

# Deep Learning for Financial Sentiment Analysis on Finance News Providers

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## Abstract

*Investors have always been interested in stock price forecasting. Since the development of electronic media, hundreds pieces of financial news are released on different media every day. Numerous studies have attempted to examine whether the stock price forecasting through text mining technology and machine learning could lead to abnormal returns. However, few of them involved the discussion on whether using different media could affect forecasting results. Financial sentiment analysis is an important research area of financial technology (FinTech). This research focuses on investigating the influence of using different financial resources to investment and how to improve the accuracy of forecasting through deep learning. The experimental result shows various financial resources have significantly different effects to investors and their investments, while the accuracy of news categorization could be improved through deep learning.*

**Keywords:** Deep Learning, Financial Sentiment Analysis, Financial Technology (FinTech), Finance News Providers, Stock Prediction

## 1. Introduction

Since the development of information technologies, especially internet technology, the spreading ranges of electronic Medias are wide, while investors are easier and more convenient to get access with information of stock market. However, analyzing so many information for finding out useful ones, and then turning these into investment decisions, is a costly process which also requires some level of professional knowledge of economy for investors. Previously researches focus on the relationship between news and stock market, but rarely concerning the different information sources. Whether these sources with different efficiencies of Taiwan stock market or industry trends will have different influences on investors. The influences on stock are mainly in three aspects: (1) fundamental information of firm-specific news articles can enrich the knowledge of investors and affect their trading activities; (2) public sentiments cause

emotional fluctuations in investors and intervene in their decision making; and (3) the media impact on firms varies according to firm characteristics and article content. [1] Therefore, in this study we assume that those investors, who only receive information from one source, will still have different efficiencies of transferring into investment decisions due to different influence levels. We establish the research range covers 4 different news providers, using methods of sentiment analysis with opinion lexicon and deep learning. Through designing experiments and implementing above methods, we will further prove that whether this assumption is supported.

Numerous studies have attempted to examine whether the stock price forecasting through text mining technology and machine learning could lead to abnormal returns. However, little research involved the discussion on whether using different media could affect forecasting results. Financial sentiment analysis is an important research area of financial technology (FinTech). This research focuses on investigating the influence of using different financial resources to investment and how to improve the accuracy of forecasting through deep learning.

This study is aiming to measure the efficiencies of their prediction models of stock price trend under different news providers of economic and financial information. The specific purposes of this study are as followed: (1) discussing that, whether the related news which is most likely to be received by normal investors, since their providers with different levels of information grasping will have influences on investment decisions. We expect to simplify the channels for investors to get access to effective information. (2) In natural language processing, sentiment analysis model is heavily dependent on opinion lexicon to make specific marks, also the selecting of opinion lexicon will have significant influences on classification effects. However, in Chinese opinion lexicon, there is few list of opinion words in economic field. With the English sentiment lexicon in economic field which is established by Loughran and McDonald, and Lin first translated it into Chinese then compared Chinese news to make a filtering, and established a Chinese sentiment lexicon in economic field. In this study, this Chinese sentiment lexicon is abbreviated as NTUFSD. During the corpus collecting, we

will also make an expansion of opinion lexicon in economic filed to make it more complete. [2, 3]

The remainder of this paper is organized as follows. Section 2 describes the research background and related works of text mining, sentiment lexicon, financial news for stock price predicting and deep learning. Section 3 shows the methodology, proposed system architecture and financial datasets for analysis. Section 4 contains the experimental result and discussion. Finally, in Section 5, we present our conclusions.

