Final Project

Predicting How Long it Will Take Properties to Sell in Chicago

BUSN 00000-00 - Machine Learning – Winter 2022 Prof. Mladen Kolar

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We pledge our honor that we have not violated the Chicago Booth Honor Code during this examination.

# Executive Summary

Understanding the time it takes to sell a property in Chicago creates a path to lucrative opportunities in the real estate market. Failing to understand how long it will take you to recoup a return on your investment when you are flipping properties is how people lose their money in real estate. By purchasing properties, fixing them up, and then selling them investors can make money. However, if an investor buys a property and can sell it after it is fixed for a long period of time, the person is at risk of losing a substantial amount of profits or can take a loss. Our objective it to create a predictive measure that can be used to understand how long it will take an investor to sell a property they have invested in. Effectively de-risking the business of property flipping.

# Background

The property flipping business can be very lucrative, but many investors complain that they lost their money in real estate. The basic goal of investors to purchase a property that appears to be profitable when you account for the purchase price and the capital expenditures necessary to bring the property to market. The amount of time it takes to sell the property after the investment is usually a guessing game for the investor. Properties can take anywhere from 14 to 600 days to sell. The most common reason for an investor to lose their money or credit worthiness is to buy a property that they estimates would take less then 30 days to sell and, the property would take more than 90 days to sell. Thanks to improvements in machine learning technology, property flippers can take the guess work out of knowing if their property will sell quickly and make them a profit.

# Dataset

Realtor MLS Data

In this paper, we used the dataset publicly available from the MLS Realtor Database ([1]). The data contains 3,000 properties that have sold from January 1st, 2021, to December 31st, 2021. The list of properties are buildings that are 2-4 unit buildings across the Chicago metro Area. The Data set is robust with 131 feature variables and 1 label columns for the property addresses. The MLS data has all of the information about the properties that help differentiate each property. Items total units, property size and types of fixtures.

United States Census Bureau Data

The data set is also mixed with United State Census Bureau data. This data was included to provide more color to the data set and include information that is not available in the MLS. Much of this information is secondary demographic information, and the goal is to provide additional information that the property focused MLS data does not provide. Much of the data from the Census Bureau is demographic in nature and describes the environment or actions of the people that live in the different areas of the properties. The Census information was coupled with the MLS data by attaching the additional columns to the area column of the MLS data. Below is an example of the column descriptions that are included in the Census data set.

Table

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# Methodology

* 1. **Overall Strategy**

In this paper we attempt to predict the time it will take to sell a property using many machine learning algorithms. We created a factor column that categorizes the data as follows:

* Property took 0-14 days to sell
* Property took 14-30 days to sell
* Property took 30-60 days to sell
* Property took 60-100 days to sell
* Property took 100+ days to sell

By segmenting out the columns, we created a prime target variable that the machine learning algorithms could train with to predict whether a home introduced to the models would give an accurate predication of how long it will take for the property to sell. We went about the research by taking the following steps

1. Preprocessing the data
2. Performing a Boruta Algorithm to indicate the important factors of the dataset
3. Performing PCA and Cluster analysis on the data set to understand how the factors play out and segment the data set into unique markets
4. Running machine learning algorithm on the data set (Random Forest, XGBoost, Decision Trees, and Vector machines)
5. Exploring the models to select the least Root Mean Squared Error (RMSE) and highest Area Under Curve (AUC)
6. Testing the chosen machine learning methods on the out of sample data.

# Data Preprocessing

To perform the machine learning research, we first had to pre process the data. The process was extensive given the number of factors and missing data points. Much of the imported data showed up as characters, so we first numerated the integers and dollar related columns. There were five columns that were data related, notably the closing dates of the sales and the dates the properties were added to the MLS for sale. We changed all of the date columns into standard date columns.

