Classification of news headlines with impact on the probability of stock prices changes

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*Abstract*—Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

# Introduction

News is part of everyday life. The channels have been extended from traditional news services to social networks. The American President Donald Trump, for example, uses Twitter as a news channel. This behavior was heavily discussed in the context of the 2016 presidential election, as statements in the form of tweets about companies affected its stock prices [1]. For example, on the same day of a positive tweet about Ford (Jan 4, 2017), Ford's stock price increased by 4.6%. On the same day of a negative tweet, the stock price decreased by 1.8% for ExxonMobil (Dec 13, 2016) [1]. Even if the stock prices returned to its previous level after some time, a correlation between news and stock price can be deduced.

It is therefore obvious to assume that these correlations do not only exist between Donald Trump's tweets and the stock market but that this correlation can be interpreted in a broader sense. Therefore, this study examines the relationship between published news headlines and the changes in stock prices. This relationship leads to the problem-solving approach of how to classify news headlines to detect the probability of stock price changes?

The solution of this problem can clarify the importance of news regarding stock price changes and may increase significantly the accuracy of the stock price change prediction. In specific, the relationship between tags (individual key words) of headlines and price changes will be explored. This will lead to design a probabilistic model of linking a headline to a price change.

The change of stock prices can be controlled with indicators like RSI (Relative Strength Index) or EMA (Exponential Moving Average). The RSI is an indicator that measures from 0 to 100 the extent of the latest price changes to assess overbought or oversold conditions in the price of a stock or other asset. In comparison, an EMA represents the trend of the price change and reacts sensitively to recent price changes depending on the included number of data points from the past. But in order to predict the probability of a stock price change, it is necessary to include daily updated news, which is not reflected in real time in indicators like RSI or EMA, but rather in headlines.

Therefore, the purpose of this study is to underline the high relevance of tags (individual key words) of headlines for stock price changes. In comparison, just analyzing stock price indicators can lead to a wrong trend or even worse, to a wrong decision for buying or selling a position. By implementing tags of headlines and their probability of a stock price change, the decision for buying or selling a position is based on recent data and includes opinions and thoughts of people.

The overall approach is divided into two parts Business Intelligence and model building. The first part, Business Intelligence, analyzes the relationship between tags of headlines and stock price changes by answering the following three subproblems:

First, it will be analyzed when [min] the stock price is affected, after the news being published. Second, it is critical to identify first the wave of the stock price change, and to analyze the development. The aim is to detect the time of the first increase, the maximum, and the time of returning to “normality”.

Second, it will be developed a deep learning neural network which takes in the current stock price, the volume of the headline pubdate, and the transformed price change for headline tags. The details of this technique will be presented in the following chapters.

# Background

Since there is a large number of potentially relevant sources of varying quality, the discussion in this paper of the identified problem will be based on an analysis of the literature which follows a standard framework for literature reviewing [2]. First, the scope of review is defined, in a structured and documented form [3]. The focus defines the "type of sources", meaning that research results, research methods and applications of stock prediction models are included in the research. The aim is to integrate them to identify research gaps. The procedure in the research is to be regarded as conceptual. The target group is to be defined as the general professional audience, professionals, and practitioners. The framework of the literature analysis is complete and selective, in the sense of a complete research in German and English language.

A first structural analysis of the researched literature results shows that the number of articles has increased in recent years. The high proportion of results from recent years in this research area is an indication of the novelty and relevance of the topic. One of the key messages from the analysis is that the literature identifies news sources as an essential component of stock prediction.

Approaches using indicators as predictors to build classification models are also widely used in this research area. Sezer’s study, for example, determines to buy and sell points for stocks by using RSI values. Therefore, a stock trading system was developed, which combines different classification algorithms. The results of their proposed system showed, in comparison to other trading systems, similar results [4]. In comparison, Balaji created in their study 14 different models, which were based on four main different techniques of deep learning and tried to forecast the stock price with accuracies above 0.5 [5]. Furthermore, another study has determined that there is a high correlation between stock market prices and returns [6].

