part2-submission

August 1, 2024

MSA 2024 Phase 2 - Part 2

In this part, I will train a model on the pre-processed data to predict sales numbers for a specific period based on input features. The goal is to predict the sales of the give features. These features include:

1. Import libraries and pre-define functions

[ ]:
```
%matplotlib inline

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import xgboost as xgb
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error
from sklearn.metrics import r2_score
from statsmodels.tsa.seasonal import seasonal_decompose

def smape(y_true, y_pred):
    # Ensure inputs are numpy arrays
    y_true = np.array(y_true)
    y_pred = np.array(y_pred)
    # Calculate the numerator (absolute difference)
    numerator = np.abs(y_true - y_pred)
    # Calculate the denominator (average of absolute actual and predicted␣
↪values)
    denominator = (np.abs(y_true) + np.abs(y_pred)) / 2
    # Calculate SMAPE
    smape_value = np.mean(numerator / denominator) * 100
    return smape_value
```

2. Load and split preprocessed data

Since I am going to build a time series regression model, I will use the data before 2017/1/1 as training set, and after 2017/1/1 as testing set.

[ ]:
```
# Load dataset
df = pd.read_csv('./dataset/store_sales_selected.csv', encoding='latin-1')
df['Order Date'] = pd.to_datetime(df['Order Date'])
df['Year'] = df['Year']-2014
df = df.set_index('Order Date')

# Creating lag features
df['sales_lag_7'] = df['Sales'].shift(7)
df['sales_lag_30'] = df['Sales'].shift(30)
df['sales_lag_90'] = df['Sales'].shift(90)
df['sales_lag_180'] = df['Sales'].shift(180)
df['sales_lag_365'] = df['Sales'].shift(365)
df = df.dropna()
```

[ ]:
```
df.columns
```

[ ]:
```
Index(['Ship Mode', 'Segment', 'City', 'Postal Code', 'Sub-Category', 'Sales',
       'Quantity', 'Discount', 'Profit', 'Day of Week', 'Year', 'Month',
       'Quarter', 'Days', 'sales_lag_7', 'sales_lag_30', 'sales_lag_90',
       'sales_lag_180', 'sales_lag_365'],
      dtype='object')
```

[ ]:
```
df.tail(10)
```

[ ]:
```
            Ship Mode  Segment  City  Postal Code  Sub-Category      Sales  \
Order Date
2017-12-28          3        1   316        98103             2     7.4000
2017-12-28          3        0   294        78664             0    78.8528
2017-12-28          3        1   261        61604             2     7.9680
2017-12-29          2        0   185        40214             1   258.7500
2017-12-29          2        0   185        40214             1   300.9800
2017-12-29          2        0   185        40214             1  1207.8400
2017-12-29          3        0   184        90049             1   393.5680
2017-12-29          3        1     5        92804             2   101.1200
2017-12-29          3        0    95        98026             2    68.4600
2017-12-30          3        0   232        10009             0   323.1360

            Quantity  Discount    Profit  Day of Week  Year  Month  Quarter  \
Order Date
2017-12-28         2      0.00    3.0340            3     3     12        4
2017-12-28         2      0.32  -11.5960            3     3     12        4
2017-12-28         3      0.60   -2.3904            3     3     12        4
2017-12-29         3      0.00   77.6250            4     3     12        4
2017-12-29         1      0.00   87.2842            4     3     12        4
2017-12-29         8      0.00  314.0384            4     3     12        4
2017-12-29         4      0.20  -44.2764            4     3     12        4
2017-12-29         8      0.00   37.4144            4     3     12        4
```