## 2. Related Works

### 2.1 Text Mining

The purpose of data mining is to find out useful information from large amount of data. Text Mining is seen as a part of Data Mining, its definition is a process of editing, organizing and analyzing large amount documents and its purpose is to provide certain information for certain users and to discover the characteristics and relationship among these characteristics. [4]

### 2.2 Word Segmentation

Clause and segmentation are important parts in Chinese text mining, while in English, each word will provide blank as segmentation. The minimum unit in Chinese is “Zi”(character), so during the process of Chinese text mining, segmentation methods and lexicon selection may both have influences on research results. The content analyzing is mainly measuring the pessimism and optimism implied in text information according to the sentiment lexicon, so a good sentiment lexicon is the fundamental basis of text information analyzing. The common Chinese opinion lexicon for Chinese text mining includes, CNKI and Chinese opinion lexicon (NTUSD) from Taiwan universities. [5, 6]. With the English sentiment lexicon in economic field which is established by Loughran and McDonald, Lin, I-Hsuan (2013) first translated it into Chinese then compared Chinese news to make a filtering, and established a Chinese sentiment lexicon in economic field and verify its validity. Research results show that this NTUFSD can actually measure the sentiments implied in news. [2]

The character recognition range of natural language processing includes three levels of text, sentence and word. Word is the minimum unit in sentence but with most meaning. Therefore the prior task of text mining is to divide this article into segmentations, to find out information word and then perform the analyzing. Chinese article is not like English article with blanks between words. So in Chinese article, we need segmentation system to divide Chinese words. The common segmentation systems in Chinese include that: (1) CKIP: established jointly by information department and language department of Central Research Institute, which are providing Chinese technology framework and knowledge resources of natural

language processing. It Contains about 100,000 word vocabulary and additional parts of speech, word frequency, parts of speech frequency, and double word frequency data.(2) ICTCLAS: Chinese lexical analysis system from Chinese Academy of Sciences, it contains part-of-speech tagging and unknown word identification. This segmentation system is mainly based on Hierarchical Hidden Markov Model. (3) Jieba: an Open Source Chinese segmentation application in Python language. Algorithm used in this application is based on Trie Tree structure to generate all possible word from the Chinese word in a sentence and then use dynamic programming to find out the maximum probability of path. This path will be the largest segmentation result based on word frequency. In addition to have the new word recognition capacity and support word segmentation in both simplified and traditional Chinese, Jieba can also be added custom lexicons to ensure higher accuracy. In this study, we hope to increase the efficiencies of segmentation and Jieba segmentation supports custom lexicon, so we choose Jieba as our segmentation tool.

### 2.3 Predictability of Share Price

Different stock selection methods reflect different principles of investors. In general, there are three common selection methods: fundamental analysis method, technical analysis method and news analysis method. These three methods only reflect the faiths and values of investors also make decisions of the basis of investment decision. Fundamental analysis method is to assume that every public company has its own intrinsic values. Through monthly financial report it can monitor financial situation and profit ability to restore its true values. With the true values as assessing basis, then analyze financial statement to predict future changes on earnings, which can impact share price as well. Ou and Penman Technical analysis method is to concern share price trends, trading volumes and other indicators, and then assessing future share price trends. [7]. The definition of technical analysis is: with objects of market behaviors, predict future price trends by technical analysis, and the used tools includes graphics[8]. News analysis method is the news, magazines and other news. News may have influence on individual share price, including government policies, industry trends, economic information and others. Since there are too many sources of these information, such as TV report, news and magazines and internet medias, investors may receive confusing information and hard to distinguish the useful ones. Tumarkin and Whitelaw studied the relationship between activeness of internet message board and trading volumes, then found out that internet information will increase investors' knowledge then provide influences on share prices.[9]

### 2.4 Stock Prediction Using the News

In previous researches in financial news on share price

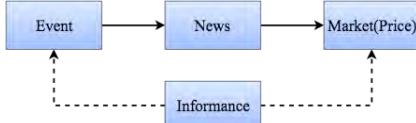


Figure 1 The relationship between Events, News and Markets (price) through Information.

forecasts, Mittermayer used Support Vector Machine, taking in the changes of stock price in 3 minutes before and after news released, make a classification of those news which have influences on stocks, into 3 types: “Good News”, “No Movers” and “Bad News”. Through the news model, make recommendations and predictions on stock trading. In research of Ahmad, Oliveira, Casey, and Taskaya, the information which have influence on financial market are usually released by e-mail, news, company newsletter and annual report. [10, 11]

## 2.5 Deep Learning

“Deep Learning” actually refers to “Deep Neural Network”. It is a part of machine learning. Since deep learning was proposed, it has been applied in various information processing. After applied deep learning, the results of related researches in various fields have been improved significantly. [12, 13] The learning theory of the neurons of deep neural network is learned from input( $x$ ), through features to learn weighting, then after weighting we can get a better output( $y$ ). Schematic diagram of learning is shown in the figure 2.

