part2-submission

July 8, 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

[4]:
```
%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

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.

[5]:
```python
# 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')
```

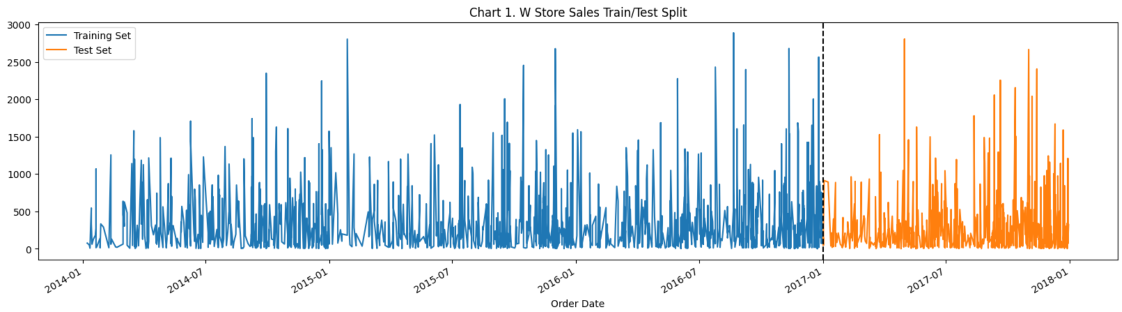
[6]:
```python
df.tail(10)
```

[6]:
```
            Ship Mode  Segment  City  Sub-Category      Sales  Quantity  \
Order Date
2017-12-28          3        1   316             2     7.4000         2
2017-12-28          3        0   294             0    78.8528         2
2017-12-28          3        1   261             2     7.9680         3
2017-12-29          2        0   185             1   258.7500         3
2017-12-29          2        0   185             1   300.9800         1
2017-12-29          2        0   185             1  1207.8400         8
2017-12-29          3        0   184             1   393.5680         4
2017-12-29          3        1     5             2   101.1200         8
2017-12-29          3        0    95             2    68.4600         2
2017-12-30          3        0   232             0   323.1360         4

            Discount    Profit  Day of Week  Year  Month  Quarter  Days
Order Date
2017-12-28      0.00    3.0340            3     3     12        4  1451
2017-12-28      0.32  -11.5960            3     3     12        4  1451
2017-12-28      0.60   -2.3904            3     3     12        4  1451
2017-12-29      0.00   77.6250            4     3     12        4  1452
2017-12-29      0.00   87.2842            4     3     12        4  1452
2017-12-29      0.00  314.0384            4     3     12        4  1452
2017-12-29      0.20  -44.2764            4     3     12        4  1452
2017-12-29      0.00   37.4144            4     3     12        4  1452
2017-12-29      0.00   20.5380            4     3     12        4  1452
2017-12-30      0.20   12.1176            5     3     12        4  1453
```

[7]:
```python
train = df.loc[df.index < '01-01-2017']
test = df.loc[df.index >= '01-01-2017']

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('01-01-2017', 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

[8]:
```
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]
```

[9]:
```
FEATURES
```

[9]:
```
['Ship Mode',
 'Segment',
 'City',
 'Sub-Category',
 'Quantity',
 'Discount',
 'Profit',
 'Day of Week',
 'Year',
 'Month',
 'Quarter',
 'Days']
```

4. Train and test a model

4.1 Boosted tree

[302]:
```
# Do a grid search to find the best hyperparameters
# Define the parameter grid
param_grid = {
    'learning_rate': [0.01, 0.05],
```

```
    'max_depth': [1, 3, 5],
    'n_estimators': [ 500, 1000],
    'reg_alpha': [ 0.5, 0.9, 2,5],
    'reg_lambda': [2, 5, 10,15]
}

xgb_model = xgb.XGBRegressor(objective='reg:squarederror')
grid_search = GridSearchCV(estimator=xgb_model, param_grid=param_grid, cv=3,␣
 ↪scoring='neg_root_mean_squared_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 192 candidates, totalling 576 fits
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reg_lambda=2; total time=   0.1s
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```

