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A Critical Review on Sentiment Analysis Based on Deep Learning Techniques

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Abstract*:*
Sentiment analysis, a vital task in natural language processing, has evolved significantly with the adoption of deep learning techniques. This review critically examines the current state of sentiment analysis based on deep learning methods, focusing on their performance, scalability, and challenges. We explore key deep learning models such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), Long Short-Term Memory (LSTM), and attention mechanisms. These models have shown remarkable improvements in sentiment prediction accuracy compared to traditional machine learning approaches. However, issues like data scarcity, interpretability, and computational complexity remain challenging. This review provides insights into existing solutions, evaluates emerging trends, and outlines future directions to enhance deep learning applications in sentiment analysis across diverse domains.

Keywords: Sentiment Analysis, Hybrid model, CNN, RNN, Deep Learning

1. INTRODUCTION

Sentiment analysis is a crucial task in natural language processing (NLP) that involves determining the sentiment expressed in a piece of text. It has wide-ranging applications, from analyzing customer reviews and social media interactions to gauging public opinion and market trends. Traditional sentiment analysis methods primarily focus on textual data, using techniques such as machine learning classifiers, lexicon-based approaches, and more recently, deep learning models like Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs). While these methods have achieved significant success, they often fall short in fully capturing the richness of human emotions, which are not only conveyed through text but also through audio and visual cues [1].

Incorporating multi-modal data—text, audio, and visual inputs—into sentiment analysis can provide a more holistic understanding of sentiment. For instance, the tone of voice and facial expressions can significantly alter the perceived sentiment of spoken or written words. This multi-modal approach can enhance the accuracy of sentiment analysis models, making them more robust and reliable. Sentiment analysis, the process of identifying opinions and emotions in text, has become a key application in natural language processing. With the rise of deep learning techniques, sentiment analysis has seen substantial advancements, particularly in its ability to handle complex and nuanced data. This paper provides a critical review of sentiment analysis based on deep learning models, highlighting their benefits, challenges, and potential for further improvements in various domains.

This research aims to develop a multi-modal deep learning framework for sentiment analysis, leveraging the strengths of LSTM networks for processing sequential text and audio data, and the VGG16 network for extracting features from images. By integrating these modalities, the proposed model seeks to capture a more comprehensive representation of sentiment. This paper presents the design, implementation, and evaluation of this multi-modal framework, demonstrating its effectiveness in improving sentiment analysis accuracy. Our experiments indicate that the multi-modal approach significantly outperforms traditional single-modal methods, highlighting the potential of multi-modal deep learning techniques in sentiment analysis.

Figure 1. Sentiment Analysis

2. BACKGROUND AND RELATED WORK

This work [1] the rating of movie in twitter is taken to review a movie by using opinion mining This paper proposed a hybrid methods using SVM and PSO to classify the user opinions as positive, negative for the movie review dataset which could be used for better decisions.

Authors [2] found that PSO affect the accuracy of SVM after the hybridization of SVM-PSO. The best accuracy level that gives in this study is 77% and has been achieved by SVM-PSO after data cleansing. On the other hand, the accuracy level of SVM-PSO still can be improved using enhancements of SVM that might be using another combination or variation of SVM with other optimization method.

Authors [3] perform sentiment analysis from the point of view of the consumer review summarization model for capitalists. Author's outlined several research concerns and possible solutions for the challenges that occur when performing sentiment analysis for raw online reviews. Using the hybrid feature extraction method proposed in this work, the input pre-processed reviews can be transformed into meaningful feature vectors, allowing efficient, reliable, and robust sentiment analysis to take place.

Authors [4] results show that sentiment analysis is an effective technique for classifying movie reviews. This analysis focused primarily on English-language movie reviews, and the models may not perform as effectively when applied to other languages due to linguistic variations and cultural differences. This study introduces a sentiment analysis approach using advanced deep learning models: Extra-Long Neural Network (XLNet), Long Short-Term Memory (LSTM), and Convolutional Neural Network-Long Short-Term Memory (CNN-LSTM).

Authors [5] Hybrid deep sentiment analysis learning models that combine long short-term memory (LSTM) networks, convolutional neural networks (CNN), and support vector machines (SVM) are built and tested on eight textual tweets and review datasets of different domains. %e hybrid models are compared against three single models, SVM, LSTM, and CNN. Both reliability and computation time

were considered in the evaluation of each technique. %e hybrid models increased the accuracy for sentiment analysis compared with single models on all types of datasets, especially the combination of deep learning models with SVM. %e reliability of the latter was significantly higher.