Next we combed through all of the factors and gave them their property type classification so that the algorithms were getting all the information needed from the data set. After we classified the data, we noticed that there were many columns that were characterized as integers but contained less than 22 levels. We transitioned those items into factors as well. Finally we imputed all of the missing numerical values with the median so that we did not have any missing items that would deter the algorithms. Finally, we ran an aggregate plot to show if there were any missing values. This was followed by a skim function to ensure that all of the features were classified properly and the data set is in order. The aggregate plot is shown below:

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# Boruta

# The first Algorithm we ran on the data set was a Boruta. The goal of running this algorithm was to filter the data set down to the most important variables. The Boruta Algorithm serves as the inference detection, so that we can see clearly which columns have the most impact on properties sell time in the marketplace. The findings were very robust, and out of the 131 feature variables we were able to reduce the data set to the most important factors. In total about 17 factor variables were significant of medium importance or high importance. These 17 factors are factors we chose to continue forward into the machine learning algorithms. Some of the factors that had the most impact on the data were as follows:

# The property being on the north side of the city or the south sides specifically.

# The among of high school and associate graduate degree holders

# The amount of white demographic residents living in the area

# The employment rate of the city

# The number of residents that work from home in the area

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# Principal Component analysis

# The next step of our analysis is involved a principal analysis and cluster map. Our initial analysis with the cluster gave varying results. We drew a scree plot for the clustes, which had a very defined elbow at the 3 principal components, with marginal increase up to 10 components

# We then autoploted the results to and defined them by our target time to sell variable and learned very little information from that exerciseChart, line chart Description automatically generated

We then proceed to complete and NBC lust measurement for our clusters. The results of that measurement were 2 clusters would be sufficient.

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Finally we ran a gap stat, which gave us the result of 10 clusters as most appropriate for the Chicago Market.

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We decided to proceed using the 10 clusters given that gap stat is a very robust algorithm. We then ran an auto plot using the 10 clusters that we re recommended from the gap stat. We combined the data from the original data set to arrive to get a PCA Cluster map with loadings that substantiate our Boruta findings.

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The PCA Cluster map shows us the direction that the loading is pointing, and the accompanying clusters that are affected by these loadings.

Our final step in understanding how the target time to sell variable impacts the clusters of the city, we mapped the clusters onto a Chicago map using the longitude and latitude of the properties that are in each cluster. The map is as follows:

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# Estimation of Predictive Model

Now we have stock market movement indicator, document term matrix and sentiment indicators per day. We aggregated all the necessary data by date and then split into three part which are based on; 1. Training dataset (1,231 days from August 8th, 2008 to June 30th, 2013, which is 62% of total observations), 2. Validation dataset (380 days from July 1st, 2013 to December 31st, 2014, which is 19% of total observations), 3. Test dataset (378 days from January 1st, 2015 to July 1st, 2016, which is 19% of total observations). We used various machine learning algorithms to estimate on the training dataset and then checked their performance by the validation dataset. The model estimation is done separately on the four sentiment indices (AFINN and Loughran/Mcdonald, unigram and bigram) and document term matrix (bigram) to compare the performance. Also, the model estimation is done once for intraday stock movement and the next day stock movement. Lastly, we also examined the effect of adding previous day’s movement to see if this addition improves the performance in validation phase.

## Logit Model

As the stock movement is described by a binary outcome, the most simple way of the model estimation is done by Logistic Regression (Logit model). The logistic model is written as below.

1

*y*ˆ =



1 + *e*−(*β*0+*β*1*x*)

(1)

The logit model will predict the probability of a rise in the stock market. The logistic regression is applied to four versions of the sentiment indices and two version of prediction which are for the intraday and the next day.

## Naive Bayes

Naive Bayes is widely used classifier based on Bayes theorem. This model classifies positive condition or negative condition of the stock market based on the word appeared in the news flow. The function of the model is described as below.



*y*ˆ = arg max *p*(*Ck*) *p*(*xi|Ck*) (2)

We used this model on the document term matrix for predicting the intraday stock movement and the next day stock movement.

## Ridge/Lasso

Ridge and Lasso regression solve an optimization (regularization) problem with a penalty func- tion. Ridge penalizes on L1 norm of coefficient, while Lasso penalizes on L2 norm. The ridge penalty shrinks the coefficients of correlated predictors towards each other while the lasso tends to pick one of them and discard the others. In the binomial model, it solves the minimization problem as below.

min

(*β*0*,β*)∈R*p*+1

1

*N*

*i*=1

*y ·* (*β* + *xT β*) *− log*(1 + *eβ*0+*xT β* )

+ *λ*[(1 *− α*) *β* 2 + *α β* 1] (3)

If *α* is zero, this equation reduces to ridge regression and if *α* is one, it reduces to lasso. *λ* controls overall strength of the penalty parameter. We applied this method for document term matrix to predict the intraday movement and the next day movement.