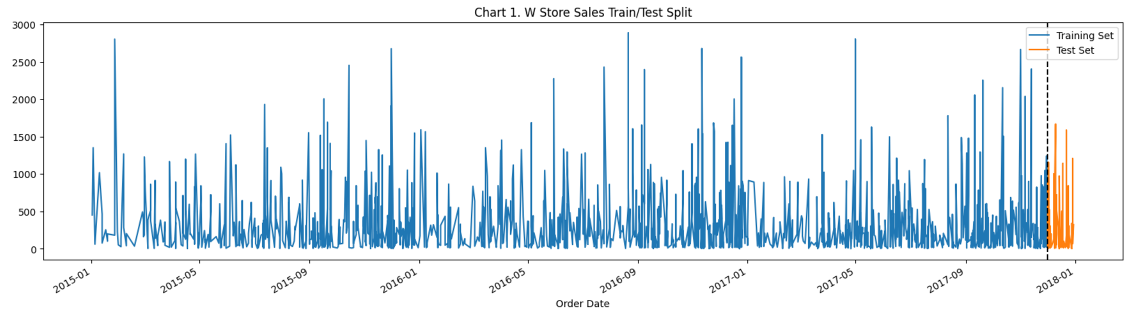
```
2017-12-29         2       0.00    20.5380            4     3      12         4
2017-12-30         4       0.20    12.1176            5     3      12         4

            Days  sales_lag_7  sales_lag_30  sales_lag_90  sales_lag_180  \
Order Date
2017-12-28  1451      41.9600        18.960       629.640        166.500
2017-12-28  1451     304.4500       119.833       897.150        128.124
2017-12-28  1451      21.0000      1141.938         7.712        101.400
2017-12-29  1452     191.9840        99.950       701.960        127.372
2017-12-29  1452       2.9600        13.360       508.704        449.568
2017-12-29  1452     340.7040       102.018       906.680       2036.860
2017-12-29  1452     113.3720        15.920       242.352          8.730
2017-12-29  1452       7.4000       182.550         8.752         28.272
2017-12-29  1452      78.8528       220.980      1159.056         30.560
2017-12-30  1453       7.9680       934.956        16.720        272.970

            sales_lag_365
Order Date
2017-12-28         31.984
2017-12-28        423.648
2017-12-28        418.296
2017-12-29         74.592
2017-12-29         16.784
2017-12-29        462.564
2017-12-29          9.940
2017-12-29         40.480
2017-12-29         88.020
2017-12-30         65.940
```

[ ]:
```
train = df.loc[(df.index < '2017-12-1') & (df.index >= '2015-01-01')]
test = df.loc[df.index >= '2017-12-1']

fig, ax = plt.subplots(figsize=(20, 5))
train.plot(ax=ax, y='Sales', label='Training Set', title='Chart 1. W Store␣
 ↪Sales Train/Test Split')
test.plot(ax=ax,y='Sales', label='Test Set')
ax.axvline('2017-12-1', color='black', ls='--')
ax.legend(['Training Set', 'Test Set'])
plt.show()
```



3. Choose an algorithm

I am going to build a boosted tree using xgboost and a multi-variable regression model, and compare the results by RMSE, SMAPE

[ ]:
```
FEATURES = [col for col in df.columns if col != 'Sales']
TARGET = 'Sales'
X_train = train[FEATURES]
y_train = train[TARGET]

X_test = test[FEATURES]
y_test = test[TARGET]
```

[ ]:
```
FEATURES
```

[ ]:
```
['Ship Mode',
 'Segment',
 'City',
 'Postal Code',
 'Sub-Category',
 'Quantity',
 'Discount',
 'Profit',
 'Day of Week',
 'Year',
 'Month',
 'Quarter',
 'Days',
 'sales_lag_7',
 'sales_lag_30',
 'sales_lag_90',
 'sales_lag_180',
 'sales_lag_365']
```

