

Machine Learning Engineer Capstone Project:

Predicting Ames house prices.

Kaggle playground competition:

House Prices: Advanced Regression Techniques

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I. Definition

Project Overview

Predicting the residential house price can guide real estate agents during the decision making and pricing process, therefore assistant their customers to find the best selling price for their houses. Industry leaders also use the prediction of the house price for various purposes. Zillow uses the prediction of the house price to provide guidance to its online seller and buyer. Airbnb leverages the house price prediction to inform their hosts to better pricing their places.

The objective of this project is to predict the final price of a house given 79 explanatory variables that describe almost all aspects of a house in Ames, Iowa. This project is from a Kaggle playground competition (<https://www.kaggle.com/c/house-prices-advanced-regression-techniques>). The data in this project is described in detail by De Cock (2011).

Kaggle is a platform for data science competition. Participants are challenged to build models given the data provided to make predictions and then submit their results to Kaggle. Kaggle usually provides a training dataset and a test dataset and the task of the participants is to build a model based on the training dataset and make predictions on the test dataset. The submitted results will be evaluated by specific evaluation metrics on the test dataset. During the competition, there will be a score calculated based a fraction of the test dataset shown on the Kaggle Leaderboard, which is known as the public score. The final competition score, also called the private score, is based on the complete test dataset. During the model construction process, Kaggle participants usually create a private cross validation score following the competition evaluation metrics on their local machine, which is often called the local score. In this project, I

will mainly focus on the Kaggle's public leaderboard, which means, I will try to improve the performance of the model prediction measured by the Kaggle's public score.

Problem Statement

The Ultimate goal of this project is to train a model based on the given data to predict the house price as accurate as possible evaluated by the Kaggle Leaderboard. The related tasks to this problem include:

- Exploratory data analysis – Understanding the type of features in the dataset, how much missing values of different features, how many outliers are existed and whether specific features are skewed, are crucial in order to create a good model in the end.
- Feature preprocessing – Preprocess the data using the insights obtained from the exploratory data analysis, potentially including feature transformation, data type transformation, outlier detection and imputing missing values.
- Benchmark modeling – Creating a model using a standard technique for the problem in order to set up a benchmark for the future modeling improvement.
- Model improvement – Tuning model parameters to improve the performance of individual model and stacking individual models to provide final submission using ensemble learning technique.

Metrics

The Root Mean Squared Logarithmic Error (RMSLE) will be used to as the evaluation metrics for this project. The RMSLE can be expressed as:

$$\epsilon = \sqrt{\frac{1}{n} \sum_{i=1}^n (\log(p_i + 1) - \log(a_i + 1))^2}$$

where ϵ is the RMSLE score, n is the total number of observations, p_i is the predicted number of the house price, a_i is the associated actual house price and $\log(x)$ is the natural logarithm of x . The value of RMSLE is higher when the differences between the predicted and actual house prices are larger.

Compared to the most common Root Mean Squared Error (RMSE), RMSLE does not heavily penalize the huge difference between the predicted and actual values. Taking logs means that errors in predicting expensive houses and cheap houses will affect the result equally.

II. Analysis

Data Exploration

The training dataset is mixed with categorical and numerical features as well as some missing values. Specifically, there are 1460 observations, each with 79 features including the sale price of the house. The test dataset has 1461 observations, each with 78 features. Our task is to fill the sale price of the test dataset using the model trained from the training dataset. The histogram of the house price is shown in Figure 1, which shows that it is skewed. Thus, the log transformation needs to be performed in order to normalize it and this is the reason why we need to use the RMSLE as our evaluation metric.