```
reg_lambda=10; total time=   0.1s
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```

```
reg_lambda=5; total time=   0.3s
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reg_lambda=10; total time=   0.3s
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reg_lambda=2; total time=   0.3s
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reg_lambda=15; total time=   0.2s
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[CV] END learning_rate=0.01, max_depth=3, n_estimators=1000, reg_alpha=0.9,
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[CV] END learning_rate=0.01, max_depth=3, n_estimators=1000, reg_alpha=0.9,
reg_lambda=10; total time=   0.2s
[CV] END learning_rate=0.01, max_depth=3, n_estimators=1000, reg_alpha=2,
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[CV] END learning_rate=0.01, max_depth=3, n_estimators=1000, reg_alpha=2,
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[CV] END learning_rate=0.01, max_depth=3, n_estimators=1000, reg_alpha=2,
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```

```
reg_lambda=10; total time=   0.2s
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```

```
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=500, reg_alpha=2,
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=500, reg_alpha=2,
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=500, reg_alpha=5,
```

```
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=2,
reg_lambda=5; total time=   0.5s
[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=5,
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[CV] END learning_rate=0.01, max_depth=5, n_estimators=1000, reg_alpha=2,
```

```
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reg_lambda=5; total time=   0.0s
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```

```
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```

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```

```
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```

```
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```

```
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```

```
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[CV] END learning_rate=0.05, max_depth=5, n_estimators=1000, reg_alpha=0.5,
```

```
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reg_lambda=2; total time=   0.5s
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```

```
reg_lambda=5; total time=   0.5s
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[CV] END learning_rate=0.05, max_depth=5, n_estimators=1000, reg_alpha=5,
reg_lambda=15; total time=   0.3s
[CV] END learning_rate=0.05, max_depth=5, n_estimators=1000, reg_alpha=5,
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[CV] END learning_rate=0.05, max_depth=5, n_estimators=1000, reg_alpha=5,
reg_lambda=15; total time=   0.3s
Best Parameters: {'learning_rate': 0.01, 'max_depth': 3, 'n_estimators': 1000,
'reg_alpha': 2, 'reg_lambda': 2}
Best Score: -198.73721466087932
```

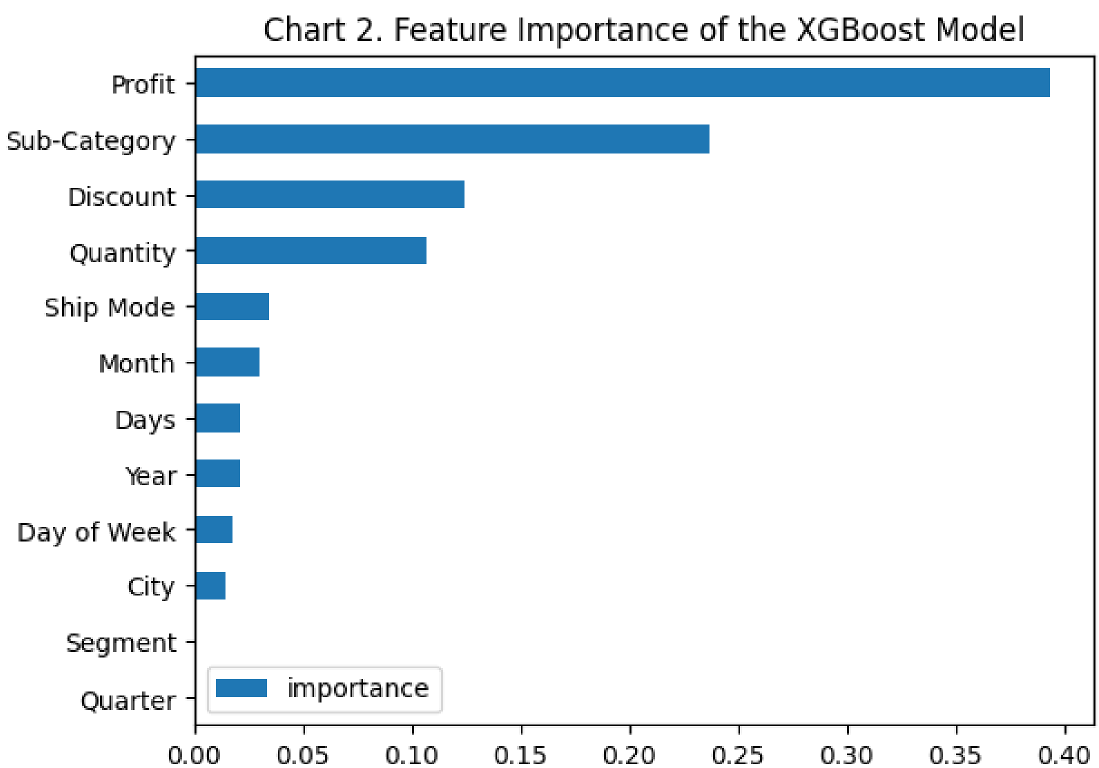
[303]:
```python
boosted_tree_model = xgb.XGBRegressor(**best_params)

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

