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Research Article

Enhancing Aspect Based Sentiment Analysis with a Hybrid Model for Hindi Language

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ABSTRACT

Sentiment analysis(SA) has become crucial in Natural Language Processing(NLP), allowing valuable perceptions from user-generated content. Aspect-based sentiment analysis(ABSA), focusing on identifying sentiment towards specific aspects, remains challenging, especially for resource-scarce languages like Hindi. Deep learning has proven effective for ABSA in English, but applying these techniques to Hindi presents challenges due to its complex morphology, limited labeled datasets, and contextual ambiguities. Pre-trained large language models, based on transformer architectures, have become standard for NLP tasks, valuable for low-resource languages. This paper introduces a hybrid model, Hi-BERT, combining rule-based aspect extraction with a transformer based multilingual BERT architecture for sentiment analysis. Hi-BERT addresses ABSA challenges in Hindi by integrating a POS tagger with a deep learning framework. The increasing prevalence of online reviews in Hindi necessitates more nuanced sentiment analysis to understand customer feedback effectively. Hi-BERT addresses this by focusing on aspect-level sentiment analysis, extracting aspects using POS tagging, and employing a pre trained multilingual BERT model for multi-class classification. This hybrid approach aims to improve ABSA accuracy in Hindi, offering valuable insights for businesses.

Keywords: ABSSA, Hindi Language, Deep Learning, Transformer Models, Hybrid Model

I.INTRODUCTION

In the field of NLP, sentiment analysis has become a crucial task that makes it easier to extract insightful information from user-generated data. However, aspect-based sentiment analysis—which focusses on determining sentiment towards particular attributes or traits of an entity—remains a formidable obstacle, especially for languages with limited resources like Hindi.[1] [2]

Prior studies have investigated a variety of methods for ABSA in Hindi, such as the use of conditional random fields, bidirectional long short-term memory models for aspect-term recognition, and deep learning architectures for SA.While these techniques have demonstrated encouraging outcomes, there remains potential for enhancement, particularly in effectively harnessing the synergistic strengths of distinct models to augment the overall performance. Sentiment analysis, alternatively mentioned to as opinion mining, enables businesses to analyze the emotions, opinions, and feelings expressed in textual reviews at different levels of granularity [23][35]. At the word level, it involves interpreting individual opinions about specific product features or services. For instance, in the statement "मैं फ़ोन की बैटरी के प्रदर्शन से खुश हूं," the sentiment is positive towards "बैटरी" aspect of the Phone model. Regarding phrase level, sentiment analysis detects opinions conveyed through multi-word expressions [24][25]. At the sentence level, it captures the overarching emotion a single sentence conveys. Sentiment analysis entails discerning the emotional orientation expressed within a text, which may manifest as positivity, negativity, or neutrality [10]. ABSA goes beyond sentiment analysis by identifying the sentiment towards specific aspects or topics in the text. Deep learning

techniques are effective in ABSA in English [13]. However, applying these techniques in Hindi languages is challenging due to the complex morphology, lack of labeled datasets, and contextual ambiguity.

ABSA investigates deeper than general sentiment analysis by identifying sentiments toward exact aspects within a text. While deep learning has proven effective for ABSA in English, applying these techniques to Hindi presents challenges due to its complex morphology, limited labeled datasets, and contextual ambiguities. Pre-trained large language models, based on transformer architectures and trained on vast datasets, have become the standard for Natural Language Processing tasks. These models are particularly valuable for low-resource languages like Hindi. While multilingual models can leverage related languages, research suggests monolingual models may outperform them with sufficient data. This paper introduces a hybrid model, Hi-BERT, combining rule-based aspect extraction with a transformer-based multilingual BERT architecture for sentiment analysis. Hi-BERT aims to address the challenges of ABSA in Hindi by integrating a POS tagger with a deep learning framework. The increasing prevalence of online reviews in Hindi necessitates more nuanced sentiment analysis to understand customer feedback effectively. Hi-BERT addresses this need by focusing on aspect-level sentiment analysis, extracting aspects using POS tagging, and employing a pre-trained, optimized multilingual BERT model for multi-class classification. This hybrid approach aims to improve ABSA accuracy in Hindi, offering valuable insights for businesses looking for to understand customer opinions and preferences.