## 3. Methodology

In this study, we use “Systems Development Research Methodology” from information system research field as our research methods. [14]

### 3.1. System Architecture

Figure 3 shows the research architecture diagram. Processes are as followed:

1. Corpus collecting and share price data compilation: it is by choosing an online news website which supports historical information query, and then using web mining to write a web crawler for capturing individual stock-related news, meanwhile making the data compilation of share prices.
2. Data pre-processing: including corpus analysis, and segmentation processing.
3. Lexicons integrated: in this study, we make an integration of opinion word collection from NTUSD, NTUFS and HowNet-VSA and sort out another list of opinion words which is frequently used in financial field in manual way, called iMFinanceSD.

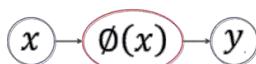


Figure 2 Schematic diagram of Neuron weight

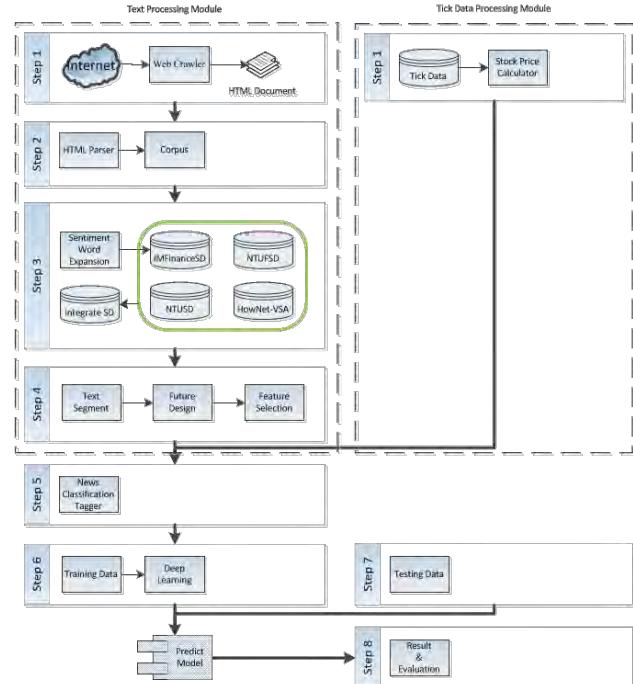


Figure 3 Research architecture diagram

4. Eigenvalue generating: select combined feature to do eigenvalue computing then generate the necessary form of training of machine learning.
5. Mark category of news: according to feature word and changes of share prices, mark categories for news as rise, fall and remain.
6. Deep Learning: provide training form to machine learning classifications, train the data and produce training models.
7. Verification and testing: make cross verification of data and provide tested data to training models, then get the results.
8. Results evaluation: analyze the assessment results and make a conclusion.

### 3.2. Financial news and corpus collecting

This study mainly discusses the relationships between financial news and stock price trend, whether they will be different due to different sources and have influences on investment decision of investors. Therefore we choose the following 4 news providers as the experimental data sources:

1. NowNews: an internet media in Taiwan, with independent interview and editing team, providing over 350 pieces of news every day. The content covers politics, economy, life, entertainment, world and other news. It's a comprehensive electronic news media.
2. AppleDaily: AppleDaily is one of the most powerful newspapers in Taiwan. The contents tend to be neutrality and entertaining, and most of them are domestic news. In the list of Medias ranking in 2012 published by Shih Hsin

Table 1 Comparison of editorial team and contents of news providers

News providers	Platform	Content	Editorial team
NowNews	Electronic media	Comprehensive	Owned
AppleDaily	Electronic media/newspaper	Comprehensive	Owned
LTN	Electronic media/newspaper	Comprehensive	Owned
MoneyDJ	Electronic media	Finance	Owned

University, AppleDaily ranked the top in click rate, content depth, objectivity & fairness and credibility.