## Boosting Tree

Boosting Tree is tree-based ensemble learning algorithm. The tree-based method divides up the sample set to make each divided region consists homogenous observations as possible. An ensemble learning is a method which produces multiple models first and combine at last to im- prove the model’s overall performance. There are two commonly used algorithms in ensemble learning applied to tree-based method. One is Boosting, and another is Bagging. Boosting method uses subset of the original data to produce series of underfitted ”Classification Trees”. The classification tree algorithm which tries to classify the states in the given dataset into dif- ferent categories. This classification algorithm adopts greedy strategy whose aim is to minimize the local misclassification error (hence ”greedy” because it cares the short-term goal and not consider the global consequence.) It tries to solve the following problem.

1

*p*ˆ*k*(*Rm*) =

### m

*xi*∈*Rm*

1*{yi*

= *k}* (4)

*y*ˆ = arg min([1 *p*ˆ*c*1 (*R*1)] + [1 + *p*ˆ*c*2 (*R*2)]) (5)

*j,s*

The *p*ˆ*k*(*Rm*) is the probability and *Rm* is each divided region. The *c*1 and *c*2 are the most common class in the region *R*1 and *R*2. Since Boosting underfits the model (hence high bias and low variance), the residuals still contain useful data and building another tree on the residuals will augment predictability of the model. After the iteration process of building up several models on top of the original tree, one of the model is selected or the models are aggregate a with particular cost function. The objective of the method is to increase the predictive power of the model by correcting the bias. We used the boosting method on sentiment indices (AFINN and Loughran/McDonald) and document term matrix.

## Bootstrap Aggregation (Bagging Tree)

Bagging is another ensemble learning method. Bagging method produces complex (overfitted) models from the iid-resampled dataset. Since overfitting the models, the bias is low while variance is high. After the iteration process of building up several overfitted models, typically those models are aggregated by weighted average to decrease the variance of the prediction. We used the Random Forest method which is a type of bagging method which randomly chooses the sub-trees so that these trees have less correlation. We used this method on sentiment indices (AFINN and Loughran/McDonald bigram) and document term matrix.

# Validation of The Models

Once the models are estimated, the prediction is performed on the validation dataset. We checked RMSE and AUC for the metrics to evaluate the machine learning algorithms. The result is shown in Table 1 and 2. Looking at the RMSE metric, the best algorithm is the logit model on sentiment index by Loughran/McDonald lexicon applied to bigram for intraday prediction, and the logit model on sentiment index by AFINN lexicon applied to unigram for

next day prediction. On the other hand, looking at AUC metric, the best algorithm is the logit model on sentiment index by AFINN lexicon applied to bigram for intraday prediction, and Random Forest on document term matrix for the next day prediction. Hence, we selected these four models to perform a prediction on the test sample. The inclusion of previous day movement didn’t contribute to improving the model. Hence the market doesn’t seem to memorize the past movement but rather depends solely on the current status to determine the next states.

# Testing of The Models

We now apply the four models selected by the validation step to the test sample. Table 3 shows the final metric of the model on the test sample. The sentiment index strategy which were performed very well in the validation sample tends not to work on test sample as the AUC of these algorithms become below 0.5. On the other hand, the random forest works well for predicting the next day stock movement. We constructed a portfolio strategy based on the prediction from the model such that if a model predicts the stock market goes up (more than 50% of the chance in intraday or the next day), we buy DJIA, and if a model predicts the mar- ket goes down, either we liquidate the position (Long-Sell), or sell further down (Short-Sell). Addition to this ”Long” and ”Long-Short” strategy, we made ”Contrarian” strategy such that we do opposite of the previous strategy (i.e., if the market goes up, we sell). Figure 4 shows the performance of the portfolio strategy if we had $1 at the beginning of test sample period (Jan- uary 1st, 2015). The ”AFINN” strategies describe the performance of AFINN sentiment index built on bigram for intraday prediction and AFINN sentiment index built on unigram for next day prediction. The ”Loughran” strategy describes the performance of Loughran/McDonald sentiment index built on bigram for intraday prediction. The ”ND” strategy describes the per- formance of Random Forest on bigram for next day prediction. ”Long” represents long strategy and ”LS” is a long-short strategy. ”Cont” is contrarian strategy. For the intraday forecast strategy, Loughran/McDonald Long (”Loughran.Long”) and Loughran/McDonald Long Short (”Loughran.LS”) slightly outperformed the DJIA index even though the AUC metric is less than

