Improving Aspect-Based Sentiment Analysis with a Deep Context-Aware Model

1. Introduction/Motivation

In the digital age, the exponential growth of online content has amplified the need for accurate and efficient analysis of user opinions. Aspect-level sentiment analysis has emerged as a crucial tool for extracting fine-grained sentiments tied to specific aspects within text. This technique holds immense value in applications such as customer feedback analysis, social media monitoring, and product reviews. However, the inherent complexity of aspect-level sentiment analysis presents challenges for existing methods, which often struggle with understanding contextual dependencies, capturing long-distance relationships between words, and interpreting implicit information embedded within text.

With the ever-increasing number of movies being produced globally, the volume of reviews has also grown substantially, reflecting the need for robust sentiment analysis. As of October 2024, more than 76 percent of Americans between the ages of 12 and 74 watched at least one movie in a cinema every year, further highlighting the scale and relevance of this domain. The IMDB dataset, comprising a vast collection of diverse movie reviews, serves as an ideal testbed for exploring aspect-level sentiment analysis due to its richness in language, contextual variety, and widespread use in benchmarking sentiment models. Contextual relationships are vital for accurately linking words to their meanings within sentences, especially in uncovering implicitly expressed aspects. By leveraging subtle contextual data and linking entities effectively, there is significant potential to enhance the accuracy of sentiment classification, offering meaningful insights in aspect-based sentiment analysis.

2. Problem Definition

Aspect-based sentiment analysis (ABSA) focuses on extracting sentiment towards specific aspects or entities within a given text. For instance, in the review, "I loved the movie's soundtrack, but the plot was terrible," aspect-level sentiment analysis identifies a positive sentiment for "soundtrack" (based on "loved") and a negative sentiment for "plot" (based on "terrible"). Such clear distinctions of sentiment polarity for specific targets within a single sentence illustrate the potential of aspect-level analysis. However, many existing works have focused primarily on examining aspect polarities in isolation, overlooking the subtle interplay between sentiment polarities and their local contexts. The challenge lies in capturing the dynamic and context-dependent nature of sentiment, where sentiment towards an aspect may change depending on surrounding words or aspects. This project seeks to address this gap by integrating a Deep Context-Aware Sentiment Analysis Model, incorporating advanced techniques like Hierarchical Attention Networks (HAN) and BERT embeddings to enhance sentiment detection at multiple granularities while considering contextual influences.

3. Proposed Method

In our approach to aspect-based sentiment analysis, we initially implemented a basic LSTM model on the IMDB dataset to capture sentiment polarity. However, this model did not fully capture the contextual complexities of sentiment within the reviews. To enhance the sentiment detection capability, we then explored the Deep Context-Aware Sentiment Analysis Model (DCASAM) with BERT embeddings and BiLSTM. This model showed improvements by incorporating pre-trained word embeddings from BERT and capturing sequential dependencies with BiLSTM, but still faced challenges in effectively identifying significant contextual information across reviews. To overcome these limitations, we propose an enhanced version of DCASAM, integrated with Hierarchical Attention Networks (HAN). The original DCASAM combines Deep Bidirectional Long Short-Term Memory Networks (DBiLSTM) with BERT which allows the model to capture sequential dependencies and complex relationships within the data. This architecture provides an improved, context-aware understanding of sentiment, particularly for longer and more intricate texts. Building on this foundation, we further enhance the DCASAM model by adding attention layers through HAN. The integration of Hierarchical Atten-

tion Networks incorporates multi-level attention mechanisms, which prioritize significant text segments at varying levels of granularity. This addition allows the model to focus on the most relevant aspects of the text, refining sentiment detection by giving greater weight to crucial parts of the input, such as aspect terms and their associated sentiments. We evaluated our enhanced model on the IMDB dataset, demonstrating its ability to capture complex sentiment patterns in movie reviews. The proposed model effectively addresses the limitations of previous approaches, providing a novel application of DCASAM+HAN for aspect-based sentiment analysis. Our findings contribute to advancing fine-grained sentiment analysis methodologies, offering a robust and adaptable framework for sentiment detection in various domains.

4. Intuition

The intuition behind the proposed method, DCASAM+HAN, lies in the need to enhance sentiment analysis by focusing on the most relevant parts of the text, which is achieved through the integration of Hierarchical Attention Networks (HAN). While the original DCASAM model, combining DBiLSTM and HAN, captures sequential dependencies and contextual relationships, it does not explicitly prioritize the most important segments of text for sentiment determination. The addition of attention layers through HAN addresses this gap by applying multi-level attention mechanisms that allow the model to focus on specific words and sentences, significantly improving the ability to capture nuanced sentiment. In sentiment analysis, especially in complex texts like movie reviews, not all parts of a sentence contribute equally to sentiment. By introducing attention layers, HAN enables the model to weigh these parts according to their relevance, thus improving the detection of sentiment toward specific aspects like "acting" or "plot." Recent works have shown improvements in sentiment analysis with models like BiLSTM or Transformer-based architectures, but they often lack the fine-grained focus on individual aspects that is crucial for accurate sentiment classification. HAN, by adding attention mechanisms at multiple levels (word and sentence), overcomes this limitation by allowing the model to dynamically prioritize important context, thus improving its ability to distinguish between mixed sentiments or identify subtle sentiment shifts. This is especially important in aspect-based sentiment analysis, where the sentiment polarity for different aspects can vary within a single review. We believe HAN is the best option because it allows the model to adaptively focus on key segments, making it more effective than traditional models that fail to capture such fine distinctions. In comparison to other models, the hierarchical attention mechanism in HAN enables a more context-aware and precise analysis, improving performance in both aspect-level sentiment detection and overall sentiment classification.