3. Liberty Times Net (LTN): established in 1980, the newspaper circulation of 620,000 in average daily. The circulation and read rate of LTN are both ranking first in the country, which reflects it confirmed by readers.

4. MoneyDJ Finance: a professional financial website operated by SysJust. It's the first information company which launched online financial data library. With rich news data base and professional financial news team, it's the biggest domestic financial website and financial service company. Table 1 presents the comparison of editorial team and contents of news providers.

### 3.3.Data pre-processing

We design a web crawler with web mining method to capture information from these 4 electronic news providers. The grabbed financial information is semi-structured or unstructured information. So we must perform structured work for information to make the effective application.

1. Remove the HTML tags: filter HTML tags and JavaScript code out of the text, only headlines and news text are remained.

2. Remove redundant information in text: such as News classification, news tag keyword.

3. Number news: according to the different sources, number news, stock, date and serial number in order.

### 3.4.New-Term Extraction

In terms of new word extraction and expansion, we use Python Suffix Array again in this study, exploring unknown sentiment words in collected news text. The principle is using Suffix Array algorithm to process large amount of text, to find out the words with high frequency of occurrences. In order to deal with the problem of string matching, Suffix Array is a simple and effective method. Also, the string through the sorted array could accelerate processing speed, which only requires to set the minimum length of each string and record the frequency, at the end we can have the result of all string combinations and their frequency. After sorting, we need to find out words frequently occurring in comments, then comparing with NTUSD, HowNet-VSA and NTUFSD, filter normal or known opinion words. Then we make a comparison to these known words from Academia Sinica Bilingual

Table 2 Sample iMFinanceSD opinion words

Positive		Negative	
No	Word	No	Word
1	衝破 (break through)	1	震盪 (shock)
2	穩住 (stabilize)	2	低於 (less than)
3	挹注 (inject)	3	放緩 (slowdown)
4	歷史新高 (Historical high)	4	走緩 (slowly)
5	不遑多讓 (be no slouch)	5	大幅砍殺 (Stabbed sharply)

Ontological Wordnet (Sinica BOW), filter effective word in manual method. The collection of opinion word of financial field is called iMFinanceSD. Table 2 presents the sample iMFinanceSD opinion words.

### 3.5.Feature Generation

This study take 4 opinion lexicons including NTUSD, HowNet-VSA, NTUFSD and iMFinanceSD to make designs for feature attributes of sentiment lexicon. We take length of news text, positive word, negative word, word difference of this text and others as experiment characteristics, and there are 11 feature words in total.

### 3.6.Deep Learning

Table 3 Feature used for financial sentiment analysis

ID	Future Name	Description
F01	NewsCharacters	Total word number of news text
F02	NewsTokens	Number of news words
F03	NTUSD_Positive	NTUSD positive word
F04	NTUSD_Negative	NTUSD negative word
F05	NTUSD_PNDiff	NTUSD difference of positive and negative word
F06	HowNet_Positive	HowNet positive sentiment word
F07	HowNet_Negative	HowNet negative sentiment word
F08	HowNet_PNDiff	HowNet difference of positive and negative word
F09	FinanceSD_Positive	NTUFSD+iMFinanceSD positive word
F10	FinanceSD_Negative	NTUFSD+iMFinanceSD negative word
F11	FinanceSD_PNDiff	NTUFSD+iMFinanceSD difference of positive and negative word

Table 4 Example of feature used for sentiment analysis

D00001, 516, 185, 3, 8, -5, 0, 1, -1, 14, 8, 6, 3008, 2013-01-04
D00002, 534, 185, 4, 2, 2, 0, 0, 13, 2, 11, 3008, 2013-01-07
D00003, 846, 296, 6, 9, -3, 0, 1, -1, 25, 15, 10, 3008, 2013-01-09
D00004, 1495, 489, 55, 19, 36, 3, 0, 3, 23, 16, 7, 3008, 2013-01-10
D00005, 872, 282, 3, 5, -2, 0, 0, 0, 12, 17, -5, 3008, 2013-01-14
D00006, 573, 183, 2, 5, -3, 0, 0, 0, 8, 9, -1, 3008, 2013-01-21