In order to improve ABSA for the Hindi language, we develop a hybrid model in this study that combines the strengths of deep learning and lexicon-based approaches.

II. LITERATURE REVIEW

ABSA has been a key research focus for the past decade. While extensive work has been conducted on the English language, research on Indian languages is only just beginning. Researchers have to use lexicon-based, ML, and DL techniques for ABSA. In thischapter, we review the previous work in ABSA:

A multi-task end-to-end methodology was presented by Md. Shad Akhtar and associates, and it performs well on aspect-term withdrawal tasks. Interestingly, this method provides a 2% improvement on Hindi datasets and beats current laptop-domain approaches. In contrast to traditional single task systems that treat aspect term extraction and aspect sentiment classification as separate goals, creating and assessing separate models, the multi-task approach combines these tasks [22].

Hetal Gandhi et al. proposed two models for extracting aspect terms from Hindi reviews: a CRF model with a novel "Cluster-id" feature, and a Bi-LSTM model with a PoS vector. The CRF model with the novel feature achieved an F-measure of 42.71%, improving upon the baseline F-measure of 41.07%. With 5-fold cross-validation, the CRF model achieved an F-measure of 44.54%. The Bi-LSTM model with the PoS vector achieved an F-measure of 44.49% [33].

Shrivastava et al. created a corpus of Hindi movie reviews from websites, manually annotating them as positive, negative, or neutral. They proposed a GRU architecture designed using a genetic algorithm to classify the reviews into the three classes. Their GA-GRU sentiment analysis model achieved an accuracy of 88.02% [45].

Two ensemble models, mBERT-E-MV and mBERT-E-AS, based on Multilingual BERT were presented by Pathak A. et al. and performed better on Hindi datasets than the state-of-the-art models. Across four domains, they reported accuracies for aspect polarity categorization that ranged from 51.22% to 78.09%. mBERT-E-AS obtained accuracies ranging from 48.78% to 79.77% for aspect polarity classification and F1-scores ranging from 52.31% to 78.61% for aspect category detection in the same domains [23].

An ABSA system was proposed by S. Rani et al. that computes the general polarity of the phrase, creates a dependency network to assign sentiment to aspects based on the minimum distance, and uses a Hindi Dependency Parser to control the suggestion between aspect and sentiment terms. The system's accuracy on a corpus of movie reviews was 83.2% [31].

The study by T. S. Aparna et al. found that for ABSA tasks in Hindi, classification models with Word2Vec embeddings outperformed those with fastText embeddings. The LSTM model specifically fared better than other deep learning

and machine learning models, with 52.32% accuracy with fastText embeddings and 57.93% accuracy with Word2Vec embeddings. In general, models utilizing Word2Vec embeddings demonstrated superior performance compared to those using fastText embeddings. The final translated dataset comprised 5,989 sentences with 5,864 aspect terms [12].

Using a dataset of Hindi product reviews from 12 distinct domains and extra review datasets for cars and vehicles, V. Yadav suggested a machine learning-based solution for ABSA in the Hindi language. It's interesting to note that, with an overall accuracy of 54.05%, an unsupervised technique was discovered to significantly affect Hindi ABSA [39].

Using a Hindi language dataset taken from Twitter, V. Gupta et al. examined how well traditional machine learning approaches performed for SA. They investigated lexicon-based methods for emotion analysis in Hindi, including Hindi Senti-WordNet and NRC Emotion Lexicon, and suggested a domain-specific sentiment dictionary. In the end, they created a deep learning algorithm that combines CNN, RNN, and LSTM approaches to achieve 85% accuracy in identifying feelings from 23,767 Hindi tweets [28].

