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論文題目	Sentiment Analysis on Social Media for Stock Market Prediction (株価動向予測のためのソーシャルメディアの感情分析)		
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論文の内容の要旨

Sentiment analysis is important in academic as well as commercial point of views. It is a task to extract people's opinions, attitudes and emotions toward entities. There are many applications of sentiment analysis such as investigation of product reviews, opinion summarization and stock market prediction. Specifically, opinion mining in the financial domain could help to make an accurate algorithm for stock market prediction. The goals of this research are: (1) studying the aspect-based sentiment analysis to identify the polarity of an aspect term or aspect category in a sentence, (2) studying the sentiment analysis on the financial domain to predict the stock market.

We propose a new topic model, Topic Sentiment Latent Dirichlet Allocation (TSLDA), to infer the topics and their sentiments simultaneously. With the observation that the topics are usually represented by nouns, whereas the opinion words are the adjectives or adverbs, words in sentences are drawn from distributions depending on its categories: topic category, opinion category and others. In addition, different topics, which are represented by word distributions, will have different opinion word distributions. Finally, to capture the sentiment meanings such as positive, negative or neutral of the opinion words for each topic, we distinguish opinion word distributions for different sentiment meanings. TSLDA is used for aspect-based sentiment analysis as well as sentiment analysis for stock market prediction.

To identify the sentiment categories for aspect terms in the first goal, an unsupervised method “ASA w/o RE” is considered. This model calculates the sentiment value of the aspect by summing over the scores of all opinion words divided by their distances to that aspect.

However, the opinion words related to the aspects will have higher affection to the sentiments of them. We firstly extract the aspect-opinion relations by using a proposed tree kernel based on the constituent and dependency trees. Then, “ASA w/o RE” is extended as “ASA with RE” by integrating these aspect-opinion relations. The experiment results show that the integration of aspect-opinion relation extraction is useful for aspect-based sentiment analysis. Next, three supervised methods RNN, AdaRNN and our proposed PhraseRNN are investigated. RNN and AdaRNN convert a dependency tree of a sentence to a binary tree. PhraseRNN combines the dependency tree and list of phrases from the constituent tree to create a phrase dependency tree. This is further converted to a target dependent binary tree. In these three models, the representation model of the aspect is constructed by recursively combining the two child nodes into a parent node in bottom-up manner. The top node is used as the representation for the aspect and fed into a logistic regression to predict the sentiment category of the aspect. The results indicate that our PhraseRNN achieved better performance than unsupervised methods “ASA w/o RE” and “ASA with RE”. In addition, our PhraseRNN is better 5.35% accuracy and 7.89% F-measure than the ordinary RNN, 5.78% accuracy and 16.37% F-measure than AdaRNN. Therefore, our PhraseRNN is much effective than RNN and AdaRNN for the aspect-based sentiment analysis.

Two topic models JST and our TSLDA, are used to extract the sentiment for aspect categories in the first goal. By mapping the topics/sentiments inferred by JST or TSLDA to human topics/sentiments, the latent topics and sentiments are used to identify the aspect categories and their sentiments in each document. Our TSLDA outperforms JST model in almost all metrics in three datasets. As a result, our TSLDA is better than JST model for aspect-based sentiment analysis.

The second goal is to predict the stock price or movement using the sentiment analysis on social media. Stock price prediction is a very challenging task because the stock prices are affected by many factors. The Efficient Market Hypothesis and random walk theory said that it could not be predictable with more than about 50¥% accuracy. On the other hand, some researches specified that the stock market prices could be predicted at some degree. Around 56% accuracy are often reported as satisfying results.

With the assumption that integration of the sentiments from the social media can help to improve the predictive ability of models, we evaluate and compare three feature sets for stock price prediction and seven feature sets for stock movement prediction. Three employed methods to predict future stock prices are Price Only, Human Sentiment and Sentiment Classification.