In comparison to the quantitative approaches above, unstructured data as text form has also already been applied in many researches and predictions were made. For example, Tweets (special tags), were used to predict the spread of diseases [7]. Natural Language Processing is a key element in this process and represents a sub-area of computer science and linguistics, where an interaction between computers and natural language takes place. The sentiment analysis is a common use case of text classification. The aim is to classify an attitude (sentiment) in a text as positive or negative.

According to Atkins the extracted information from news sources is better for predicting the direction of stock volatility movements than the direction of price movements. Using a Latent Dirichlet Allocation (LDA) followed by a Naïve Bayes classification model, the accuracy achieved an increased value for predicting the stock's volatility of 56% [8].

Another approach predicts the daily stock price changes by using a deep neural generative model (DGM) of news articles. By creating a market simulation [9].

Besides, in the study of Y. Xie text mining and support vector machine was chosen to forecast the Chinese stock market. First, Chinese online news was analyzed by text mining technology and sentiment analysis as a basis for predicting the stock price by using a support vector machine (SVM). However, this approach was better for predicting a specific stock price than predicting the trend of stock [10].

Another relevant approach was shown by Evans. This study detected cashtags ($) on twitter and, by using classification models, classifies if a tweet relates to a stock exchange-listed company. They used twitter as a data source by claiming that investors share information and discussions about the stock market [11].

Based on the documented literature research and analysis, similar approaches can be identified, but with different thematic focuses. Similar to other studies is that the approach of this study is based on the thesis that news headlines have an impact on the stock price change [8], [9], [11]. However, exploring the relationship between tags (individual key words) of headlines and price changes in order to design a model of linking a headline to a price change is not tackled in the literature results presented.

Atkins’s approach of using LDA to model the semantic of the news is similar but used Naïve Bayes as a classification model, which shows a simplistic assumption. Therefore, the learnings of this analyzed study are being integrated but beyond that, the relationship between tags (individual key words) of headlines and price changes will be explored so it will lead to design a model linking a headline to a price change. This study explores therefore the use of neural networks. Especially in speech or image recognition neural networks are applied, since solutions in these fields are difficult to achieve with logical programming. To define a neural network, it can be stated that a network consists of at least one or more parallel working neurons. These neurons send information in directional connections using activation signals while each neuron receives one or more inputs and returns an output [12].

# Methodology

The aim of this study is to determine the relationship between published news, the publication time, and the changes in close stock prices. To accomplish this, a deep learning artificial neural network will be produced to automate the classification of tags and close price changes by predicting the price change with a random split of 60% as training set, 20% as validation set, and 20% as a testing set.

## Data Sources

The data sources differ between news and stock prices. For collecting news data, the open source API of “News” with different client libraries are chosen [13]. This API can be used for receiving articles form many news sources and filtering with different criteria, like a keyword. For this study, the Python client library is used to implement the News API into a Python application [14]. For stock prices, the API of Dukascopy is used, which provides historical stock prices and more [15]. The result is historical news and stock prices for the year 2019.

The collected data fit the Big Data characteristics by fulfilling the five “Vs” of Big Data [16]. The volume is limited to the time frame but can be extended to live data or a bigger time frame. The velocity can be identified as fast because considering the data via the open source API’s can be generated in less than a minute. The variety is limited to JSON data, so the challenges for integration, transforming or processing the data do not cause a serious challenge. The quality of the data is very high despite the sources are publicly accessible. Nevertheless, some invalid and noisy data are removed during the process of data Validation and Cleansing. This study focuses on the Close price, therefore the prices for open and more are removed. As a result, the data show high veracity and is analyzed effectively and quickly, so the value of the data, defined by the usefulness of the data, is very high.

