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Leveraging Big Data for Sentiment Analysis: A Review of Techniques, Applications and Challenges

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Abstract
Sentiment analysis, a subfield of natural language processing, plays a crucial role in understanding public opinion, customer feedback, and social media sentiment. With the advent of big data, sentiment analysis has witnessed significant advancements in terms of techniques and applications. This paper presents a comprehensive review of leveraging big data for sentiment analysis, focusing on the techniques, applications and challenges employed in the field.

Keywords: Big data, Sentiment Analysis, Hadoop, Spark, Social Media

1. INTRODUCTION

The exponential growth of digital data in recent years has created a massive opportunity for extracting valuable insights and understanding public sentiment at an unprecedented scale. With the proliferation of social media platforms, online reviews, and other user-generated content, businesses, organizations, and researchers are increasingly turning to sentiment analysis techniques to gain deeper understanding and make data-driven decisions. However, analysing sentiment in large-scale datasets, often referred to as big data, poses unique challenges that necessitate the use of specialized tools and techniques.

In this paper, we aim to provide a comparative analysis of different tools for sentiment analysis tasks on big data.

Traditional sentiment analysis techniques, designed for small to medium-sized datasets, struggle to cope with the velocity, volume, and variety of data found in big data scenarios. As a result, researchers and practitioners have developed specialized tools and frameworks to handle the challenges posed by big data sentiment analysis.

In this study, we consider a range of popular tools and frameworks commonly used in big data sentiment analysis, such as Apache Hadoop, Apache Spark, and many more. Additionally, we explore various sentiment analysis techniques that can be employed in conjunction with these tools, including lexicon-based approaches, machine learning algorithms, and deep learning models.

By comparing these tools and techniques, we aim to provide insights into their performance, scalability, ease of use, and applicability to different big data sentiment analysis scenarios. The findings of this study will be valuable for researchers, data scientists, and practitioners seeking to navigate the complex

landscape of big data sentiment analysis. By understanding the strengths and limitations of different tools and techniques, stakeholders can make informed decisions regarding the selection and implementation of sentiment analysis approaches in big data environments.

2. LITERATURE REVIEW

A paper by Paulraj et al (2024)[1] introduces a novel Deep Learning Modified Neural Network(DLMNN) designed specifically for sentiment analysis on twitter data. The authors highlight the effectiveness of their model in handling the unique challenges os Twitters short and informal text. The DLMNN demonstrates superior performance in accuracy and computational efficiency compared to traditional methods, making it a valuable contribution to the field of sentiment analysis on social media platforms.

Alslarity and Orji (2024) [2] provide a comprehensive overview of the current state of machine learning techniques used for emotion detection and sentiment analysis. The paper discusses various challenges, such as the complexity of human emotions and the limitations of existing datasets. It also explores future directions, suggesting advancements in model architectures and data collection methods to improve the accuracy and applicability of emotion detection systems.

Xu(2024) [3] presents a real-time sentiment analysis framework based on the Bigura algorithm, applied to new media content. The study emphasizes the scalability and efficiency of the Bigura-based approach, which can process large volumes of data in real-time. This paper is particularly relevant for applications requiring immediate sentiment insights, such as monitoring public opinion during live events or breaking news.

The review paper by Umar et al(2024) [4] delves into various corpus-based approaches for sentiment analysis. It covers the advantages and limitations of different methods, providing a clear comparison of their effectiveness. The authors also discuss the importance of selecting appropriate corpora and highlight potential areas for future research in enhancing corpus- based sentiment analysis.

Jadhav and Saha(2023) [5] explore the application of Robotic Process Automation(RPA) in sentiment analysis of mobile app reviews. The paper demonstrates how RPA can automate the extraction and analysis of user feedback, providing valuable insights into user satisfaction and areas for app improvement. The integration of RPA with sentiment analysis offers a practical solution for handling large volumes of user-generated content efficiently.