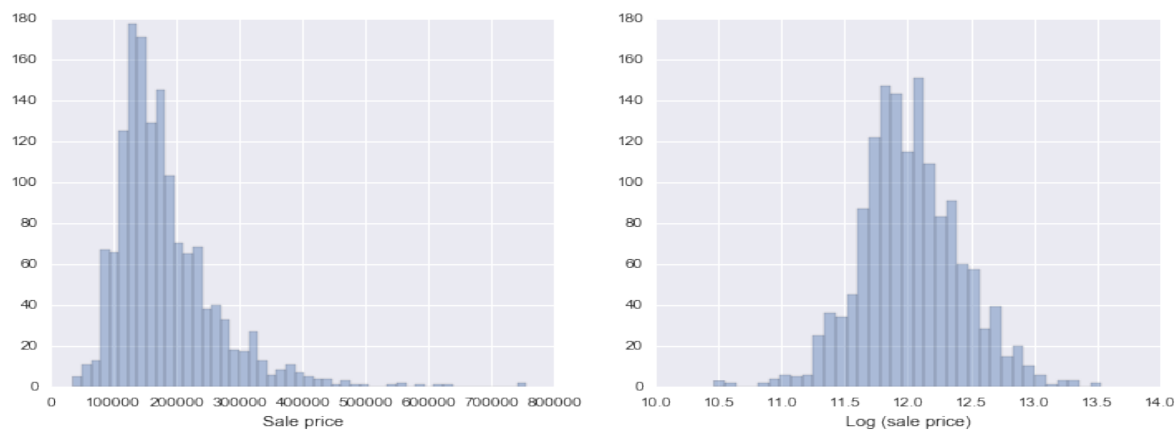


Figure 1: The histograms of the house sale price. (left) Original data; (right) Log transformed data.

Exploratory Visualization

Figure 2 shows the correlation matrix between the numerical variables and the house sale. There are several variables that are strongly correlated with the house price shown in Figure 2. I also explore the top six variables that are highly correlated with the sale price in Figure 3.

OverallQual	0.790982
GrLivArea	0.708624
GarageCars	0.640409
GarageArea	0.623431
TotalBsmntSF	0.613581
1stFlrSF	0.605852
FullBath	0.560664
TotRmsAbvGrd	0.533723
YearBuilt	0.522897
YearRemodAdd	0.507101
GarageYrBlt	0.486362
MasVnrArea	0.477493
.....	