## Procedure

First, the news must be transformed to serve as an input for the deep learning network. A possible solution is to manually annotate the sentence components of the news. Words can be represented as vectors of real numbers for the calculations in deep neural networks. This type of representation is also called *Word Embeddings*. This is, from a mathematical point of view, an embedding, a mapping, in which an object can be seen as a part of another object. Word Embeddings make it possible to transfer semantic meanings into a geometric space [17]. These semantic relationships are shown in the following illustrated example by assuming that v(x) is the corresponding vector for the word x [1]:

*v(Germany) – v(Berlin) ≈ v(France) – v(Paris)* 

Another approach is to automatically tag news with corresponding stock symbols. A tag refers to the marking of content. During this process, additional information is assigned to the news. Therefore, tagging gives information on a specific keyword, which makes the users search simple. Both approaches result in input data for the deep neural network, which explores a close price change. This study used the approach of tagging as followed:

First, each headline was transformed by replacing special characters, the text was cleaned, and common words like “and” were removed. Afterwards, a term-document matrix was built with the tag and the frequency (the tag update was found 162 times). Then, the average price differences from minute 1 to 15 were calculated for each tag and with the z-Score function *Z* normalized, so outlies are processed:

*Z =*  2

Also, the counts are normalized by using the z-Score function. Then, the normalized counts and price differences for each tag were summarized by using a weighted average. The following table shows the process of the transformation for the tag “update” for headlines with reference to Apple:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Tag** | **Default** | | **z-Score normalization** | | **Weighted average** |
| ***Count*** | ***Avg. price diff.*** | ***Count*** | ***Avg. price diff.*** |
| update | 162 |  |  |  |  |

Figure 1: Process of input transformation

Lastly, the top three tags by the weighted average for each headline are extracted. These three values, the current close price and volume at the pubdate of the news are the input for the deep neural network. The dependent variable is the actual price change which is concerning the correct comparison also transformed with the z-Score function. The following table summarizes the input for the deep neural network:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Input** | | | | | **Output** |
| ***Close price*** | ***Volume*** | ***Tag 1*** | ***Tag 2*** | ***Tag 3*** | ***Price difference*** |
| 150.163 | 822,766 | -0.1407 | 0.1759 | -0.0137 | -0.0678 |

Figure 2: Input variables for the deep neural network

This first row of this table represents a headline with the current close price, the volume and the top three tags with the weighted and normalized price difference. The last column represents the output variable as the normalized actual price difference.

Since this study focuses on stock price changes at the minute-level, all published news between 4 pm and 9:30 am are excluded because there is no market reaction when the market is closed. Also, all stocks are limited to the symbol “AAPL” and the news are filtered for Apple. This restriction provides that the selected approach can be evaluated in this study and will be developed and tested in a pilot project in a further research design with more stock symbols.

As a deep neural network, a multi-layer feedforward neural network is proposed to implement the defined inputs and to predict the close stock price change. The information in this network moves forward in one direction from the input nodes, through the hidden layers to the output nodes. This deep learning neural network has five input layers and one output layer (compare figure 2).

Concerning the deep neural network architecture and strategy, this study explores two approaches. The first approach is looking at the error between the predicted close price change and the actual close price change and is, therefore, about error minimizing. To detect the best architecture of the deep neural network in this approach, the permutation of the hidden layers and the number of epochs are tested. In detail, up to 3 hidden layers with a permutation of 5, 10, 20, 40, 80, 100, and 200 neurons and with different number of epochs (10, 100, 1000 up to 10,000) are created. As a result, this study will compare the *Mean Squared Error* of XXX different network structures.

The second approach is about a classification model accuracy. The model predicts a close price change for the incoming headline. But in this approach, it is explored if the predicted price change is positive (1), negative (-1) or no price change (0). Therefore, the prediction and the actual price changes are transformed into categories and the accuracy is the metric which is used as a binary classification model, the errors in relation to the test data set are divided into four categories: True positive (TP); True negative (TN); False positive (FP); and False negative (FN). This metric will be compared through the different architectures of the neural network.