Arghya et al. addressed the shortcomings of existing Hindi aspect extraction datasets by proposing a parallel corpus created by translating the SemEval-2014 ABSA dataset into Hindi. They demonstrated that this new resource significantly improved the performance of baseline and state of the art models for aspect extraction in Hindi, with the best-performing model being the fine-tuned Seq2Seq4ATE model, which realized an F1 score of 66.28% [50].

In order to categorize opinionated social media texts in both Hindi and English, Kavitha et al. created a lexicon-based method that successfully classified reviews in both languages. In particular, in class, the lexicon-based method achieved an accuracy of 86.45%.

The summarized research highlights various approaches to ABSA across multiple domains and languages, particularly focusing on Hindi and English. Methods include using CRF, SVM, Naive Bayes, and advanced models like GA-GRU, Bi-LSTM, and Multilingual BERT. Results show varying levels of success, with F-measures and accuracy varying depending on the technique and dataset. Innovations such as multi-task systems, lexicon-based approaches, and feature selection methods have shown improvements in aspect term extraction and sentiment classification, particularly in resource-rich languages.

III. METHODOLOGY

A. Data Collection: The model under consideration utilized a domain-specific dataset comprised of mobile reviews for its training phase. Initially, the process entailed assembling a dataset from various origins, encompassing the IIT Patna Hindi dataset, social media channels, and Hindi news websites featuring mobile reviews. As depicted in Table 1, this compiled dataset comprises text samples annotated with sentiment polarities, classified into neutral multi-class categories, positive or negative. Additionally, Figure 2 illustrates the scale of the experimental dataset.

Table 1: Hindi labeled Dataset

Text	Sentiment
मेरे पास अब तक का सबसे अच्छा सेल फोन है।	Positive
फोन ठीक है और बहुत अच्छा प्रदर्शन कर रहा है।	Positive
फोन वाकई तेज है, चित्र बढ़िया है, बहुत बढ़िया उत्पाद।	Positive
मैं इस फोन को वापस करना चाहूंगा क्योंकि यह चार्ज नहीं होगा	Negative
इस फोन को कभी न खरीदें , मैंने देखा सबसे खराब फोन	Negative
फ़ोन बहुत बार हैंग हो जाता है, बिल्कुल भी संतुष्ट नहीं होता	Negative
लेकिन, सिर्फ 6GB वाले के लिए ही पैसे खर्च करना समझ आता है.	Neutral
डिस्प्ले ब्राइट है, रंग अच्छे मिलते हैं, सारा श्रेय पैनल को जाता है।	Neutral
फिंगरप्रिंट स्कैनर डिवाइस को अनलॉक करने में फास्ट था।	Neutral

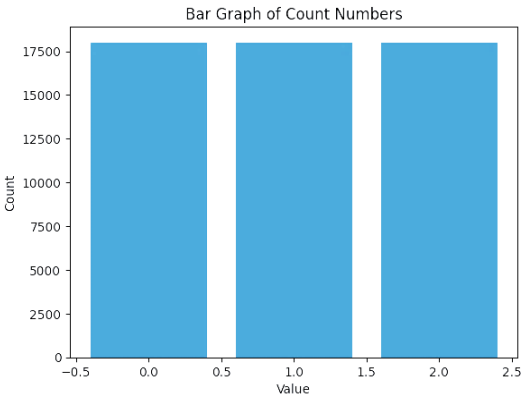

Fig 2: Size of labeled dataset

B. Data Pre-processing: In this stage, the data collected undergoes preprocessing, which involves several tasks [19]. These tasks include removing special characters, symbols, numbers, duplicate words, English words, stop-words, and sentences from the dataset. This preprocessing step shown in Figure 2, is crucial as it converts the raw text into a structured format suitable for training in deep learning models. By cleaning and standardizing the data, it becomes more manageable and consistent, facilitating the training process and improving the concert of the models [21]. Figure 3 shows the sequence of steps elaborate in the data preprocessing process.