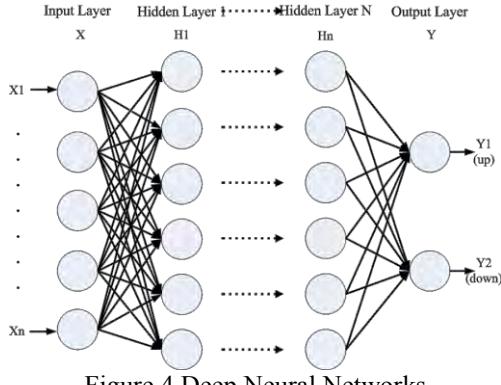


Figure 4 Deep Neural Networks

The study adopts deep learning as the machine learning method to perform classification forecasting of the experimental data. Deep learning is a branch of the machine learning. It actually refers to the multi-layer artificial neural network as well as its training method. The deep neural network belongs to a kind of neural-like network. It consists of three parts, including the input layer (X), the multi-layer hidden layer (H<sub>n</sub>) and the output layer (Y). As shown in Figure 4, it can express the complex non-linear relationships.

When executing train for models, DNN employs the Backpropagation Algorithm to adjust weights among neurons and then gain the learning goal. The input neuron connects to the next layer of neuron through junction, the output value of the upper layer multiply weights and plus

$$y_j = f(\sum_i w_{ij}x_i + b_j)$$

$y_j$  : Output Value

$f$  : Activation Function

$w_{ij}$  : Weight

$x_i$  : Input Value

$b_j$  : Bias

the bias, and output to the next layer with the activation function and finally output to the output layer. The formula is shown as below:

The main function of the Activation Function is a kind of mapping that adding inputs of neurons based on various weights before converting to output. It is also a design that introduces the non-linear effect into network. Without the neural network of the non-linear activation function, the output boasts the similar linear combination as the input. This makes the deep neural network become the same as the monolayer neural network. Therefore, activation function plays a rather important role in the neural network. The following are several common non-linear activation functions that used in classification models:

1. Sigmoid function: This is an activation function that

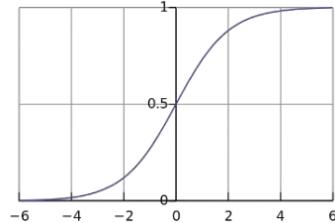


Figure 5 Sigmoid Function[15]

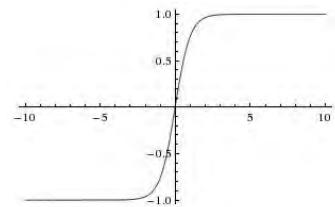


Figure 6 TanH Function[15]

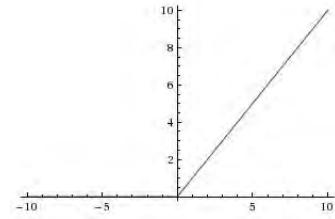


Figure 7 ReLu Function[15]

usually used in the back-propagation neural network. It is able to convert the input value to the value between 0 and 1. The formula of Sigmoid are shown as below:

$$f(x) = \frac{1}{1 + e^{-x}}$$

2. TanH function : TanH Function: It is a function that the output value drop in -1~1. It equals to the transformation of sigmoid. The formula of TanH are shown as below:

$$f(x) = \tanh(x) = \frac{2}{1 + e^{-2x}} - 1$$

3. Rectified Linear Unit (ReLU): ReLu has become the most popular activation function in the field of deep learning. The algorithm of ReLu is that 0 would be directly output when the input is negative value; or else, the input will be directly output. This greatly saves the mass and complex calculating process. In this way, ReLu can effectively improve the training speed of the deep neural network. The formula of ReLu are shown as below:

$$f(x) = ReLu(x) = \max(0, x)$$

In this study, we use Google TensorFlow deep learning library with ReLu activation function for developing financial sentiment analysis on finance news