4. Train and test a model

4.1 Boosted tree

[ ]:
```python
# Do a grid search to find the best hyperparameters
# Define the parameter grid
param_grid = {
    "learning_rate": [0.005, 0.01],
    "max_depth": [1, 3, 5, 7],
    "n_estimators": [1000, 1500, 2000],
    "reg_alpha": [ 4, 7, 10],
    "reg_lambda": [5, 7, 10],
}

xgb_model = xgb.XGBRegressor()
grid_search = GridSearchCV(
    estimator=xgb_model,
    param_grid=param_grid,
    cv=3,
    scoring="neg_mean_absolute_error",
    verbose=2,
    n_jobs=-1,
)
grid_search.fit(X_train, y_train)
best_params = grid_search.best_params_
best_score = grid_search.best_score_

print(f"Best Parameters: {best_params}")
print(f"Best Score: {best_score}")
```

```
Fitting 3 folds for each of 216 candidates, totalling 648 fits
[CV] END learning_rate=0.005, max_depth=1, n_estimators=1000, reg_alpha=4,
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```

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```

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```

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```

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[CV] END learning_rate=0.005, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=5; total time=   3.2s
```

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reg_lambda=7; total time=   3.2s
[CV] END learning_rate=0.005, max_depth=7, n_estimators=1500, reg_alpha=4,
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reg_lambda=10; total time=   2.8s
[CV] END learning_rate=0.005, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=10; total time=   3.5s
```

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```

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[CV] END learning_rate=0.01, max_depth=1, n_estimators=1000, reg_alpha=4,
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reg_lambda=10; total time=   0.1s
```

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reg_lambda=7; total time=   0.4s
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reg_lambda=5; total time=   0.5s
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reg_lambda=7; total time=   0.5s
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reg_lambda=5; total time=   0.5s
[CV] END learning_rate=0.01, max_depth=3, n_estimators=1500, reg_alpha=4,
reg_lambda=10; total time=   0.4s
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reg_lambda=10; total time=   0.4s
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reg_lambda=7; total time=   0.5s
[CV] END learning_rate=0.01, max_depth=3, n_estimators=1500, reg_alpha=4,
reg_lambda=10; total time=   0.5s
```

```
[CV] END learning_rate=0.01, max_depth=3, n_estimators=1500, reg_alpha=7,
reg_lambda=5; total time=   0.5s
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reg_lambda=5; total time=   0.5s
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reg_lambda=5; total time=   0.4s
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reg_lambda=7; total time=   0.5s
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reg_lambda=10; total time=   0.5s
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reg_lambda=5; total time=   0.5s
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reg_lambda=5; total time=   0.5s
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reg_lambda=7; total time=   0.4s
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reg_lambda=10; total time=   0.5s
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reg_lambda=7; total time=   0.5s
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[CV] END learning_rate=0.01, max_depth=3, n_estimators=2000, reg_alpha=4,
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reg_lambda=7; total time=   0.6s
[CV] END learning_rate=0.01, max_depth=3, n_estimators=2000, reg_alpha=4,
reg_lambda=7; total time=   0.6s
[CV] END learning_rate=0.01, max_depth=3, n_estimators=2000, reg_alpha=4,
reg_lambda=10; total time=   0.6s
```

```
[CV] END learning_rate=0.01, max_depth=3, n_estimators=2000, reg_alpha=4,
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[CV] END learning_rate=0.01, max_depth=3, n_estimators=2000, reg_alpha=4,
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reg_lambda=7; total time=   0.6s
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reg_lambda=10; total time=   0.6s
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reg_lambda=5; total time=   0.8s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=4,
reg_lambda=5; total time=   0.9s
```

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[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=4,
reg_lambda=7; total time=   0.9s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=4,
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reg_lambda=7; total time=   0.8s
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=10,
reg_lambda=10; total time=   0.8s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=10,
reg_lambda=10; total time=   0.9s
```

```
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=1500, reg_alpha=4,
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reg_lambda=7; total time=   1.3s
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reg_lambda=5; total time=   1.2s
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reg_lambda=7; total time=   1.3s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=1500, reg_alpha=10,
reg_lambda=7; total time=   1.2s
```