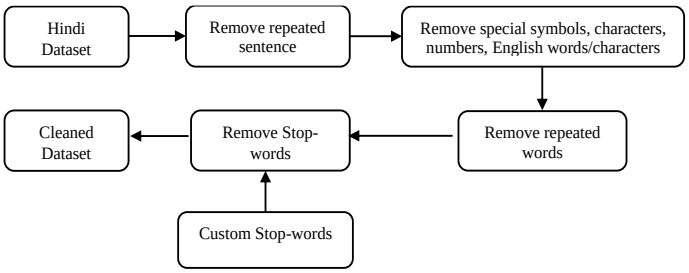

Fig 3: Process of cleaning data

C. Aspect Extraction: When conducting sentiment analysis on reviews written in Hindi, ABSA seeks to ascertain the opinions expressed regarding particular characteristics or aspects of a product that are mentioned in the reviews [51][52]. However, extracting these aspects from the text can be challenging, particularly in languages like Hindi where annotated data for training models is limited. The mentioned approach utilizes the concept of part-of-speech tagging for aspect extraction [41]. Trigram refers to a sequence of three consecutive words within a sentence. In this case, Trigram is used as a statistical tagger based on Hidden Markov models. The Trigram HMM POS tagger model is efficient and can be trained in various languages and tagsets. Table 2 shows the sample of extracted aspects from the text.

Table 2: Dataset with aspects

Final_Text	Aspect
शानदार फोन वास्तव में अच्छी बैटरी और कैमरे के साथ बहुत तेज।	बैटरी/ कैमरे
यह वास्तव में एक शानदार स्मार्टफोन है और मैं इसे फिर से खरीदूंगा	स्मार्टफोन
मेरा फ़ोन चार्ज नहीं होगा और यह एक टूटी हुई बैटरी के साथ आया है	बैटरी
मैं यह फोन लौटा रहा हूं ऑडियो खराब है इनकमिंग और आउटगोइंग कॉल दोनों।	ऑडियो
कैमरा चालू होने पर इसमें हीटिंग की समस्या होती है। बैटरी लाइफ अच्छी नहीं	कैमरा /हीटिंग/बेटरी
बकवास बैटरी बैकअप है	बैटरी
आईफोन एस इससे कहीं बेहतर है	आईफोन

It works by analyzing the context provided by the three-word sequences to identify aspects. Additionally, any unknown tagged words identified as aspects are added separately as features in the dataset for training purposes [16][17]. To enhance the accuracy of aspect extraction, the approach suggests removing aspect words if they resemble stopwords. By removing aspect words that resemble stopwords, the trigram HMM POS tagger approach aims to progress the precision of aspect extraction. Figure 4 shows the trigram HMM POS tagger model for aspect extraction.

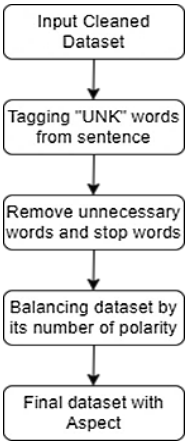

Fig 4: Process of trigram HMM POS tagger Aspect Extraction

D. Multi-class Classification: One effective approach for building such sentiment classifiers is to utilize deep learning transformer-based models, such as multilingual BERT [48][49]. BERT stands as a robust language representation model, having undergone pre-training on extensive text corpora. Its exceptional performance spans multiple natural language processing tasks, among which sentiment analysis is notable. A labeled dataset is used to train the sentiment classifier, and each feature is associated with the sentiment polarity that corresponds to it [38][39]. The sentiment polarity of each review aspect was carefully explained to build this dataset. A review mentioning "battery life" and expressing a favorable opinion on it, for instance, would be classified as a positive element. Additionally, if the review conveys a poor opinion of "customer service," it would be classified as such. During training, the sentiment classifier learns to associate features extracted from the text with the corresponding sentiment polarity labels [11]. This process involves fine-tuning the parameters of the pre-trained transformer-based model on the labeled dataset. The goal is to minimize the prediction error and maximize the accuracy of sentiment polarity predictions concerning the aspect. The complete work of the predictable model is shown in Fig. 4.6. This diagram outlines a process for ABSA using a combination of lexicon-based polarity detection, aspect term extraction, data preprocessing, and classification through fine-tuning a BERT model.