The first method uses only historical prices. The second combines the past prices of the stock with the sentiments annotated by posters, whereas third method uses both human and automatically classified sentiments. The results of regression models indicate that these sentiments are not useful to predict the future stock price. For the stock movement prediction, in addition to three previous models, additional four features are used: LDA-based Method, JST-based Method, TSLDA-based Method and Aspect-based Sentiment Method. Latent topics are extracted in LDA-based Method, whereas both latent topics and sentiments are exploited in the JST-based Method and TSLDA-based Method. In Aspect-based Sentiment Method, not latent but explicit topics and sentiments that appear in the sentence are incorporated into the prediction model. In addition, to address the question how automatic sentiment analysis contributes the prediction, we evaluate the automatically identified sentiment against the human annotated sentiment. The results show that our TSLDA-based and Aspect-based Sentiment Method outperform others in terms of the accuracy. The average accuracy on prediction of 5 and 18 stocks of TSLDA-based and Aspect-based Sentiment method are 56.43% and 54.41%, respectively. Besides, our method is comparable to the method using manually annotated sentiments. Therefore, the automatic sentiment analysis can be the alternative of the manual annotation. In addition, the important contribution of our experiment is that we evaluate our method for many stocks (18 stocks) and for a long time period of the test set (four months).

In future work, a nonparametric topic model for TSLDA which can guess the number of topics and sentiments by itself will be explored. In aspect term polarity identification, we will investigate the way to learn the weight parameters in ``ASA with RE'' method from the training dataset to capture more accurately how the aspect-opinion relations contribute to the sentiment of the aspect. In addition, we will try to develop more sophisticated stock prediction model to also predict the degree of the change by setting more fine grained classes such as `great up', `little up', `little down', `great down' and so on.

Keywords: Text Mining, Sentiment Analysis, Opinion Mining, Stock Prediction, Social Media, Message Board, Tree Kernel, Topic Model, Recursive Neural Network, Support Vector Machine.

論文審査の結果の要旨

本論文は、株価の変動を予測するモデルを構築する手法について論じている。特に、過去の株価の変動履歴に加え、株の売買に関するウェブ上の掲示板に投稿されたテキストを取得し、人々が企業に対して肯定的あるいは否定的見解を持っているかを自動的に分析し、その結果を予測モデルに反映させている点に特徴がある。

まず、テキストから潜在的トピックとその感情極性(肯定的か否定的か)を獲得する Topic Sentiment Latent Dirichlet Allocation (TSLDA)と呼ばれる手法を提案した。従来手法がトピックと感情極性の同時確率分布を推定するのに対し、TSLDA ではトピック毎に感情極性の確率分布を推定するため、トピックに固有の肯定的・否定的なキーワードを学習できる点が優れている。

次に、株価変動予測モデルを構築するための基盤技術として、属性の感情分析手法を 2 つ提案している。ここでの属性とは、一般的に事物を評価する具体的な対象(パソコンにおける CPU やメモリなど)であり、株価変動予測においては企業の製品、サービス、収支報告などが該当する。1 つ目は、まず機械学習手法により属性と評価語の関係を自動的に抽出し、属性と関係を持つ評価語のスコアに高い重みを与えて加算することで属性の極性スコアを算出し、属性の極性を決定する手法である。もう一つは、ニューラルネットワークに基づく属性の感情分析手法 AdaRNN を拡張した Phrase Recursive Neural Network (PhraseRNN)である。AdaRNN では文の依存木のみの情報を用いるのに対し、PhraseRNN では、文の依存木と句構造木の両方の情報を利用することで解析精度を向上させている。

これらの研究を踏まえ、株価変動予測モデルを自動構築した。株価が上がるか下がるかを予測する分類器を Support Vector Machine により学習する。学習素性として、過去の株価の変動、掲示板上のテキストの感情分析の結果、属性の感情分析の結果(すなわち属性とそれに対する極性)、TSLDA によって推定されたトピックと感情極性のスコア、などを利用した。実験の結果、過去の株価の変動だけを用いるベースライン手法や、既存の属性の感情分析手法を利用した手法に比べて、提案手法が優れていることを確認した。

以上、本論文は、感情分析に関する新しい手法を複数提案し、それらを株価の変動を予測するタスクに適用し、優れた成果を示したものであり、学術的に貢献するところが大きい。よって博士（情報科学）の学位論文として十分価値あるものと認めた。