5. Experiments

The testbed for this experiment utilizes the IMDb dataset, which consists of 50,000 movie reviews labeled for binary sentiment classification (positive or negative). Since the reviews are already classified into positive and negative sentiment, it simplifies the training process by allowing the model to focus on aspect-based sentiment classification rather than having to classify the overall sentiment. The goal is to perform sentiment analysis on each aspect individually, categorizing sentiments as positive or negative for each specific aspect mentioned in the review. The experiment aims to evaluate the performance of aspect-based sentiment analysis models by measuring their accuracy in classifying sentiment for individual aspects and comparing them to models that do not consider aspect-specific sentiment. In the context of this testbed, accuracy serves as a critical metric to evaluate how well the model can correctly identify the sentiment associated with each aspect of a review. Since the IMDb reviews are already classified into binary sentiment labels, the accuracy metric directly reflects how effectively the models can differentiate and classify sentiment for specific aspects of the review. This allows for a deeper understanding of how well the models can capture nuanced sentiments for different aspects and whether advanced models, such as the Deep Context-Aware Sentiment Analysis Model (DCASAM) combined with a Hierarchical Attention Network (HAN), provide significant improvements in performance over base models.

5.1. List of Research Questions

1. Does the integration of a Hierarchical Attention Network (HAN) improve the accuracy of aspect-specific sentiment analysis in the Deep Context-Aware Sentiment Analysis Model (DCASAM)? 2. How well does the enhanced model (DCASAM + HAN) perform when handling reviews with multiple aspects compared to the base model (DCASAM)? 3. What is the performance of the DCASAM + HAN model compared to existing state-of-the-art models for aspect-based sentiment analysis?

6. Details of the experiments

In Experiment 1, we trained and tested an LSTM model using the Restaurant14 dataset. The accuracy achieved was relatively low compared to the IMDb dataset, primarily due to the smaller size of the Restaurant14 dataset, which limited the model's learning capability. Additionally, the domain-specific challenges of the dataset made it harder for the LSTM to capture complex patterns and sentiments effectively. In Experiment 2, we applied the DCASAM model to the IMDb dataset to evaluate its performance, but the accuracy was lower than that of the LSTM model on the same dataset. This suggested that DCASAM alone struggled with aspect-specific sentiment classification. Finally, in Experiment 3, we enhanced the model by integrating a Hierarchical Attention Network (HAN) with DCASAM (DCASAM + HAN) and tested it on the IMDb dataset. The accuracy improved over the DCASAM model, indicating that the integration of HAN helped the model focus on important words and sentences, leading to better aspect-level sentiment classification.

6.1. Observations

The observations across the three experiments highlight key insights into the performance of different models and configurations. In Experiment-1, the LSTM model trained on the Restaurant14 dataset achieved relatively low accuracy, influenced by the smaller dataset size and domain-specific challenges, which limited the model's ability to capture complex sentiment patterns. In Experiment-2, the DCASAM model applied to the IMDB dataset showed limited performance, with a test accuracy of 53.89 percent, indicating that it struggled with aspect-specific sentiment classification due to its inability to focus on critical elements of the text effectively. However, Experiment-3 demonstrated significant improvement with the integration of a Hierarchical Attention Network (HAN) into the DCASAM architecture, achieving a high test accuracy of 84.82 percent. This enhancement enabled the model to identify and emphasize important words and sentences, resulting in better generalization and improved aspect-level sentiment analysis performance. These results underscore the importance of incorporating attention mechanisms for effective sentiment classification in domain-specific contexts.

7. Conclusion

This research focused on enhancing aspect-based sentiment analysis (ABSA) by addressing the limitations of traditional models in capturing the complex, context-dependent nature of sentiment expressed in text. The study proposed an enhanced Deep Context-Aware Sentiment Analysis Model (DCASAM) integrated with Hierarchical Attention Networks (HAN) to improve sentiment detection across multiple granularities and better capture intricate contextual relationships in movie reviews. The results revealed that while the original DCASAM, with BERT embeddings and BiLSTM, improved sequential dependency capture, it still struggled to prioritize significant portions of the text. The DCASAM+HAN model outperformed the base DCASAM and traditional models, achieving an impressive 84.82 percent accuracy, compared to 53.89 percent for DCASAM. This success demonstrates the importance of contextual understanding and attention mechanisms for handling complex, multi-aspect reviews. The findings have broad implications for applications such as customer feedback analysis and social media monitoring, where nuanced sentiment understanding is crucial. In conclusion, the DCASAM+HAN model offers a robust solution for aspect-based sentiment analysis, advancing the field by capturing both sequential dependencies and critical contextual relationships, and providing a promising framework for future research and applications in varied textual domains.

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If a paper is accepted, the final camera-ready version can (and probably should) include acknowledgements. In this case, please place such acknowledgements in an unnumbered section at the end of the paper. Typically, this will include thanks to reviewers who gave useful comments, to colleagues who contributed to the ideas, and to funding agencies and corporate sponsors that provided financial support.

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