Abubakar et al(2022) [6] propose a novel scheme of pairwise feature combinations to enhance sentiment classification accuracy. Using a book review dataset, the study demonstrates that combining features in pairs can capture more nuanced sentiment cues, leading to improved classification performance. This approach offers a significant improvement over traditional single- feature methods.

Raghunathan and Kandasamy(2023) [7] provide an exhaustive survey of the challenges and issues in sentiment analysis. The paper covers various aspects, including data preprocessing, feature extraction, and model selection. It also addresses practical challenges such as handling sarcasm, slang, and multilingual content. This comprehensive survey is a valuable resource for researchers looking to understand and overcome the obstacles in sentiment analysis.

Bordoloi and Biswas(2023)[8] conduct a detailed survey on the design frameworks used in sentiment analysis, along with their applications and future scopes. The paper categorizes existing frameworks and evaluates their effectiveness across different domains. It also identifies emerging trends and suggests future research directions to enhance sentiment analysis methodologies.

The paper by Umar et al(2022) [9] provides a beginner-friendly overview of sentiment analysis in the context of Web 2.0. it covers essential application, implementation tools, and approaches, making it an excellent resource for novice researchers. The authors emphasize the importance of understanding the fundamentals before diving into more advanced techniques.

Kumar et al(2023)[10] offer a comprehensive review of sentiment analysis, focusing on the various tasks, approaches, and applications. The paper is well-structured, providing insights into the different stages of sentiment analysis, from data collection to model deployment. It also discusses the latest advancements and potential future developments in the field.

Vergas-Sierra and Orts [11]examine the impact of COVID-19 on financial journalism through a corpus-based, cross-linguistic sentiment and emotional analysis. The study reveals significant changes in the tone and emotional content of financial news during the pandemic. This paper highlights the importance of sentiment analysis in understanding the broader effects of global events on media content.

Alves and Bekavac(2023) [12] analyze corpus-based word-order typological methods, providing insights into the systematic structures of different languages. The paper emphasizes the importance of word-order typology in improving natural language processing tasks, including sentiment analysis. This research contributes to the development of more robust and linguistically aware sentiment analysis models.

Munnes et al(2022) [13] compare various computational approaches for sentiment analysis of complex texts. The paper evaluates the strengths and weaknesses of different methods, providing valuable insights into their suitability for analysing intricate and nuanced content. This comparison helps identify the most effective approaches for specific types of sentiment analysis tasks.

Heidarypur et al(2023) [14] explore the application of corpus linguistics in the sentiment analysis of Persian texts. Using a Farsi news agency website as a case study, the paper demonstrates the effectiveness of corpus-based approaches in handling the unique linguistic features of Persian. The study highlights the importance of language-specific adaptations in sentiment analysis.

Ahmed, H. M, et.al [15], in their paper delves into an exploration of various methods and techniques for sentiment analysis on large datasets of Amazon Fine Food reviews. The Apache Spark data processing system is utilized for this purpose. They employed three mechanisms, namely Linear SVC, Logistic Regression, and Naïve Bayes, implemented using MLlib, which is Apache Spark's library for machine learning. Their findings demonstrate that when applied, these methods achieve an accuracy of over 80%. Notably, they observed that Linear SVC outperforms Naïve Bayes and logistic regression in terms of efficiency.

Mudassir Khan & et. al [16], introduced a novel approach to sentiment analysis, utilizing a combination of a Hadoop framework and a deep learning classifier. The Hadoop cluster is employed to distribute the data and extract relevant features from Twitter data. To classify the input data as positive or negative reviews, a deep recurrent neural network classifier, specifically designed for this task, assigned a real-valued review to each Twitter input. Performance analysis was conducted using various metrics such as classification accuracy, sensitivity, and specificity. In comparison to traditional methods, the proposed approach achieves significantly improved results, with a classification accuracy of 0.9302, enhanced sensitivity of 0.9404, and high specificity of 0.9157.