0.5. On the other hand, for the next day forecast strategy, Random Forest Long (”ND.Long”) and Random Forest Long Short (”ND.LS”) outperformed the DJIA index significantly.

# Consideration

As from the out-of-sample testing, the sentiment index based strategy didn’t work well even it was fitted very well during the validation phase. One of the reason could because of the bias. While one of the sources of the bias is the simple logit model, another source of bias is the construction method of sentiment index. As seen in Figure 1, even after the correction of double-negations, the sentiment score is highly biased to a negative score. This could stem from numerous negative words which appears infrequent in the text because the higher filtering threshold of tf-idf reduces this biases, and the every graph of four version of sentiment index become similar to what we had for AFINN unigram. However, increasing the level of threshold makes document term matrix sparse, and reduces observation. We had 1989 days observations (about eight years), but used only 1231 days for training (about five years) and filtering reduces the number further. In addition, the overall sentiment bias can be affected by the economic condition. In our paper, the training period covered worldwide recession but didn’t experienced expansion. This might have affected the sentiment score biased toward negative territory . It would be better to construct the sentiment index on longer period which covers both good economic conditions and bad times. Thus, the duration of period might have been too short to construct a robust sentiment indicator. Also, the world news contains an event not only occurred in the U.S. but also in outside of the U.S. These events might be popularly read in the news site, but not necessarily affect the U.S. market. Therefore, narrowing down the focus area of the news specific to the U.S. may improve the predictive power of the model. Having

said that, the portfolio strategy using the AFINN sentiment index and the Loughran/McDonald sentiment index are not worse than the DJIA performance (Figure 4). Thus, while it seems that our models didn’t detect the true positives correctly, it didn’t seem to make mistakes on the significant market rises and drops. The model might have mistaken on the day when the market rose but slightly (e.g., +0.01%) or decreased but slightly (e.g., -0.01%). To see this point, we may be able to include the magnitude of misclassification of true positive/ false positive. This study would be the subject of the future research. On the other hand, the Random Forest algorithm worked well in the test sample, and the both metrics of RMSE and AUC were stable. This may be because of the nature of the algorithm whose main focus to minimize the variance among the estimated overfitted models. Since the time series availability is limited in stock market (we can gather only 1989 daily observations over eight year period), the variance of the estimated model tend to be high. Thus, the method of growing multiple subtrees and averaging them tend to build a robust model for time series prediction.

# Conclusion

In this paper, we tried to develop a model to predict intraday and next day’s price movement of Dow Jones Industrial Average (DJIA). We employed two strategies to accomplish this predic- tion, one of which is the estimation by using the sentiment index, and the other is by fitting with the document term matrix. While performed well in validation sample, fitting on the sentiment index was not a good strategy given the number of observation. However, if a model is fitted with document term matrix by Random Forest algorithm, the performance of the model was stable during the period of the test sample. As the stock market is complex and highly volatile, an algorithm which focuses on minimizing the variance would be more suitable to formulate the predictive model. If we construct a portfolio strategy which uses the prediction for the investment decision making, we could see the performance of such strategy is better than the DJIA index. This implies that if we choose an algorithm to model a prediction, we would be able to extract an useful information from a news feed.

