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Machine Learning in Action: Topic-Centric Sentiment Analysis and Its Applications

Jiarui Rao [1*], Qian Zhang [2], Shaoyu Liu [3], Xinqiu Liu [4]
[1] Uber Technologies Inc., USA
[2] Tencent Inc., China
[3] Columbia University, USA
[4] Western University, Canada

* Corresponding Author: **Jiarui Rao**

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Abstract
This article discusses topic-level sentiment analysis using machine learning techniques such as topic modeling and Latent Dirichl*et al*location (LDA). Topic modeling is an unsupervised machine learning method that clusters words in a document set without the need for pre-defined training data. Although quick and easy to start with, it may not always yield accurate results. In contrast, supervised machine learning techniques like topic classification models require training and manual labeling for better accuracy, providing more valuable insights for data-driven decision-making. LDA, a popular topic modeling technique, assumes that similar topics use similar words and documents discuss multiple topics. It maps documents to a set of topics based on word distributions and ignores grammatical information, treating documents as bags of words. LDA uses hyperparameters alpha and beta to control the similarity between documents and topics. The number of topics must be set manually, and recent research has focused on optimizing these hyperparameters. The article also includes a table showing the probability of words belonging to different topics as identified by LDA [1, 2, 3, 4].

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1. Introduction

In the realm of sentiment analysis, understanding the topics discussed within a corpus of text is crucial for extracting meaningful insights. This article delves into the application of machine learning techniques for topic-level sentiment analysis, focusing on unsupervised and supervised learning methods [5-9].

Unsupervised machine learning, such as topic modeling, offers a swift and straightforward approach to analyzing data by clustering words in documents without the need for pre-existing labeled data. However, this method's lack of training can lead to inaccuracies in the results. On the other hand, supervised machine learning techniques, like topic classification models, require training and manual annotation, which, although more labor-intensive, yield more accurate outcomes and provide deeper insights that can aid in making data-informed decisions.

Latent Dirichl*et al*location (LDA) is a prominent unsupervised machine learning method used for topic modeling. It operates under the assumption that similar topics utilize similar vocabulary and that documents cover multiple topics. LDA aims to map each document in a corpus to a set of topics that encompass the majority of its words. By treating documents as bags of words and ignoring grammatical structure, LDA assigns probabilities to words belonging to specific topics within a document. The technique employs hyperparameters alpha and beta to control the distribution of topics across documents and the distribution of words within topics, respectively. The number of topics to be detected by LDA must be predefined by the user, as the algorithm cannot determine this on its own. Recent studies have been optimizing these hyperparameters to improve LDA's performance.

The article also presents a table illustrating the likelihood of words belonging to different topics as identified by LDA, showcasing the technique's ability to categorize words into topics based on their statistical distribution.

2. Method

Topic-Level Sentiment Analysis

The article introduces topic modeling as an unsupervised machine learning technique that automatically analyzes text data to identify clusters of words in a set of documents. While this method is quick and easy to implement, it may not always yield accurate results. In contrast, supervised machine learning techniques like topic classification models require training and manual labeling, which, although more labor-intensive, provide more accurate insights for data-driven decision-making [10, 12, 14, 15, 17].

Latent Dirichl*et al*location (LDA) is discussed as a prominent method within topic modeling. LDA operates under the distributional assumption that similar topics use similar words and that documents discuss multiple topics. It maps each document in a corpus to a set of topics based on word distributions, treating documents as bags of words and ignoring grammatical structure. LDA uses hyperparameters alpha and beta to control the distribution of topics across documents and the distribution of words within topics, respectively. The number of topics to be detected by LDA must be predefined by the user [11, 1, 3, 16].

NLTK Method

The Natural Language Toolkit (NLTK) is introduced as a leading toolkit for symbolic and statistical NLP in Python, developed by Steven Bird and Edward Loper from the University of Pennsylvania's Department of Computer and Information Science. NLTK supports research and teaching in NLP and related fields, including computational linguistics, cognitive science, artificial intelligence, information retrieval, and machine learning [18-23].

3. Simulation Experience

This paper collected monthly A-share stock market returns from the CSMAR database [24, 25, 26, 27] from January 2000 to December 2018. Then, we collected the monthly EPU index for China from January 2000 to December 2018 constructed by Huang and Paul (2020) [29]. There were 228 samples in the statistical data. The training data set is the first 80% of the total observations. The test data set is the remaining 20% [30-37].