# Results and discussion

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##### References

[1] D. Selivanov, “Linguistic regularities,” 2020. [Online]. Available: https://cran.r-project.org/web/packages/text2vec/vignettes/glove.html. [Accessed: 09-Apr-2020].

[2] J. M. vom Brocke, A. Simons, B. Niehaves, K. Riemer, R. Plattfaut, and A. Cleven, “Reconstructing the Giant : on the Importance of Rigour in Documenting,” *17th Eur. Conf. Inf. Syst.*, pp. 1–13, 2013.

[3] H. M. Cooper, “Organizing knowledge syntheses: A taxonomy of literature reviews,” *Knowl. Soc.*, 1988.

[4] O. B. Sezer, M. Ozbayoglu, and E. Dogdu, “A Deep Neural-Network Based Stock Trading System Based on Evolutionary Optimized Technical Analysis Parameters,” *Procedia Comput. Sci.*, vol. 114, no. 2016, pp. 473–480, 2017.

[5] A. Jayanth Balaji, D. S. Harish Ram, and B. B. Nair, “Applicability of deep learning models for stock price forecasting an empirical study on bankex data,” *Procedia Comput. Sci.*, vol. 143, pp. 947–953, 2018.

[6] A. Joseph, M. Larrain, and C. Turner, “Daily Stock Returns Characteristics and Forecastability,” *Procedia Comput. Sci.*, vol. 114, pp. 481–490, 2017.

[7] A. Culotta, “Towards detecting influenza epidemics by analyzing Twitter messages,” in *SOMA 2010 - Proceedings of the 1st Workshop on Social Media Analytics*, 2010.

[8] A. Atkins, M. Niranjan, and E. Gerding, “Financial news predicts stock market volatility better than close price,” *J. Financ. Data Sci.*, vol. 4, no. 2, pp. 120–137, 2018.

[9] T. Matsubara, R. Akita, and K. Uehara, “Stock price prediction by deep neural generative model of news articles,” *IEICE Trans. Inf. Syst.*, vol. E101D, no. 4, pp. 901–908, 2018.

[10] Y. Xie, “Stock Market Forecasting Based on Text Mining Technology: A Support Vector Machine Method,” *J. Comput.*, vol. 12, no. 6, pp. 500–510, 2017.

[11] L. Evans, M. Owda, K. Crockett, and A. F. Vilas, “A methodology for the resolution of cashtag collisions on Twitter – A natural language processing & data fusion approach,” *Expert Syst. Appl.*, vol. 127, pp. 353–369, 2019.

[12] J. Schmidhuber, “Deep Learning in neural networks: An overview,” *Neural Networks*. 2015.

[13] “News API Documentation,” 2020. [Online]. Available: https://newsapi.org/docs. [Accessed: 09-Apr-2020].

[14] M. Lisivick, “News API - python,” 2019. [Online]. Available: https://github.com/mattlisiv/newsapi-python. [Accessed: 09-Apr-2020].

[15] Dukascopy, “Dukascopy,” 2020. [Online]. Available: https://www.dukascopy.com/trading-tools/widgets/quotes/historical\_data\_feed. [Accessed: 09-Apr-2020].

[16] T. Erl, W. Khattak, and P. Buhler, *Big Data Fundamentals Concepts, Drivers & Techniques*. 2016.

[17] F. Chollet, “Using pre-trained word embeddings in a keras model.,” 2016. [Online]. Available: https://blog.keras.io/using-pre-trained-word-embeddings-in-a-keras-model.html. [Accessed: 09-Apr-2020].

[18] A. Severyn and A. Moschitti, “Twitter Sentiment Analysis with deep convolutional neural networks,” in *SIGIR 2015 - Proceedings of the 38th International ACM SIGIR Conference on Research and Development in Information Retrieval*, 2015.