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Table 1: Evaluation Metrics on Validation Sample for Intraday Prediction

| Algorithm | RMSE | AUC |
| --- | --- | --- |
| afinn unigram | 9.6777 | 0.5494 |
| afinn unigram + prevous | 9.6777 | 0.5365 |
| afinn bigram | 9.6702 | 0.5896 |
| afinn bigram + previous | 9.6691 | 0.5558 |
| afinn boosting | 9.6947 | 0.5288 |
| afinn random forest | 10.1413 | 0.5355 |
| loughran unigram | 9.6640 | 0.5350 |
| loughran unigram + previous | 9.6679 | 0.5336 |
| loughran bigram | 9.6154 | 0.5546 |
| loughran bigram + previous | 9.6205 | 0.5557 |
| loughran boosting | 9.6657 | 0.5583 |
| loughran rondom forest | 9.6719 | 0.5365 |
| bayes | 14.0000 | 0.5081 |
| ridge | 9.6961 | 0.5000 |
| lasso | 9.6961 | 0.5000 |
| xgboost | 9.9905 | 0.5166 |
| xg random forest | 9.7248 | 0.5350 |

\*afinn: model on sentiment indicator by AFINN lexicon

\*loughran: model on sentiment indicator by Loughran/Mcdonald lexicon

\*previous: including previous day’s move to the regression

Table 2: Evaluation Metrics on Validation Sample for Next Day Prediction

| Algorithm | RMSE | AUC |
| --- | --- | --- |
| afinn unigram next day | 9.6941 | 0.5031 |
| afinn unigram next day + previous | 9.6953 | 0.5133 |
| afinn bigram next day | 9.6957 | 0.5062 |
| afinn bigram next day + previous | 9.6970 | 0.5153 |
| afinn boosting next day | 9.7007 | 0.4318 |
| afinn random forest next day | 10.5706 | 0.4756 |
| loughran unigram next day | 9.7504 | 0.4937 |
| loughran unigram next day + previous | 9.7523 | 0.4982 |
| loughran bigram next day | 9.7470 | 0.4744 |
| loughran bigram next day + previous | 9.7499 | 0.4838 |
| loughran boosting next day | 9.6970 | 0.4821 |
| loughran rondom forest next day | 9.7497 | 0.4994 |
| bayes next day | 13.9289 | 0.4695 |
| ridge next day | 9.6961 | 0.5000 |
| lasso next day | 9.6961 | 0.5000 |
| mix next day | 9.6961 | 0.5000 |
| xgboost next day | 10.9398 | 0.4497 |
| xg random forest next day | 9.7248 | 0.5563 |

\*afinn: model on sentiment indicator by AFINN lexicon

\*loughran: model on sentiment indicator by Loughran/Mcdonald lexicon

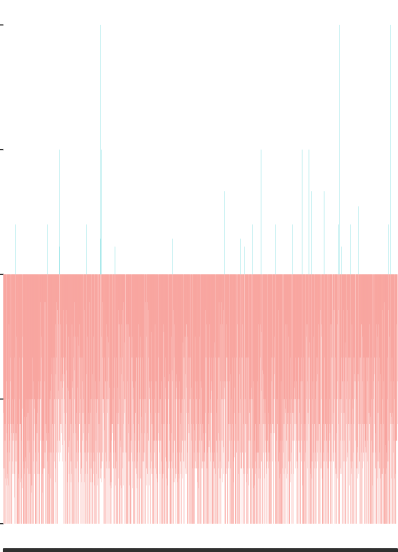
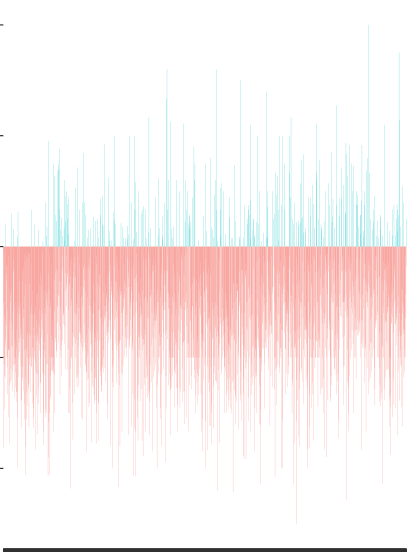
\*previous: including previous day’s move to the regression

Table 3: Evaluation Metrics on Test Sample for Intraday/ Next Day Prediction



| Algorithm | RMSE | AUC |
| --- | --- | --- |
| afinn bigram | 9.8320 | 0.4171 |
| loughran bigram | 9.8128 | 0.4527 |
| afinn unigram next day | 9.7637 | 0.4601 |
| xg random forest next day | 9.8469 | 0.5132 |

afinn\*: model on sentiment indicator by AFINN lexicon loughran\*: model on sentiment indicator by Loughran/Mcdonald lexicon