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[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=4,
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=10,
reg_lambda=5; total time=   1.7s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=10,
reg_lambda=5; total time=   1.7s
```

```
[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=10,
reg_lambda=7; total time=   1.6s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=10,
reg_lambda=7; total time=   1.7s
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=10,
reg_lambda=7; total time=   1.7s
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=2000, reg_alpha=10,
reg_lambda=10; total time=   1.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=4,
reg_lambda=5; total time=   1.6s
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reg_lambda=5; total time=   2.0s
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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=4,
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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=4,
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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=4,
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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=5; total time=   1.9s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=4,
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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=5; total time=   2.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=7; total time=   2.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=7; total time=   1.8s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=7; total time=   2.2s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=10; total time=   2.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=10; total time=   1.9s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=7,
reg_lambda=10; total time=   2.3s
```

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[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=10,
reg_lambda=5; total time=   1.8s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=10,
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reg_lambda=7; total time=   2.0s
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reg_lambda=7; total time=   2.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=10,
reg_lambda=7; total time=   1.9s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=10,
reg_lambda=10; total time=   2.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=10,
reg_lambda=10; total time=   1.9s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1000, reg_alpha=10,
reg_lambda=10; total time=   2.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=5; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=7; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=5; total time=   3.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=5; total time=   3.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=7; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=7; total time=   3.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=10; total time=   3.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=10; total time=   2.8s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=4,
reg_lambda=10; total time=   3.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=5; total time=   3.4s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=5; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=5; total time=   3.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=7; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=7; total time=   3.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=10; total time=   3.0s
```

```
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=7; total time=   3.4s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=10; total time=   3.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=7,
reg_lambda=10; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=5; total time=   3.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=5; total time=   2.8s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=5; total time=   2.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=7; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=7; total time=   2.5s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=10; total time=   2.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=7; total time=   3.2s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=10; total time=   2.9s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=1500, reg_alpha=10,
reg_lambda=10; total time=   2.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=5; total time=   3.5s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=5; total time=   4.4s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=5; total time=   3.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=7; total time=   3.4s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=7; total time=   3.5s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=7; total time=   4.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=10; total time=   3.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=10; total time=   3.7s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=4,
reg_lambda=10; total time=   3.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=5; total time=   4.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=5; total time=   3.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=5; total time=   3.6s
```

```
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=7; total time=   3.4s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=7; total time=   3.8s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=10; total time=   3.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=7; total time=   4.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=10; total time=   3.5s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=7,
reg_lambda=10; total time=   3.4s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=5; total time=   4.3s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=5; total time=   3.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=5; total time=   3.6s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=7; total time=   3.2s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=7; total time=   3.1s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=10; total time=   2.9s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=7; total time=   4.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=10; total time=   3.0s
[CV] END learning_rate=0.01, max_depth=7, n_estimators=2000, reg_alpha=10,
reg_lambda=10; total time=   3.1s
```

```
/Users/jxiao/Desktop/code/msa/phase2/msa2_env/lib/python3.11/site-
packages/numpy/ma/core.py:2820: RuntimeWarning: invalid value encountered in
cast
  _data = np.array(data, dtype=dtype, copy=copy,
```

```
Best Parameters: {'learning_rate': 0.005, 'max_depth': 3, 'n_estimators': 1500,
'reg_alpha': 4, 'reg_lambda': 10}
Best Score: -115.47690118845685
```