Figure 2: The correlation coefficients between some variables and the sale price

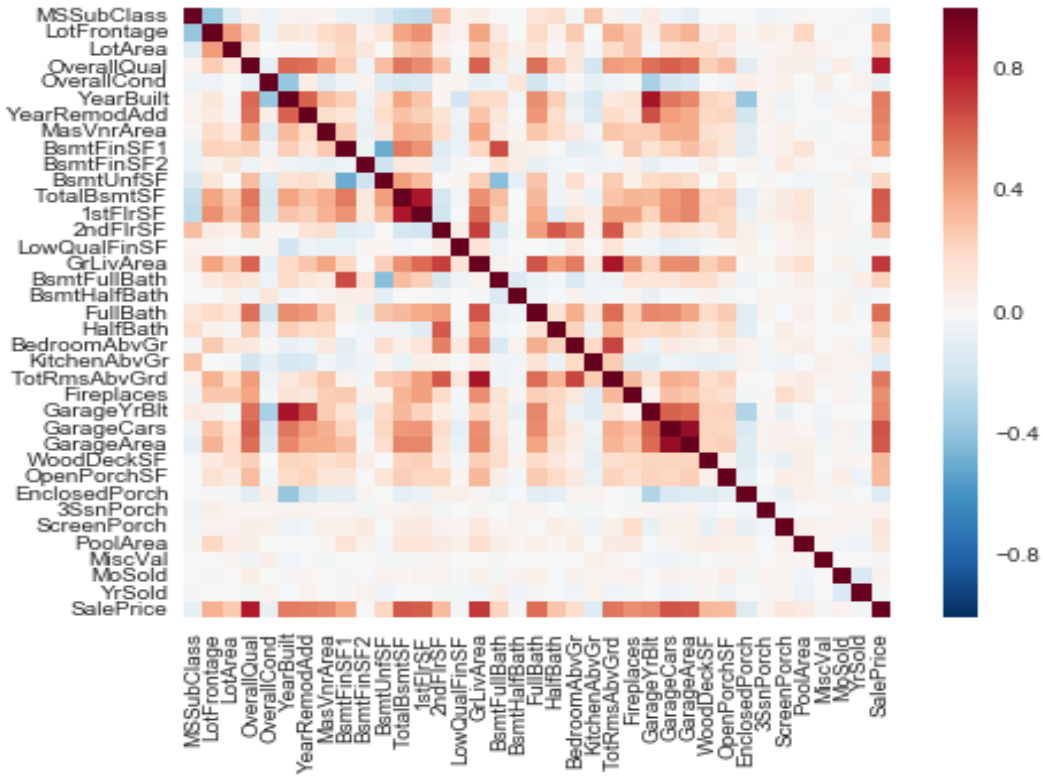


Figure 3: The correlation matrix between different numerical variables.

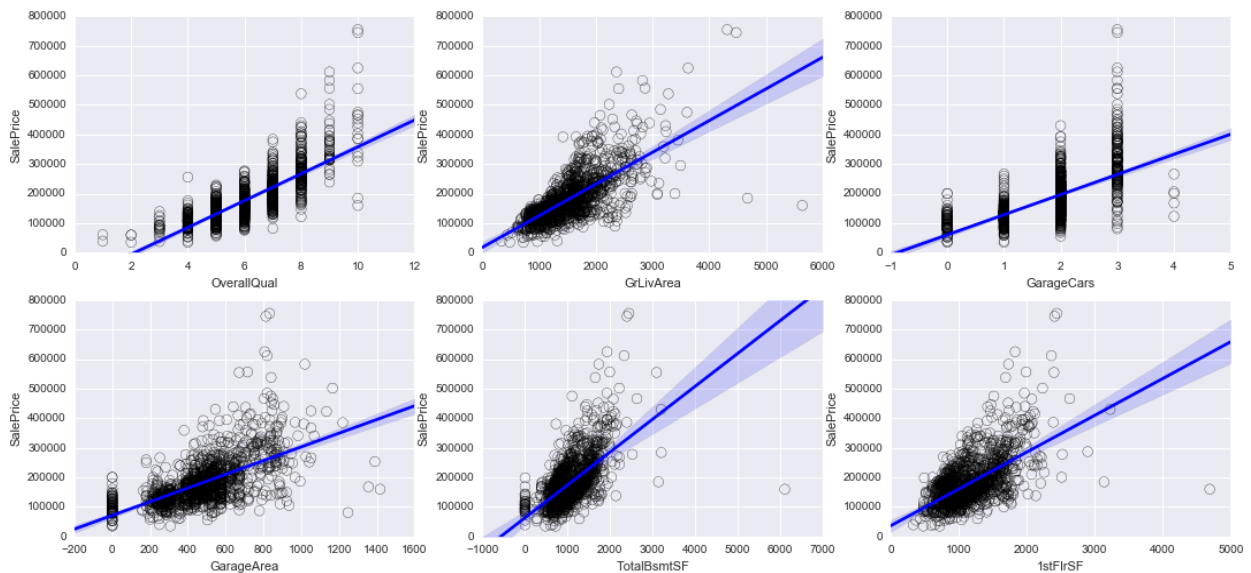


Figure 4: The scatter plot of the top 6 strongly correlated variables with the house price. The regression curve is shown in blue.

To give an example of the categorical variable, the boxplot between the neighborhood and the sale price is shown in Figure 5. We can observe a clear pattern that the neighborhood feature can greatly affect the house price. In order to include all categorical features into our machine learning model, the categorical variables can be transformed into some dummy variables, which takes the value 0 or 1 to indicate the absence or presence of some categorical effect.