Authors [6] examine primary taxonomy and newly released multimodal fusion architectures. Recent developments in MSA architectures are divided into ten categories, namely early fusion, late fusion, hybrid fusion, model-level fusion, tensor fusion, hierarchical fusion, bi-modal fusion, attention-based fusion, quantum-based fusion and word-level fusion. A comparison of several architectural evolutions in terms of MSA fusion categories and their relative strengths and limitations are presented. Finally, a number of interdisciplinary applications and future research directions are proposed.

Authors [7] review the multimodal sentiment analysis by combining several deep learning text and image processing models. These fusion techniques are RoBERTa with EfficientNet b3, RoBERTa with ResNet50, and BERT with MobileNetV2. This work focuses on improving sentiment analysis through the combination of text and image data. The performance of each fusion model is carefully analyzed using accuracy, confusion matrices, and ROC curves. The fusion techniques implemented in this study outperformed the previous benchmark models. Notably, the EfficientNet-b3 and RoBERTa combination achieves the highest accuracy (75%) and F1 score (74.9%).

3. FINDINGS OF THE SURVEY

The review of sentiment analysis using multi-modal deep learning techniques reveals several key insights across various aspects of model development, data handling, and challenges in the field:

Enhanced Sentiment Understanding through Multi-Modal Integration: Traditional text-based sentiment analysis struggles to capture the full spectrum of sentiment expressed across different content types. By integrating multiple modalities such as text, images, and audio, multi-modal models can capture richer context and nuanced emotions. The fusion of these modalities provides a deeper understanding of sentiment, especially in cases where text alone may be ambiguous or lacking in emotional cues.

Deep Learning Models for Multi-Modal Sentiment Analysis: Various deep learning models have been applied to multi-modal sentiment analysis. Convolutional Neural Networks (CNNs) are primarily used for image and video data, Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks for textual and sequential data, and Transformer-based models for both text and multi-modal tasks. Feature fusion, cross-modal attention mechanisms, and late fusion strategies have proven effective in combining information from multiple modalities.

Feature Fusion and Cross-Modal Attention: Feature fusion techniques, which combine text, image, and audio features, have shown superior performance in multi-modal sentiment analysis. Cross-modal attention, where one modality helps guide the interpretation of another, has also emerged as a powerful method for aligning data from different sources and enhancing the overall sentiment prediction.

Challenges in Multi-Modal Sentiment Analysis:

Data Alignment: Synchronizing and aligning multi-modal data remains a significant challenge, especially when data from different modalities (e.g., text and video) are not temporally aligned.

Missing Modality: In real-world applications, it is common to encounter missing or incomplete modalities, which can lead to degraded performance in multi-modal models.

Computational Overhead: The computational cost of training deep learning models with multi-modal inputs is substantially higher compared to uni-modal approaches, making scalability a concern.

Table 3.1: Important Aspects of Multi-Modal Deep Learning in Sentiment Analysis

Aspect	Description	Models/Techniques	Challenges
Data Modalities	Integration of text, images, audio, and video for deeper sentiment analysis	Feature Fusion, Cross-Modal Attention	Data alignment, missing modalities
Deep Learning Models	Use of CNNs for images, RNNs/LSTMs for text, Transformers for multi-modal tasks	CNNs, RNNs, LSTMs, Transformers	High computational cost, data heterogeneity
Feature Fusion Techniques	Combining features from multiple modalities to enhance sentiment understanding	Early Fusion, Late Fusion, Cross-Modal Attention	Ensuring effective modality interaction, avoiding overfitting
Cross-modal Representation Learning	Relationships between text, audio, and visual data. Improves sentiment prediction accuracy.	Early Fusion, Late Fusion, Cross-Modal Attention	Ensuring effective modality interaction, avoiding overfitting

CONCLUSION

In conclusion, deep learning techniques have significantly advanced the field of sentiment analysis, offering superior accuracy and flexibility compared to traditional machine learning methods. Models such as CNNs, RNNs, LSTMs, and attention-based mechanisms have demonstrated remarkable capabilities in capturing complex linguistic patterns and improving sentiment classification. However, despite these advancements, several challenges persist. Data scarcity, model interpretability, and high computational costs are among the key limitations that hinder the widespread adoption of deep learning models in sentiment analysis. Furthermore, the need for large, diverse datasets to train these models and ensure generalizability across different languages and domains remains an open issue. Addressing these challenges will require the development of more efficient and explainable models, as well as strategies for transfer learning, data augmentation, and resource-efficient training. Future research should focus on improving model interpretability, reducing computational demands, and creating scalable solutions that can be applied to real-world applications, enabling broader adoption of deep learning in sentiment analysis.

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