.predict(X_test).clip(0, 20)
Y_test_lreg = model_linreg.predict(X_test).clip(0, 20)
Y_test_ridge = model_ridge.predict(X_test).clip(0, 20)
Y_test_lasso = model_lasso.predict(X_test).clip(0, 20)
```

```
[105]: models = [Y_test_lgbm, Y_test_xgbm, Y_test_lreg, Y_test_ridge,
    Y_test_lasso]
names = ['LGBM', 'XGBM', 'LINREG', 'RIDGE', 'LASSO']

for model, name in zip(models, names):
    temp = pd.DataFrame({'ID': test.index, 'item_cnt_month': model})
    temp.to_csv('submissions/submission_' + str(name) + '.csv', index=False)
```

Public leaderboard **Score**:

Model	XGBoost	LightGBM	LinearRegression	Ridge	Lasso
Score	0.98971	0.98313	1.07821	1.07822	1.21744

My official submission is LightGBM. Writing the data to `submission.csv`.

```
[106]: temp = pd.DataFrame({'ID': test.index, 'item_cnt_month': Y_test_lgbm})
temp.to_csv('submissions/submission.csv', index=False)
```