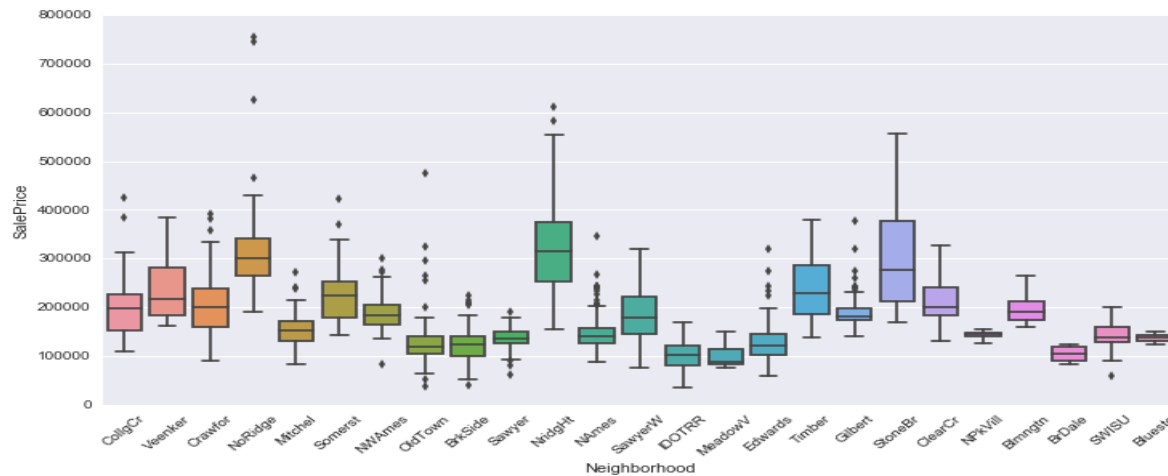


Figure 5: Boxplot of sale price in different neighborhood.

Algorithms and Techniques

Given one of the purposes of this project is to explore advanced regression techniques, I am going to use the ensemble learning technique to achieve better evaluation score. The ensemble learning techniques aim to learn a weighted combination of the base models and it sometimes called a committee method (Murphy, 2012). The technique we implemented in this project is called stacking. Stacking, which stands for “stacked generalization”, was introduced by Wolpert (1992). The data science competition participants use this method extensively in order to win the competition. One well known example is the Netflix prize competition winning solution, BellKor’s Pragmatic Chaos.

The basic idea of stacking is to use another model or “stacker” to combine all previous model predictions in order to reduce the generalization error. An illustration of a 2 level 5 folds stacking approach is shown in Figure 6. First, the training dataset need to be split into 5 folds. Second, we iterate over this 5 folds training dataset. In each iteration, each base model will be trained using 4 folds and predict on the hold out fold. At the same time, each base model also need to provide a prediction on the entire test dataset. After the iteration over all folds, we will have the prediction of the entire training dataset for each model and 5 copies of the prediction of the entire test dataset for each model. Finally, we train second level model, or stacker, using the prediction in the training dataset as new features and use the average of the 5 copies of the test dataset predictions as the test input for the trained model to provide the final prediction.

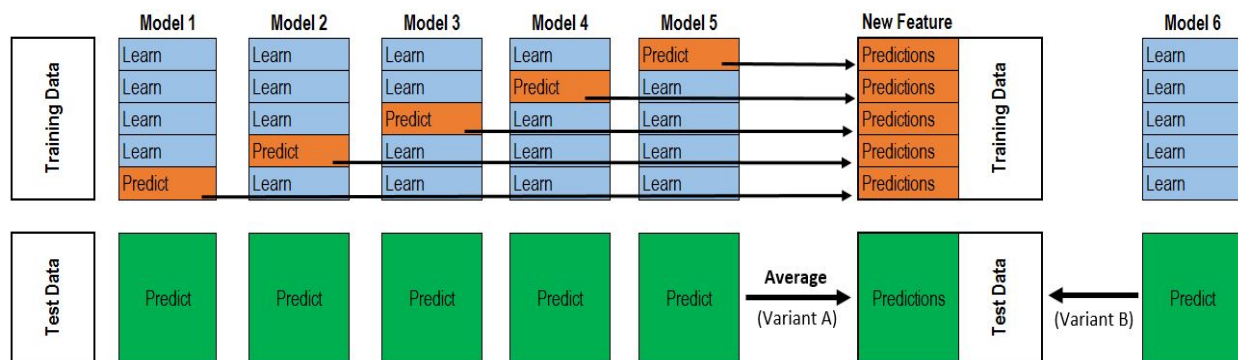


Figure 6: An illustration of stacking approach. (Credit: Kaggle forum)