Thandaga Jwalanaiah, et al. [17], This article presents a new deep learning-based multimodal sentiment analysis (MSA) model using multimodal data such as images, text and multimodal text. The text analytic unit, the discretization control unit, the picture analytic component and the decision-making component are all included in this system. The discretization unit separates the text from the picture using the variant

and channel augmented maximally stable extremal regions (VCA-MSERs) technique, which are then analysed as discrete elements and fed into the appropriate image and text analytics units. The text analytics system utilizes a stacked recurrent neural network with multilevel attention and feedback module (SRNN-MAFM) to detect the sentiment of the text. A deep convolutional neural network (CNN) structure with parallel-dilated convolution and self-attention module (PDC-SAM) is developed to forecast the emotional response to visual content. Finally, the decision component employs a Boolean framework including an OR function to evaluate and classify the output into three fine-grained sentiment classes: positive, neutral and negative. The proposed work is simulated in the python platform using the STS-Gold, Flickr 8k and B-T4SA datasets for sentiment analysis of text and visual and multimodal text. Simulation outcomes proved that the suggested method achieved better accuracy of 97.8%, 97.7% and 90% for text, visual and MSA individually compared to other methods.

Vanam, H. [18], in their research paper, revolved around hashtag identification and determining the industry with the highest share of voice. To gather relevant data, they utilized live Twitter data through the implementation of Apache Spark. Subsequently, they employed machine learning techniques provided by the Apache Spark machine learning library to classify each tweet. In order to evaluate the model, we utilize Convolutional Neural Network (CNN) and logistic regression (LR) methods. The CNN method demonstrates superior performance compared to the Logistic Regression approach, achieving an average accuracy of approximately 95% and an F1 score of 0.60. The findings of this study indicate that real-time tweet evaluation using the Apache Spark tool for big data significantly outpaces traditional execution environments in terms of speed. Therefore, the results suggest that the Apache Spark tool for big data offers a much faster evaluation of real-time tweets compared to conventional execution environments.

The paper titled "NAGNet: A novel framework for real-time students' sentiment analysis in the wisdom classroom" by Zhu, H. & et. al.[19] (2023) presented a new framework called NAGNet for conducting real-time sentiment analysis of students' emotions in a classroom setting. The authors recognized the importance of understanding students' sentiments as it can greatly impact their learning experience and overall performance. NAGNet leveraged the power of big data analytics and machine learning techniques to analyze and interpret students' sentiment in real-time. The framework incorporated various data sources, including facial expressions, textual inputs, and physiological signals, to capture a comprehensive view of students' emotions. The authors described the architecture and components of NAGNet, which included feature extraction, sentiment classification, and real-time monitoring modules. They also provided experimental results to demonstrate the effectiveness and accuracy of the framework in accurately detecting and analysing students' sentiments. The paper concludes by highlighting the potential applications and benefits of NAGNet in improving teaching strategies and student engagement in the wisdom classroom

The paper titled "Robust optimization based extreme learning machine for sentiment analysis in big data" by Menakadevi, P., & Ramkumar, J. [20],(2022) focuses on sentiment analysis in the context of big data. The authors propose a novel approach that combines robust optimization and extreme learning machine techniques to perform sentiment analysis effectively. Sentiment analysis involves determining the sentiment or emotion expressed in textual data, which is crucial for understanding public opinion, customer feedback, and other applications. The authors address the challenges posed by big data by employing robust optimization to handle uncertainties and noise in the data. They also leverage extreme learning machine, a machine learning algorithm known for its efficiency and ability to handle large-scale datasets. The proposed approach is evaluated through experiments, and the results demonstrate its

effectiveness in achieving accurate sentiment analysis in the context of big data. The paper provides insights into the potential of combining robust optimization and extreme learning machine techniques for sentiment analysis and highlights their relevance in handling large-scale data in real-world applications.