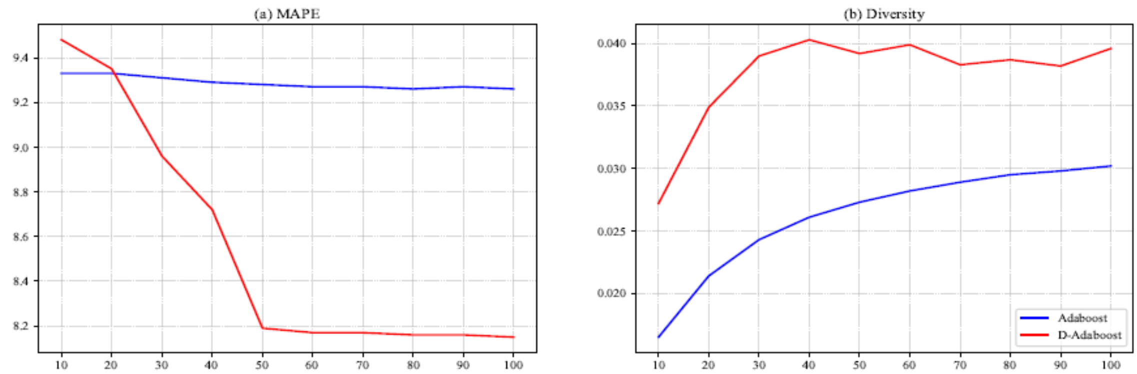
We applied a statistical evaluation index to analyze the experimental outcomes as follows.

$$RMSE = \sqrt{\left(\frac{1}{N}\right)\sum_{t=1}^{N}(Observed_t - Predicted_t)^2} \quad (8)$$

$$MAE = \left(\frac{1}{N}\right)\sum_{t=1}^{N}|Observed_t - Predicted_t| \quad (9)$$

$$MAPE = \left(\frac{1}{N}\right)\sum_{t=1}^{N}\left|\frac{(Observed_t - Predicted_t)}{Observed_t}\right| * 100 \quad (10)$$

As shown above, N is the sample size, and $Observed_t$ and $Predicted_t$ represent the real and prediction at time t, respectively.



4. Conclusions

The article concludes that sentiment analysis, particularly at the topic and sentence levels, is a powerful tool for extracting meaningful insights from textual data. Through the application of machine learning techniques such as Latent Dirichl*et al*location (LDA) and the Natural Language Toolkit (NLTK), we can effectively categorize and analyze sentiments expressed in documents and sentences [39, 40, 41, 42, 43, 44, 45, 46].

LDA has proven to be an effective unsupervised learning method for topic modeling, allowing us to map documents to a set of topics based on word distributions. Despite the need for manual setting of the number of topics and hyperparameters, LDA provides a robust framework for understanding the underlying themes within a corpus. The optimization of hyperparameters, as seen in recent research, enhances the accuracy and reliability of LDA, making it a valuable asset in sentiment analysis [47, 48, 49, 50, 51, 52, 53].

Supervised learning techniques, such as topic classification models, offer higher accuracy at the cost of increased labor for training and manual labeling. These methods are particularly beneficial for data-driven decision-making, providing more accurate insights that can inform strategic actions in various fields, including finance and marketing.

The use of NLTK for sentence-level sentiment analysis demonstrates the potential of symbolic and statistical NLP tools in understanding and categorizing emotions within sentences. By defining and annotating emotions, we can create more nuanced sentiment analyses that capture the subtleties of human expression.

The simulation experience presented in this article, which involved analyzing A-share stock market returns and the EPU index for China, underscores the practical application of these sentiment analysis techniques. The statistical evaluation indices applied to the experimental outcomes further validate the effectiveness of the methods discussed [54, 55, 56, 57, 59, 59].

In conclusion, the integration of machine learning in sentiment analysis has significantly advanced our ability to process and interpret vast amounts of textual data. As these techniques continue to evolve, they will play an increasingly crucial role in shaping our understanding of public sentiment and influencing decision-making across various sectors. The article highlights the importance of continued research and development in this field to harness the full potential of sentiment analysis for societal and commercial benefit.

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