Benchmark

The Random Forest regression is selected as our benchmark model for this project. The default parameters in scikit-learn package will be used as the benchmark, which earns a local cross validation score of 0.138194 and 0.15702 on the public leaderboard (rank 457 out of 662 teams).

III. Methodology

The overall methodology and modeling approach can be summarized using the flowchart shown in Figure 7. The details of the approach will be discussed in the following subsections.

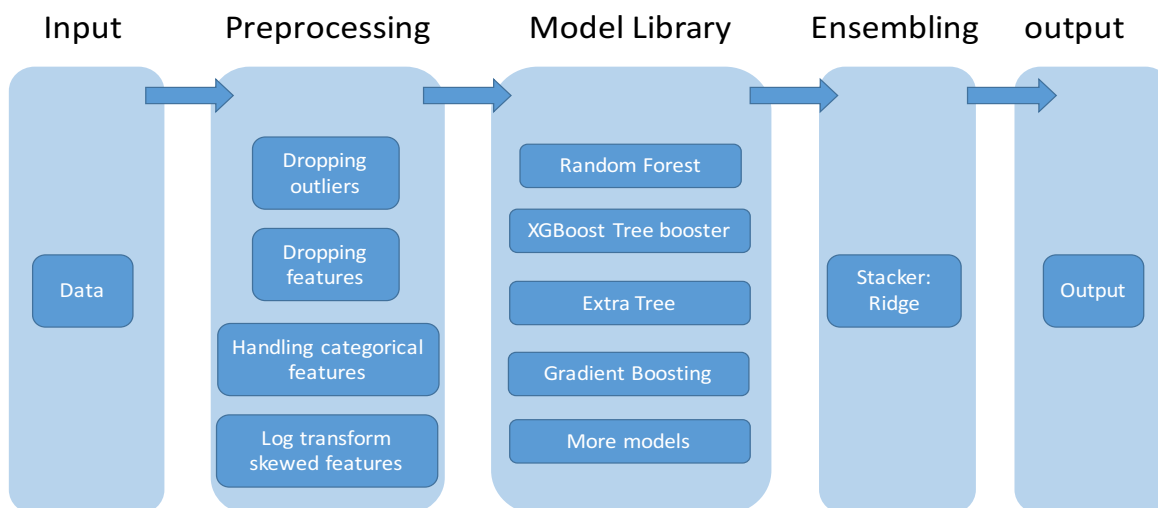


Figure 7: Flowchart of the modeling approach.

Data Preprocessing

- Outliers deletion

Any predictions from the benchmark that differ more than \$12000 than the actual house price are labeled as outliers. All outliers are deleted from the training dataset for the final submission.

- Feature selection

The feature selection approach I adopted here is a very simple and naïve one: delete features with high number of missing values. The categorical variables with the largest number of missing values are Alley, FireplaceQu, PoolQC, Fence and MiscFeature.

There are many other useful and advanced feature selection techniques, such as the boruta method (<https://m2.icm.edu.pl/boruta/>). A detail discussion of feature selection techniques is beyond the scope of this project.

- Log transform skewed features

All features that have a skewness larger than 0.75 are log transformed.

- Handle categorical features

The categorical features are handled by the pandas `get_dummies` function that converts categorical variables into dummy or indicator variables. See pandas documentation for more details (http://pandas.pydata.org/pandas-docs/stable/generated/pandas.get_dummies.html).

Implementation

Before applying the ensemble learning method, I trained and tuned 4 base model including Random Forest regressor, Extra Trees regressor, Gradient Boosting regressor, Extreme Gradient Boosting regressor.