Sun, S., & Li, L. [21], in their article aimed to explore the utilization of deep learning models on extensive datasets for semantic sentiment analysis. The primary focus was to address the challenges associated with comprehending natural language text. Natural language possesses complexity and ambiguity, making it difficult for computer programs to effectively tackle such problems. Additionally, the ever-evolving nature of language further compounds these difficulties. Furthermore, the peculiarities of Chinese language, such as text vectorization and Chinese word segmentation, present additional challenges. The article begins by introducing the recognition of relevant emotion words, primarily focusing on grammar construction and recognition methods. Subsequently, the study delves into semantic emotion analysis technology and concludes with the preprocessing steps involved in semantic emotion analysis. The experimental findings indicate that the W2V-Att-CNN model achieves the highest performance, scoring approximately 0.87. It is followed by the W2V-CNN model with a score of around 0.85, then the W2V-SVW model with a score of approximately 0.81, and finally the CBOW-SVM model with a score of about 0.77. Based on the results of the comparative experiments, it can be inferred that the W2V-Att-CNN model outperforms other models in terms of accuracy.

A Hybrid Lexicon-Naive Bayesian Classifier (HL-NBC) approach is introduced for sentiment analysis by Rodrigues et al. [22], in their study “A new big data approach for topic classification and sentiment analysis of Twitter data”. This study also presents a topic classification step before the sentiment analysis engine, which categorizes tweets into various topics and filters out irrelevant ones. The proposed method is evaluated against Lexicon and Naïve Bayesian classifiers using uni-gram and bi-gram features. Among the different approaches, the HL-NBC method demonstrates enhanced sentiment classification, yielding an accuracy of 82%, which surpasses the performance of alternative methods. Additionally, the proposed approach achieves faster sentiment analysis compared to traditional methods, showcasing a remarkable 93% improvement in processing time when dealing with larger datasets.

The paper titled "A novel adaptable approach for sentiment analysis on big social data" by El Alaoui, et al. [23], introduced a novel approach for sentiment analysis on big social data. Sentiment analysis is the task of determining the sentiment expressed in text, which is particularly challenging when dealing with large-scale social data. The authors propose an adaptable approach that addresses the limitations of traditional sentiment analysis methods in handling big data. Their approach combines feature selection, feature extraction, and classification techniques to accurately analyse sentiments. The authors also introduce a new sentiment representation model called Bag of Entities (BoE) that captures the syntactic, semantic, and sentiment information from social data. The proposed approach is evaluated using various benchmark datasets, and the results demonstrate its effectiveness in achieving high accuracy in sentiment analysis tasks. The paper highlights the adaptability and scalability of the proposed approach, making it suitable for handling big social data and improving sentiment analysis applications in areas such as social media monitoring, customer feedback analysis, and opinion mining.

Ragini, J. R., et al. [24], presented a novel approach utilizing big data for disaster response through sentiment analysis. The proposed model gathers data related to disasters from social networks and organizes them based on the requirements of affected individuals. Machine learning algorithms are employed to classify the categorized disaster data, enabling the analysis of people's sentiments. Different features, such as parts of speech and lexicons, are examined to determine the optimal classification strategy

for disaster data. The findings indicate that a lexicon-based approach is well-suited for assessing the needs of people during disasters. The practical significance of this methodology lies in its ability to categorize and classify social media big data in real-time, facilitating effective disaster response and recovery. This analysis empowers emergency responders and rescue personnel to develop improved strategies for managing rapidly evolving disaster environments.

3. FINDINGS AND COMPARISONS

3.1. Results and techniques used in reviewed papers

In this paper, we have reviewed findings of ten research articles and few of the results are presented in this section. "Sentiment analysis of online food reviews using big data analytics",[15], presents the evaluation in the form of Bar chart. The Fig1. is taken from the same article.