[ ]:
```
boosted_tree_model = xgb.XGBRegressor(**best_params)

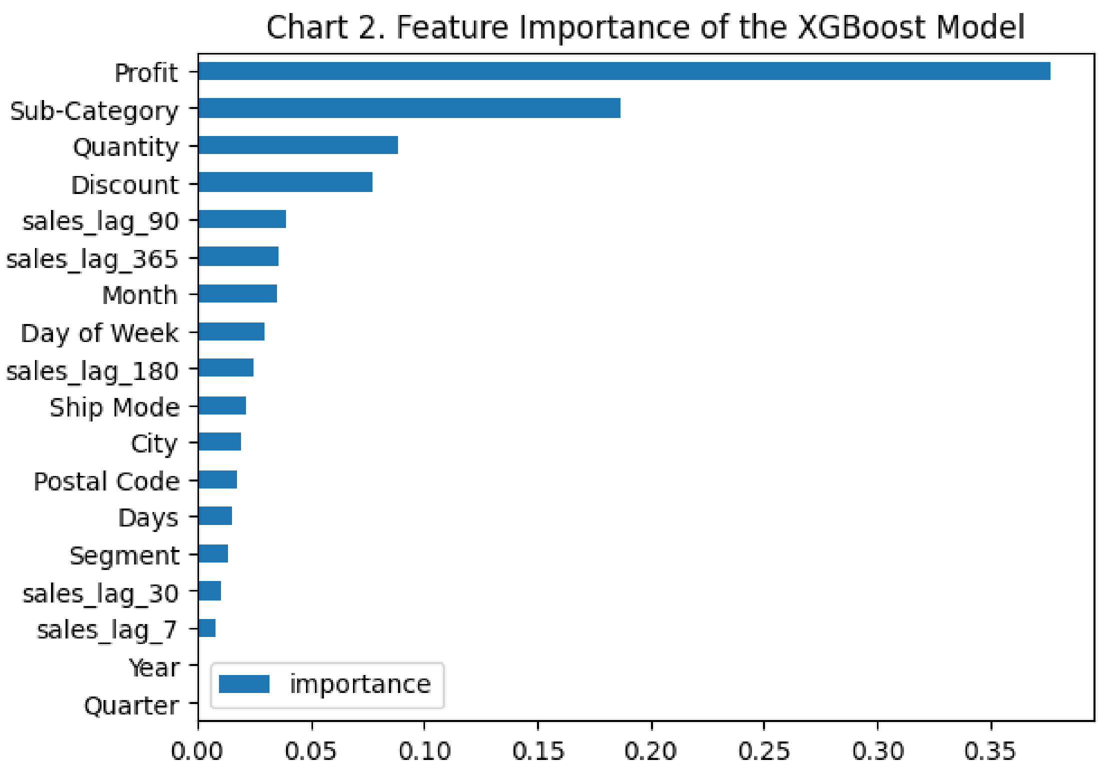
boosted_tree_model.fit(
    X_train, y_train,
    eval_set=[(X_train, y_train),(X_test, y_test)],
    verbose=100
)
```

```
[0]     validation_0-rmse:408.76686     validation_1-rmse:355.34256
```

```
[100]   validation_0-rmse:332.03050     validation_1-rmse:283.10979
[200]   validation_0-rmse:285.05318     validation_1-rmse:244.25628
[300]   validation_0-rmse:255.67149     validation_1-rmse:220.48927
[400]   validation_0-rmse:235.33573     validation_1-rmse:204.87151
[500]   validation_0-rmse:218.86230     validation_1-rmse:191.90225
[600]   validation_0-rmse:207.62020     validation_1-rmse:182.05685
[700]   validation_0-rmse:199.75784     validation_1-rmse:177.19904
[800]   validation_0-rmse:194.16662     validation_1-rmse:173.62259
[900]   validation_0-rmse:190.34102     validation_1-rmse:171.66118
[1000]  validation_0-rmse:186.98948     validation_1-rmse:170.00925
[1100]  validation_0-rmse:184.29253     validation_1-rmse:168.00724
[1200]  validation_0-rmse:181.97555     validation_1-rmse:166.12026
[1300]  validation_0-rmse:179.85667     validation_1-rmse:164.57605
[1400]  validation_0-rmse:178.09080     validation_1-rmse:164.05301
[1499]  validation_0-rmse:176.45930     validation_1-rmse:163.03743
```