At the beginning of the ensembling implementation, I use only 4 base models to form my model library, including Random Forest regressor, Extra Trees regressor, Gradient Boosting regressor, Extreme Gradient Boosting regressor. And I use the Ridge Regression as my stacker. For my final, I use a much larger much library including Random Forest regressor, Extra Trees regressor, Gradient Boosting regressor, Extreme Gradient Boosting regressor, LassoCV regressor, K neighbors regressor, LassoLarsCV regressor, Elastic Net regressor, Support Vector Machine regressor. The Extreme Gradient Boosting regressor is from the XGBoost package, all other techniques are from scikit-learn package. For the purpose this project, some of the base models are trained with their scikit-learn default parameter values.

Refinement

The refinement is conducted using the grid search technique. For the learning purpose of this project, I only use a few tunable parameters shown in the following (the detailed grid range can be found in the submitted code). Figure 8 shows the best performance of each base model based on the local cross validation score.

```
Gradient boosted tree regression...
Best Params:
{'max_features': 10, 'n_estimators': 500, 'learning_rate': 0.05, 'max_depth': 6, 'subsample': 0.8}
Best CV Score:
0.111495013076

Random forest regression...
Best Params:
{'max_features': 25, 'n_estimators': 500, 'max_depth': 11}
Best CV Score:
0.131998045253

eXtreme Gradient Boosting regression...
Best Params:
{'n_estimators': 500, 'subsample': 0.8, 'learning_rate': 0.05, 'colsample_bytree': 0.75, 'max_depth': 7}
Best CV Score:
0.109164143602

Extra trees regression...
Best Params:
{'max_features': 20, 'n_estimators': 500}
Best CV Score:
0.139196375677
```

Figure 8: The results of the grid search for each base model.

IV. Results

Model Evaluation and Validation

One interesting observation during the model ensembling process is that increasing the size of the model library can potentially increase both the local validation score and the Kaggle Leaderboard score. In the final submission, a variety of base models are included in the model library with their scikit-learn default parameter values. Using a much larger library enables me to rank top 10 among more than 600 teams at the time when I wrote this project report. I need to acknowledge that the approach is somewhat brute force and a more elegant way to do this is to find the base models to be as uncorrelated as possible. Nevertheless, I will address some of the issues of the model ensembling in the improvement section. Table 1 shows the local validation score and the Kaggle Leaderboard score for different modeling approaches. Figure 9 shows the Kaggle Leaderboard rank for my final submission at the time of preparing for this project.

Model	Local validation	Kaggle Leaderboard
Random forecast	0.13200	0.14831
Extra Tree	0.13920	0.15233
Gradient Boosted Tree	0.11150	0.12856
XGBbooster	0.10916	0.12815
Stacking 4 best	0.10755	0.12459
Final stacking	0.10069	0.11696

Table 1: The local validation score and Kaggle public score for different model setup.

#	Δ5d	Team Name <small>* in the money</small>	Score <small>🔍</small>	Entries	Last Submission UTC (Best - Last Submission)
1	—	ThúlioCosta <small>*</small>	0.07832	24	Tue, 06 Sep 2016 01:47:15
2	↑61	DoingItWithModels <small>👤</small>	0.10345	30	Tue, 20 Sep 2016 03:35:27
3	↓1	andrewwoohoo	0.10683	3	Mon, 12 Sep 2016 19:23:52
4	↑27	Boris Klyus	0.11614	28	Tue, 20 Sep 2016 20:13:19 (-14.5h)
5	↑3	labros	0.11617	73	Wed, 21 Sep 2016 14:42:12 (-42.1h)
6	↓3	MeiChengShih	0.11648	65	Mon, 19 Sep 2016 14:43:52 (-3.5d)
7	↓3	Steven Wang	0.11696	21	Wed, 14 Sep 2016 00:05:49 (-0h)
8	↑38	Bojan Tunguz	0.11737	22	Mon, 19 Sep 2016 18:44:17 (-0h)
9	↑1	Russ Boucher	0.11804	19	Mon, 19 Sep 2016 14:11:59

Figure 9: The Kaggle leaderboard at the time of my submission.