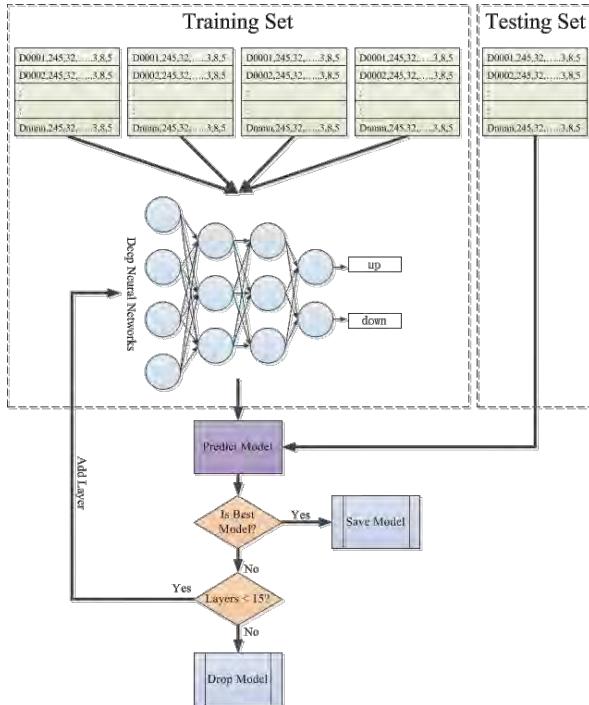


Figure 8 Construction flow chart of deep learning prediction model

providers. Figure 8 shows the flow chart of deep learning prediction model for financial sentiment analysis.

#### 4. Experimental Results and Discussion

We write a web crawler in Python language, grabbing respectively from NowNews, AppleDaily, LTN and MoneyDJ, the four electronic news providers, choosing 18 public companies from our research objects, and related news released during 2013/01/01~2014/12/31, with a total of 8,472 articles used in this experiment.

Sentiment analysis, also known as subjective analysis or opinion mining, extraction and evaluation, is defined as a process using method of natural language processing, automatically doing mining in texts, speeches or data bank for attitudes, opinions, viewpoints and sentiments. Throughout the literature of sentiment analysis, mining methods can be divided into two categories: [16, 17]

1. Machine learning approach: Machine learning approach can also be divided into Supervised Learning and Unsupervised Learning. Supervised Learning usually requires two sets of data, including training data collection and measure data collection. Marked training data collection can be used to train classification, and then

Table 5 total news number of each news provider

Provider	NowNews	AppleDaily	LTN	MoneyDJ
Total	5,499	456	1,147	1,370

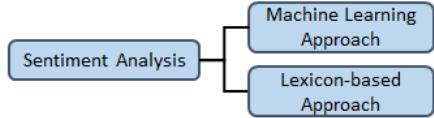


Figure 9 Sentiment analysis

learned a function from it. When new data come in, we can make predictions according to this function. While in Unsupervised Learning, prepared data collection will not be marked manually. The purpose of unsupervised analysis is to find out the internal relationship between the input variables and data pattern, also to find out general distribution trends among data, without predictable object.  
2. Lexicon-based approach: Lexicon-based approach based on lexicon is assuming that the total sentiment trend of every opinion word or phrase will decide the whole sentiment of this article. The advantage of this method is no requirements of training data collection or training process, while its disadvantage is requiring opinion lexicon in this field.

This study will conduct respective experiments for machine learning approach and lexicon-based approach. (1) Use lexicon-based approach to classify the sentiments of