[ ]:
```
XGBRegressor(base_score=None, booster=None, callbacks=None,
             colsample_bylevel=None, colsample_bynode=None,
             colsample_bytree=None, device=None, early_stopping_rounds=None,
             enable_categorical=False, eval_metric=None, feature_types=None,
             gamma=None, grow_policy=None, importance_type=None,
             interaction_constraints=None, learning_rate=0.005, max_bin=None,
             max_cat_threshold=None, max_cat_to_onehot=None,
             max_delta_step=None, max_depth=3, max_leaves=None,
             min_child_weight=None, missing=nan, monotone_constraints=None,
             multi_strategy=None, n_estimators=1500, n_jobs=None,
             num_parallel_tree=None, random_state=None, …)
```

[ ]:
```
fi = pd.DataFrame(data=boosted_tree_model.feature_importances_,
             index=boosted_tree_model.feature_names_in_,
             columns=['importance'])
fi.sort_values('importance').plot(kind='barh', title='Chart 2. Feature␣
 ↪Importance of the XGBoost Model')
plt.show()
```



4.2 Multi-variable linear regression

[ ]:
```
# Train the Linear Regression model
linear_model = LinearRegression()
linear_model.fit(X_train, y_train)
```

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

5. Evaluate the model

[ ]:
```
# Make predictions with XGBoost
y_pred_xgb = boosted_tree_model.predict(X_test)
rmse_xgb = mean_squared_error(y_test, y_pred_xgb, squared=False)
print(f"XGBoost RMSE: {rmse_xgb}")

# Make predictions with Linear Regression
y_pred_linear = linear_model.predict(X_test)
rmse_linear = mean_squared_error(y_test, y_pred_linear, squared=False)
print(f"Linear Regression RMSE: {rmse_linear}")
```

```
XGBoost RMSE: 163.03743158525043
Linear Regression RMSE: 314.86077815905577
```

```
/Users/jxiao/Desktop/code/msa/phase2/msa2_env/lib/python3.11/site-
packages/sklearn/metrics/_regression.py:492: FutureWarning: 'squared' is
deprecated in version 1.4 and will be removed in 1.6. To calculate the root mean
squared error, use the function'root_mean_squared_error'.
  warnings.warn(
/Users/jxiao/Desktop/code/msa/phase2/msa2_env/lib/python3.11/site-
packages/sklearn/metrics/_regression.py:492: FutureWarning: 'squared' is
deprecated in version 1.4 and will be removed in 1.6. To calculate the root mean
squared error, use the function'root_mean_squared_error'.
  warnings.warn(
```

[ ]:
```
# Calculate R^2 for XGBoost
r2_xgb = r2_score(y_test, y_pred_xgb)
print(f"XGBoost R^2: {r2_xgb}")

# Calculate R^2 for Linear Regression
r2_linear = r2_score(y_test, y_pred_linear)
print(f"Linear Regression R^2: {r2_linear}")
```

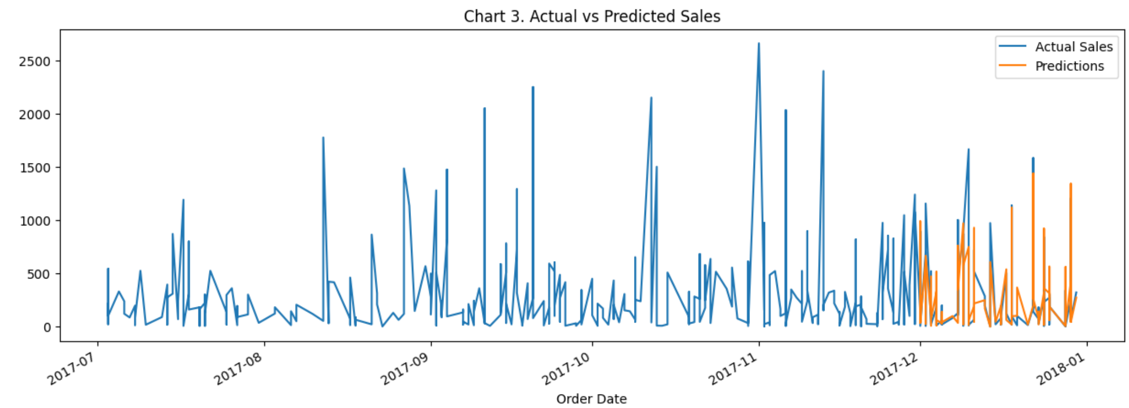
```
XGBoost R^2: 0.904819879650135
Linear Regression R^2: 0.44875065500589895
```