Justification

In summary, the ensemble approach in this project greatly improve the performance of the model in terms of the Kaggle Leaderboard score and rank from the benchmark random forecast regression ranked 457/662 to the final model ensemble stacking approach ranked 7/662. The result is quite encouraging and opens a lot more to think, learn and explore.

V. Conclusion

Free-Form Visualization

As my ultimate goal in this project is to build a model as accurate as possible measure by the Kaggle Leaderboard score, I will use the Kaggle Leaderboard score at the different model development stage as my final project visualization.

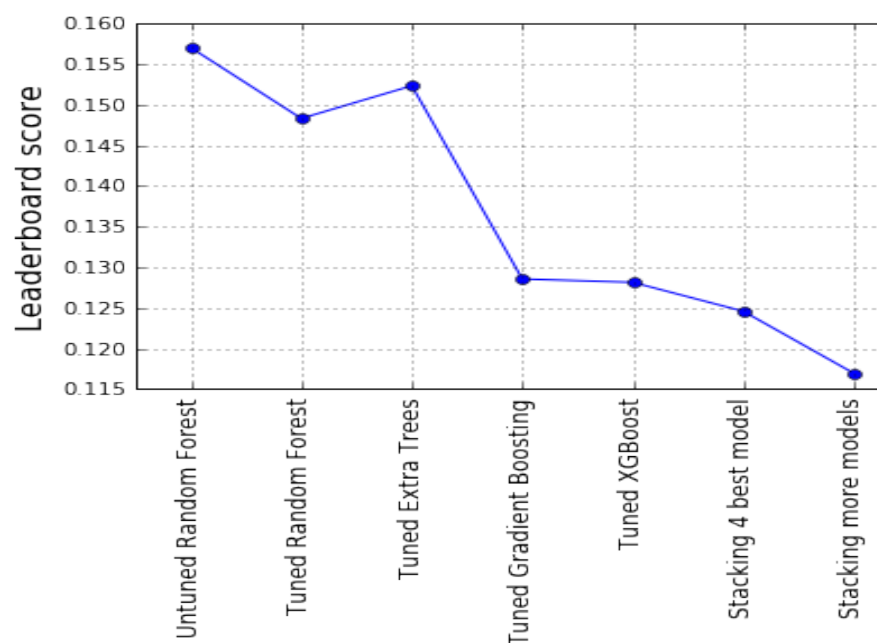


Figure 10: The Kaggle Leaderboard score at the different model development stage

Improvement

This project opens several avenues for future work. One part is for data preprocessing, such as more advanced outlier detection techniques, more advanced feature selection techniques, fine tuning of the log transform threshold of the skewed variable and so on. More creative feature

engineering will be also extremely useful. Another part is for the regression techniques. My intuition for ensemble learning technique is that a better score may be achieved by increasing the size of the model library. Kaggle competition winners usually train hundreds even thousands of different base models, see Kaggle Otto product classification challenge winning solution for an example (<https://www.kaggle.com/c/otto-group-product-classification-challenge/forums/t/14335/1st-place-winner-solution-gilberto-titericz-stanislaw-semenov>). The dilemma here is a tradeoff between the amount of time and engineering efforts you want to spend and the actual value of the tiny improvement. A very interesting idea to automate this ensembling process is suggested by MLwave (<http://mlwave.com/kaggle-ensembling-guide/>).

Reference:

De Cock, D. (2011). Ames, Iowa: Alternative to the Boston housing data as an end of semester regression project. *Journal of Statistics Education*, 19(3).

Murphy, K. P. (2012). *Machine learning: a probabilistic perspective*. MIT press.

Wolpert, D. H. (1992). Stacked generalization. *Neural networks*, 5(2), 241-259.

Friedman, J., Hastie, T., & Tibshirani, R. (2001). *The elements of statistical learning* (Vol. 1). Springer, Berlin: Springer series in statistics.

MLWave <http://mlwave.com/>