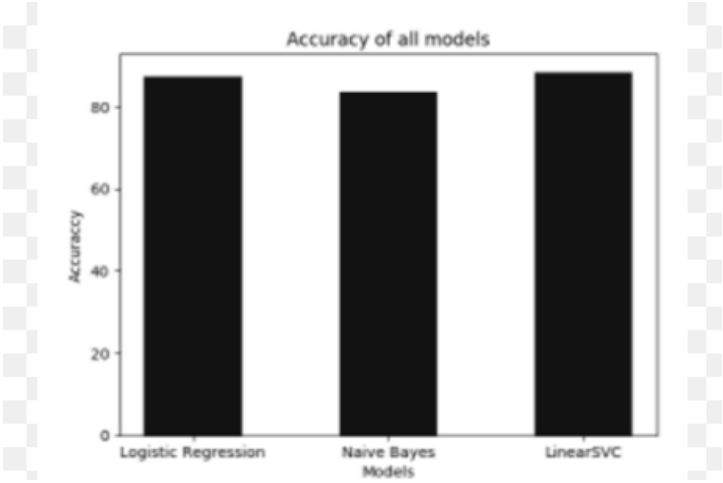

Fig. 1. Bar chart presented by Ahmed, H. M, et.al [15]

This study has concluded by saying Linear SVC performs better than Logistic regression and Naïve Bayes Algorithms.

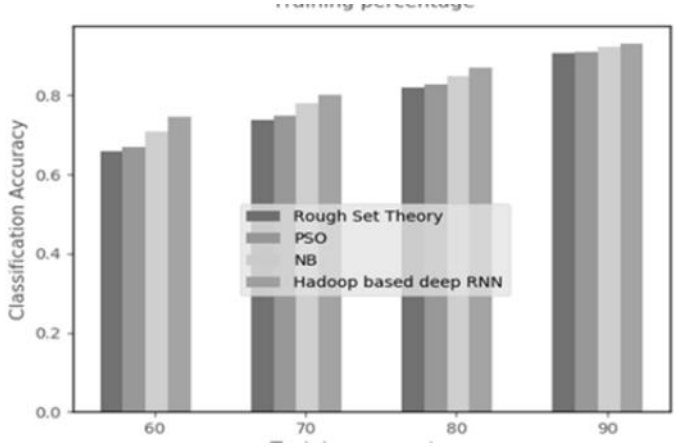

Fig. 2. Result presented by Mudassir Khan & et. al [16]

Fig 2 presents the result of the study "Big data approach for sentiment analysis of twitter data using Hadoop framework and deep learning" [16]. This article concludes that Hadoop based deep learning RNN method outperformed and gave maximum accuracy.

It is observed that, data can be fetched real time from social media site using Spark framework [15][16] and further processed using machine learning and Deep learning methods. Authors [22] have shown that tuning the parameters can change the accuracy and will produce better result.

Table. 1. provides a comprehensive comparison of all the reviews, offering a clear overview of their distinctive features and characteristics. As you can observe in this table, few of the studied fetched data real-time using Spark or Hadoop framework and processed data using Machine Learning and Deep learning algorithms. This table also highlights the algorithms used and their performances.

TABLE. 1. PERFORMANCE COMPARISON

Authors	Framework Used for data extraction and processing	Dataset	Mechanisms	Accuracy
Ahmed, H. M ,et.al [1]	Apache Spark	Amazon Fine Food reviews	Linear SVC, Logistic Regression, Naïve Bayes	Linear SVC with 80%
Mudassir Khan & et. Al [2]	Hadoop Framework	Twitter	Deep Learning RNN	93%
Thandaga Jwalanaiah,et, al. [3]	----	STS-Gold, Flickr 8k and B-T4SA	Deep Learning CNN	97.8%, 97.7% and 90% for text, visual and MSA individually
Vanam, H. [4],	Apache Spark	Live Twitter Data	Logistic Regression and CNN	CNN with 95%
Zhu, H. et al [5]	--	large-scale learner emotion dataset FERPlus	Res2Net+nonlocal attention+GeM Pooling	89.3%
Menakadevi, P., & Ramkumar, J. [6]	--	Large review datbase	Robust Optimization-based Extreme Learning Machine	Supreme
Sun, S., & Li, L. [7]	-	Some extensive dataset	W2V-Att-CNN, W2V-CNN, W2V-SVW, CBOW-SVM	W2V-Att-CNN outperforms with 87%
Rodrigues et al. [8]	-	Twitter	Lexicon and Naïve Bayesian classifiers using uni-gram and bi-gram features	Hybrid Lexicon-Naive Bayesian Classifier gives 93%
El Alaoui, et al. [9]	-	2016 US election	Bag of Entities (BoE) and machine learning tasks	High accuracy
Ragini, J. R., et al. [10	-	Disaster data	Machine learning algorithms	-

3.2 Notable Applications

1. **Twitter Sentiment Analysis**
- Enhanced sentiment analysis on Twitter data using deep learning modified neural networks for better accuracy and performance.
- Real time sentiment analysis focusing on processing large volumes of data swiftly.