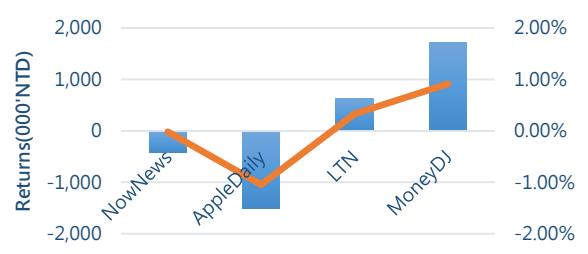


Figure 10 ROI of 5 days lexicon-based trading

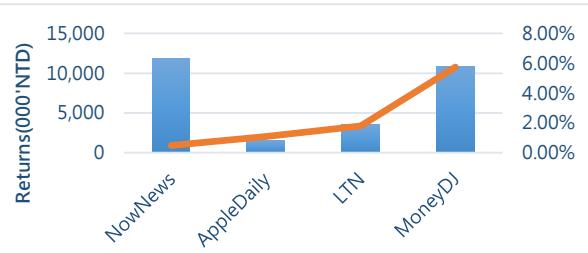


Figure 11 ROI of 20 days lexicon-based trading

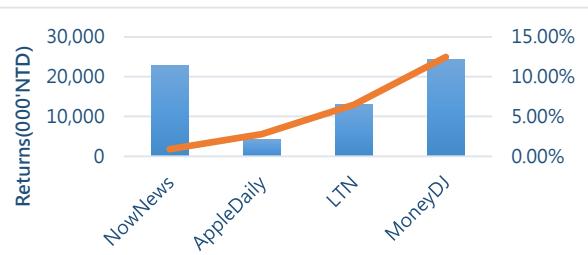


Figure 12 ROI of 60 days lexicon-based trading

news text for simulated trading. (2): use deep learning approach to train prediction models in 5 days, 20 days and 60 days of 4 news providers for simulated trading. The output items of the prediction model are rise, fall and remain. When it's "rising", then buy in at the closing price in that day, and sell out in 5 days, 20 days and 60 days at that day's closing price since news released. While "falling", then sell out at the closing price in that day, and in 5 days, 20 days and 60 days since news released, buy in at that day's closing price. When it's "remaining", conduct no trading. In each trade, the unit is 1000 stock. We will make a trading followed by every trade signal, when every signal is accounted, do the calculation of overall profitability of 4 news providers respectively.

Figure 10, 11 and 12 make a conclusion of positive and negative sentiments in news according to opinion lexicon, for the trading strategy of stock price trends. We can see that after the news are released on 4 news providers, the ROI value of 5 days are all under 1%, which is not qualified to be included in effective investment strategy; in 20 days of trading strategy, the ROI value of prediction model of MoneyDJ reach 5.74%, which is higher than other three providers; while in 60 days, the ROI value of prediction model of MoneyDJ reach 12.46%, which is still higher than other three providers.

Figure 13 shows that according to the results of Lexicon-Base simulated trading in 5 days, 20 days and 60 days, we found that the ROI value of prediction model of MoneyDJ is higher than other three providers.

After comparing Figure 14, 15 and 16, we found that after putting data collection in prediction models applied with deep learning, 4 news sources all have positive ROI values, while the greatest ROI is only 1.27%, which is not qualified to be included in investment strategy.

In prediction model of future 20 days situation, among the ROI values of the data collection trained in prediction model of 4 news providers, MoneyDJ presents best

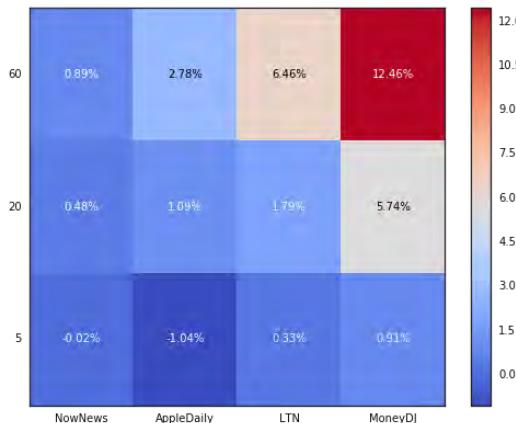


Figure 13 ROI Heatmap of lexicon-base trading

efficiency, which shows that the news provider of MoneyDJ has better performance in predicting situation in future 20 days than other three news provider.

In prediction model of future 60 days situation, among the ROI values of the data collection trained in prediction model of 4 news providers, MoneyDJ achieve 22.43% of ROI value, which is significantly higher than prediction models of other news providers.

Figure 17 presents the ROI heatmap of trading in deep Learning of 5 days, 20 days and 60 days. As shown in figure 17, we found the ROI value of prediction model of MoneyDJ is higher than other three news providers. While in the prediction model of AppleDaily, its ROI value is only 1.5% at best, which is not qualified to be included in trading strategy. Comparing the results of 5 days, 20 days and 60 days, in general, prediction model has the best performance in 60 days in this experiment.