2 1.0

1

0.5

0

0.0

−1

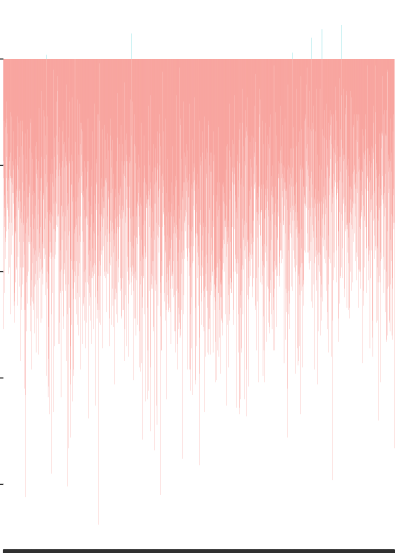
−0.5

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Date

* 1. AFINN Lexicon to Unigram

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−50

−100

−150

−200

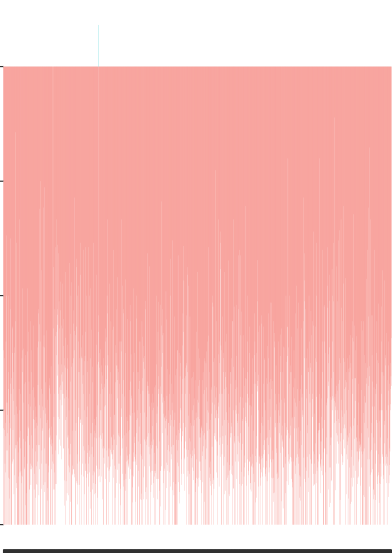
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(c) AFINN Lexicon to Bigram

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Date

* 1. Loughran Lexicon to Unigram

0.00

−0.25

−0.50

−0.75

−1.00

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Date

* + 1. Loughran Lexicon to Bigram

Figure 1: Sentiment Indicators

x-axis is date, y-axis is aggregated sentiment score (blue: positive, red: negative) Period: 2008-08-08 to 2016-07-01

0 1 0 1

(a) Intraday Prediction by Sentiment Indi-(b) Intraday Prediction by Sentiment Indi-

cator on AFINN Bigram cator on Loughran Bigram



0 1 0 1

(c) Next Day Prediction by Sentiment Indi-(d) Next Day Prediction by Random Forest

cator on AFINN Unigram on Bigram DTM

Figure 2: Boxplot

* + - 1. axis is actual up/down of the market, y-axis is prediction from the model (probability) Period: 2013-06-30 to 2014-12-31

ROC Curve ROC Curve

1.00 1.00

0.75 0.75

0.50 0.50

0.25 0.25

0.00 0.00

0.00 0.25 0.50 0.75 1.00

False Positive Rate

0.00 0.25 0.50 0.75 1.00

False Positive Rate

* + - * 1. Intraday Prediction by Sentiment Indi-(b) Intraday Prediction by Sentiment Indi-

cator on AFINN Bigram cator on Loughran Bigram

ROC Curve

ROC Curve

1.00 1.00

0.75 0.75

0.50 0.50

0.25 0.25

0.00 0.00

0.00 0.25 0.50 0.75 1.00

False Positive Rate

0.00 0.25 0.50 0.75 1.00

False Positive Rate

1. Next Day Prediction by Sentiment Indi-(d) Next Day Prediction by Random Forest

cator on AFINN Unigram

on Bigram DTM

Figure 3: ROC

Period: 2013-06-30 to 2014-12-31



#### Cumulative Performance − Best Intraday Strategy (Bigram)

2015−01−02 2015−05−01 2015−08−03 2015−11−02 2016−03−01 2016−06−01

* 1. Intraday Prediction

#### Cumulative Performance − Best Next Day Strategies

2015−01−02 2015−05−01 2015−08−03 2015−11−02 2016−03−01 2016−06−01

* 1. Next Day Prediction

Figure 4: The Performance of Strategies (Intraday/Next Day)

Test Sample: from 2014-12-31 to 2016-07-01