2. **Emotion Detection and sentiment analysis**
- Applications of machine learning techniques for detecting emotions and sentiments in various contexts, including online reviews and social media.
- Sentiment analysis in financial journalism to understand the impact of global events like COVID-19.

3. **Mobile App Reviews**
- Automating sentiment analysis of mobile app reviews using RPA to efficiently process user feedback.

4. **Book Reviews and Complex Texts**
- Improving sentiment classification of book reviews by using pairwise feature combinations.

- Comparing different computational approaches for sentiment analysis in complex texts.

5. **Web 2.0 and Big Data**

- sentiment analysis in online food reviews using big data analytics
- topic classification and sentiment analysis of Twitter data using Big data approaches.

6. **Multimodal Sentiment Analysis**

- Utilizing deep learning for sentiment analysis from unstructured big data, integrating multiple modalities for enhanced insights.

7. **Educational and classroom settings**

- Real time sentiment analysis in classroom to gauge student sentiments using novel frameworks like NAGNet.

8. **Disaster Response and Recovery**

- Leveraging big data analytics for sentiment analysis to aid in disaster response and recovery efforts.

3.3 Challenges

1. **Complexity of Emotions**

- Accurately detecting and integrating complex human emotions remains a significant challenge, as emotions can be subtle and context dependent.

2. **Data preprocessing**

- Efficiently preprocessing large datasets to ensure quality and relevance is a common challenge, especially with unstructured data.

3. **Feature Extraction**

- Identifying and extracting relevant features from text data to improve sentiment classification accuracy.

4. **Handling Sarcasm and Slang**

- Developing methods to correctly interpret sarcasm, slang and other informal language that can distort sentiment analysis results.

5. **Multilingual Content**

- Addressing the difficulties in analysing sentiments across different languages and dialects, which may require language specific adaptations

6. **Real Time Processing**

- Ensuring real time sentiment analysis capabilities, especially for applications requiring immediate insights, such as monitoring public opinion during live events.

7. **Scalability**

- Scaling sentiment analysis models to handle vast amount of data efficiently without compromising accuracy or speed.

8. **Contextual Understanding**

- Improving model's ability to understand context, which is crucial for accurate sentiment analysis in complex and nuanced texts.

9. **Integration with big data Technologies**

- Seamlessly integrating sentiment analysis models with big data technologies and frameworks to handle large datasets effectively.

10. **Model Interpretability**

- Enhancing the interpretability of sentiment analysis models, making it easier to understand how decis-

ions are made and to identify potential biases.

11. Resource intensive

- Managing the computational resources required for training and deploying advanced sentiment analysis models especially deep learning-based approaches.

4. CONCLUSIONS

In conclusion, the paper titled "Leveraging Big Data for Sentiment Analysis: A Review of Techniques and Applications" provides a comprehensive overview of the various techniques, applications and challenges in sentiment analysis using big data. This paper emphasizes the importance of leveraging big data for sentiment analysis due to its potential to uncover valuable insights from vast amounts of textual data. The paper reviews different techniques such as HDFS frameworks, machine learning, and deep learning, highlighting their strengths and limitations in sentiment analysis tasks. It also explores various applications of sentiment analysis, including social media monitoring, customer feedback analysis, brand reputation management, and market research. This paper also presents the results shown in various studies. Overall, this paper serves as a valuable resource for researchers and practitioners interested in understanding the state-of-the-art techniques and applications of sentiment analysis using big data, ultimately driving advancements in sentiment analysis and its real-world impact.

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