The result of boosted tree is better than the linear regression model. Let's explore some other metics and visualise the results

[ ]:
```
test['prediction'] = boosted_tree_model.predict(X_test)
df_merged = df.merge(test[['prediction']], how='left', left_index=True,␣
↪right_index=True)
df_merged = df_merged.loc[(df_merged.index >= '07-01-2017')]
ax = df_merged[['Sales']].plot(figsize=(15, 5))
df_merged['prediction'].plot(ax=ax)
plt.legend(['Actual Sales', 'Predictions'])
ax.set_title('Chart 3. Actual vs Predicted Sales')
plt.show()
```

```
/var/folders/w8/w02d673x2yl186vbpbmfssbh0000gn/T/ipykernel_26938/2977699579.py:1
: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  test['prediction'] = boosted_tree_model.predict(X_test)
```



[ ]:
```
# calcuate the SMAPE
smape_value_xgb = smape(y_test, y_pred_xgb)
print(f"sMAPE of xgb model: {smape_value_xgb:.2f}%")
smape_value_lr = smape(y_test, y_pred_linear)
print(f"sMAPE of lr model: {smape_value_lr:.2f}%")
```

```
sMAPE of xgb model: 51.19%
sMAPE of lr model: 96.87%
```

6. Summary

Model Training and Evaluation

- **Features used:**
  - 'Ship Mode',
  - 'Segment',
  - 'City',
  - 'Postal Code',
  - 'Sub-Category',
  - 'Quantity',
  - 'Discount',
  - 'Profit', this is the most dominant feature. Although it may seem unusual, we assume it is available for predicting sales.
  - 'Day of Week',
  - 'Year',
  - 'Month',
  - 'Quarter',
  - 'Days'

  Shifted sales data were also added to capture the time series pattern, the model is designed to predict the sales data fro the next day
  - 'sales_lag_7'
  - 'sales_lag_30'
  - 'sales_lag_90'
  - 'sales_lag_180',

    - 'sales_lag_365'
- **Training/Test Splits:**
    - Used data before 2017.12.1 as the training set and data from 2017.12.1 onwards as the test set to ensure consistency and prevent data leaking.
- **Algorithms Used:**
    - Boosted Tree using XGBoost.
    - Multi-variable Linear Regression.
- **Hyperparameter Tuning:**
    - Employed Cross-Validation Grid Search to optimize the parameters for both models.
- **Performance Metrics:**
    - Boosted Tree:
        * sMAPE: 51.19%
        * R^2: 90.48%
    - Linear Regression:
        * sMAPE: 96.87%
        * R^2: 44.87%

  The R-squared value for the boosted tree model indicates that it explains about 90.48% of the variance in the sales data, compared to only 44.87% for the linear regression model. The RMSE and sMAPE values for the boosted tree model are also lower, indicating better predictive accuracy and lower percentage error compared to the linear regression model.

Conclusion

The boosted tree model outperforms the linear regression model, indicating its ability to capture non-linear patterns in the data. Despite this, there is room for improvement in overall performance. Potential enhancements include explicitly modeling trends and seasonal patterns separately and refining the prediction task to be more specific, such as focusing on certain categories or cities.

[ ]:

```

```