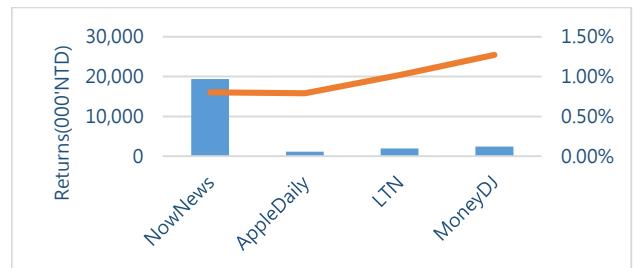


Figure 14 ROI of 5 days trading with deep learning predicting stock price trend

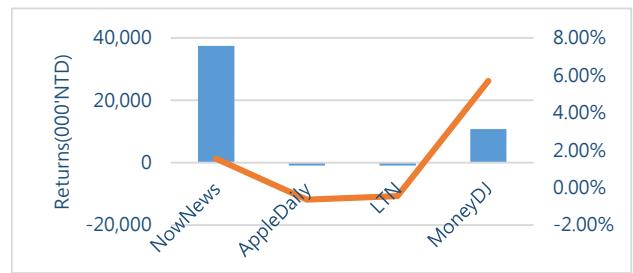


Figure 15 ROI of 20 days trading with deep learning predicting stock price trend

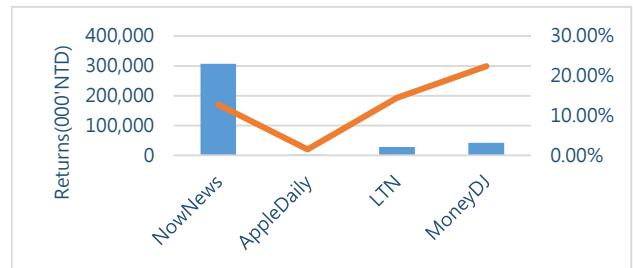


Figure 16 ROI of 60 days trading with deep learning predicting stock price trend

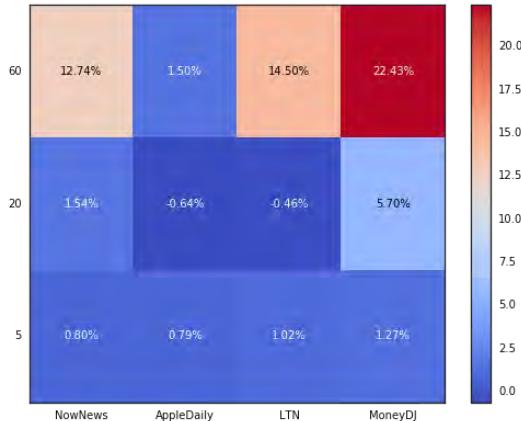


Figure 17 ROI Heatmap of trading in deep Learning

## 5. Conclusion

This study presents analytical methods use deep learning in financial news sources on the stock price trend forecasts. The results showed that the source of financial news media for the exclusive domain of Finance and Economics, revealed its investment information representing a reference value. Comprehensive research process and the results of this study, the contribution of specific studies are as follows: (1)The Different news media release financial news different from its reference value level messages containing investment, as investors choose FINANCE message referenced sources. (2)The prediction accuracy will be improved via a prediction model of the deep learning.

Since modern information technologies are developed with high speed and become popularized, people may get access to increasing large amount of information. Dealing with this information into useful knowledge and decisions is a hard and time-cost process. Currently researches concerned with the relationship between financial news and share prices are most focusing single news provider. However, different news media have their own characteristics and specializations. The values of their information may be different due to the following reasons:

- 1 Company's business principles.
- 2 Edition team's specializations and their knowledge of industry.
- 3 Journalist's habits and preferences in wording.
- 4 Sensitivity of market trends of the Media.

The result of this research can be available to normal investors, for receiving financial information and making weightings of message filtering.

## 6. Acknowledgement

This research was supported in part by Tamkang University (TKU) research grant.

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