```
[0]     validation_0-rmse:411.75337     validation_1-rmse:379.13466
[100]   validation_0-rmse:273.63304     validation_1-rmse:265.93358
[200]   validation_0-rmse:219.67771     validation_1-rmse:224.74219
[300]   validation_0-rmse:194.34965     validation_1-rmse:207.35065
[400]   validation_0-rmse:181.51395     validation_1-rmse:201.56899
[500]   validation_0-rmse:173.52989     validation_1-rmse:198.27698
[600]   validation_0-rmse:168.04950     validation_1-rmse:196.46355
[700]   validation_0-rmse:164.09878     validation_1-rmse:194.89002
[800]   validation_0-rmse:160.42987     validation_1-rmse:193.29047
[900]   validation_0-rmse:157.58861     validation_1-rmse:193.61784
[999]   validation_0-rmse:155.14672     validation_1-rmse:195.76415
```

[303]:
```
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=0.01, 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=1000, n_jobs=None,
                 num_parallel_tree=None, random_state=None, …)
```

[304]:
```
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

[305]:
```
# Train the Linear Regression model
linear_model = LinearRegression()
linear_model.fit(X_train, y_train)
```

[305]: LinearRegression()

5. Evaluate the model

[306]:
```
# 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: 195.76415050568806
Linear Regression RMSE: 323.5036696346123
```

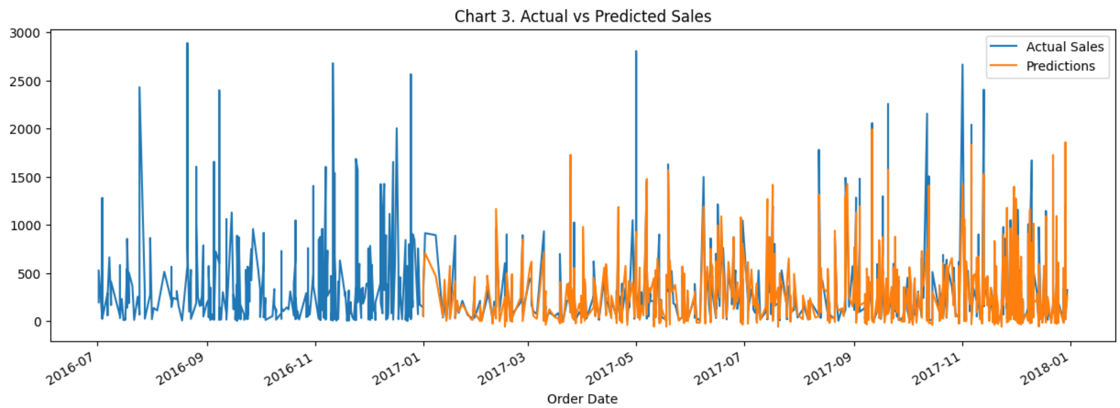
[310]:
```
# Calculate R^2 for Linear Regression
r2_linear = r2_score(y_test, y_pred_linear)
print(f"Linear Regression R^2: {r2_linear}")

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

```
Linear Regression R^2: 0.2701472935342507
XGBoost R^2: 0.7327343603595161
```

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

[312]:
```
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 >= '07-01-2016')]
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_50612/3029988083.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)
```



[308]:
```python
# 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: 34.01%
sMAPE of lr model: 44.09%
```

6. Summary

Model Training and Evaluation

- **Features used:**
  - 'Ship Mode',
  - 'Segment',
  - 'City',
  - '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'
- **Training/Test Splits:**
  - Used data before 2017 as the training set and data from 2017 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:
    * RMSE: 195.7
    * sMAPE: 34.01%
    * R^2: 73%
  - Linear Regression:
    * RMSE: 323.5
    * sMAPE: 44.09%
    * R^2: 27%

  The R-squared value for the boosted tree model indicates that it explains about 73% of the variance in the sales data, compared to only 27% 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.