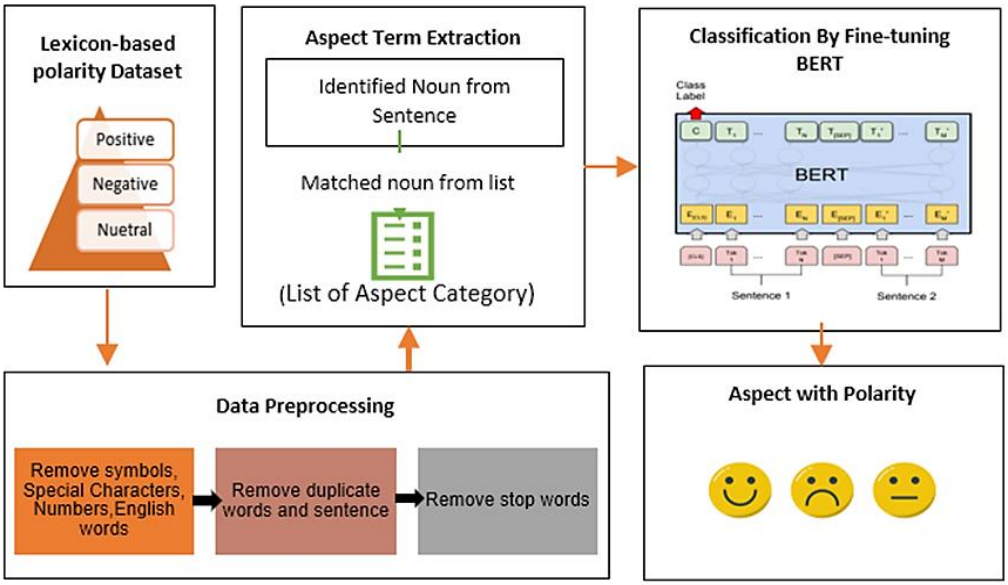

Fig 5. Process of Proposed Model

This integrated methodology merges the advantages of rule-based aspect term extraction, which provides precise identification, with the powerful contextual comprehension of BERT models to enable accurate sentiment classification. By seamlessly integrating these complementary components, this approach seeks to enhance the

overall performance of ABSA for the Hindi language, thereby addressing the complexities and resource constraints inherent to the language.

IV. RESULTS AND ANALYSIS

We rigorously evaluated the efficacy of our novel hybrid model through comprehensive experimentation on a carefully curated dataset for ABSA in the Hindi language. The dataset encompasses user reviews spanning multiple mobile product domains, with annotations denoting aspect terms and sentiment polarity.

The suggested Hi-BERT hybrid model combines a multilingual BERT model that has previously been trained for text classification with a rule-based method for aspect extraction. Applied to a dataset of 45,000 mobile reviews in Hindi, the model demonstrated outstanding performance, achieving an accuracy of 86.46%, an F1 score of 86.68%, a precision of 86.92%, and a recall of 86.46% in ABSA.

This model is unique due to its dual approach, which combines the advantages of a pre trained multilingual BERT for text classification with the trigram HMM POS tagger for aspect extraction. A comparison of the outcomes attained by various models as stated by the authors is given in Table 3.

Table 3: Comparative Analysis Sentiment Analysis Techniques

ABSA Techniques	Dataset Size	Accuracy (%)
Machine Learning (SVM) [1]	5417	54.05
mBERT-E-AS [29]	878	79.77
LSTM-based model [51]	5000	64.58
Hindi Dependency Parser [50]	NA	83.2
Manually built Hindi lexicon [49]	2717	86.45
NB,DT,SMO[6]	5417	64.84
Hi-BERT (Proposed model)	**45000**	**86.46**

A graphical representation of the obtained results is depicted in the figure 6 below:

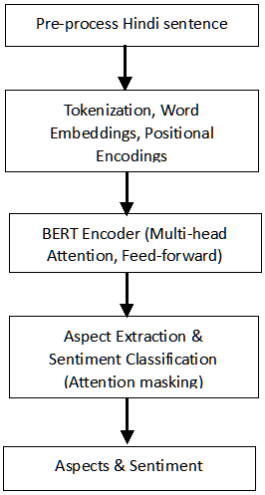

Fig 6: Proposed model of ABSA

The model's ability to recognize elements and the sentiments that go along with them for any given mobile review sentence shows how effective it is at analyzing sentiment for different mobile device characteristics. Figure 7, which shows an example output of the suggested approach, illustrates how the model's output appears when tested with actual reviews.

```
# Identify elements and emotions in sentence
sentence = ["यह फ़ोन की बैटरी बहुत अच्छी है।"]
aspect: बैटरी
sentiment: POSITIVE
```

Fig 7: A sentiment text with aspect

Consequently, the confusion matrix is displayed in Figure 8, and the precise values of the hyperparameters used in the training phase for each dataset are shown in Table 4.

Table 4. Fine-tune values used in the datasets

Dataset	Max Sequence Length	Batch Size	Learning rate	Training Epochs
Hindi: Mobile review	128	32	2×10^{-5}	7

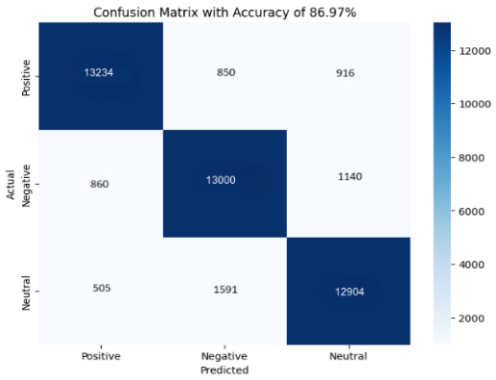

Fig 8: Confusion matrix for Mobile reviews

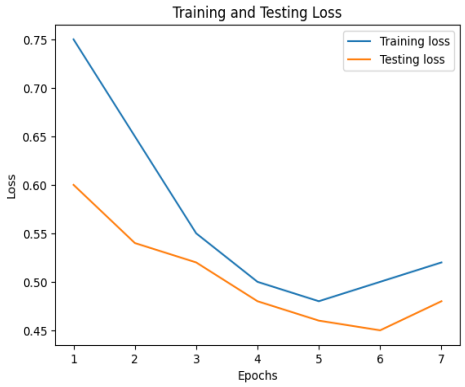

Fig 9: Hi-BERT Training and testing loss graph

The loss trends during the training and testing phases are depicted, highlighting how the models performed across different iterations shown in figure 9. The graphs serve to illustrate how effectively each model was able to learn from the dataset and generalize to unseen data, with an emphasis on the reduction of loss over time.

These results highlight Hi-BERT's proficiency in addressing the unique challenges of ABSA in Hindi, offering valuable insights for practical applications such as business intelligence and social media monitoring.

V.CONCLUSION

To improve ABSA for the Hindi language, we have presented a novel hybrid approach in this study called Hi-BERT, which combines the benefits of transformer-based SA with rule-based aspect extraction. Our extensive tests confirm that the recommended strategy outperforms current state-of-the-art techniques, exhibiting notable improvements in sentiment classification and aspect term extraction.

This research presents Hi-BERT, a hybrid model enhancing ABSA in Hindi by combining a trigram HMM POS tagger with the BERT model. The rigorous evaluation demonstrates Hi-BERT's efficacy, achieving 86.46% accuracy and outperforming existing methods. This underscores the model's strength in capturing nuanced sentiment expressions within Hindi text, addressing key challenges in ABSA for this language. The study's findings hold practical implications for diverse applications like business intelligence, customer relationship management, and social media monitoring, showcasing the value of advanced transformer models for Hindi sentiment analysis. Future research directions include refining the model, addressing domain-specific challenges, and incorporating ongoing BERT model enhancements to further improve sentiment analysis performance in Hindi.

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