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Hindi Sentiment Analysis: A Comprehensive Review of Research and Its Implications

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Abstract: ***Sentiment analysis in Hindi has become crucial for scholars, political analysts, and businesses due to the growing amount of Hindi content on digital platforms. This study discusses the unique challenges that the Hindi language shows, such as linguistic diversity, the use of both Devanagari and Roman scripts, and code-switching with English. Because of this complexity, effective sentiment classification requires specialized methods. This paper discusses a number of different approaches to analysing sentiment in Hindi, including lexicon-based approaches, deep learning strategies such as CNNs, LSTMs, and BERT, and machine learning models such as SVM and Naive Bayes approaches. To improve sentiment classification, a number of studies have used domain-specific dictionaries and Hindi-specific lexicons such as Hindi SentiwordNet (HSWN). Social media monitoring, consumer feedback analysis, and political sentiment analysis are among this research's beneficial applications. Despite these advancements, analysing code-mixed language and domain-specific sentiment remains challenging. Future research should focus on expanding Hindi lexicons to capture contextual and emotional subtleties, developing hybrid approaches that combine lexicon-based methods with deep learning, and creating specialized lexicons for politics, healthcare, and entertainment. Creating better Hindi and regional language sentiment analysis tools requires improving datasets and analytical approaches.***

Keywords: ***Natural Language Processing (NLP), Machine Learning (ML), Deep Learning (DL), Sentiment Analysis of Hindi Text, and Lexicon-based Approaches (LM).***

I. INTRODUCTION

Nowadays, we're in the internet era. It's called the Internet age because it has transformed how people share their thoughts and opinions [1]. Many of these ideas and opinions are circulated rapidly among internet users and mobile device users after being posted on social media. The method of determining whether a text conveys a neutral, negative, or positive feeling is known as sentiment analysis [2]. This technique examines the text to determine its polarity, applicable to entire documents, passages, sentences, or clauses [3]. Daily, millions of people worldwide express their ideas on social media, making it essential for understanding public sentiment for informed decision-making. Users express their opinions and emotions in their original languages on platforms such as Twitter, blogs, Facebook, and Instagram [4]. This constant flow of different input provides essential insights for corporations, political leaders, and organizations seeking to engage effectively with their audiences [5]. Sentiment analysis interprets these messages by classifying them into positive, negative, or neutral, so guiding improved marketing strategies, policy decisions, and community engagement initiatives. Sentiment analysis, a computational technique for assessing sentiments conveyed in textual data, has garnered increasing importance across various domains, facilitating a deeper understanding of public perceptions and attitudes [6]. Sentiment analysis has emerged as a leading area of research in the field of online text analysis. The explanation is to make sense of the information and grasp the sound of the information being given. There are various uses, ranging from product/customer care analysis to enhancing the organizational quality of service (QOS) to recognizing geopolitical motives as such news breaks.

On social media, people respond. It has been found that while they are emotionally charged and feelings take the form of textual material to vent, they do so in a way that is more analogous to a person's mother tongue [7]. Hindi is a language that is extensively spoken in India and is written using the Devanagari script. This study is aimed at correctly analyse thoughts expressed in Hindi, a language utilized by over 500 million people globally, making it one of the most widespread languages worldwide [8]. However, sentiment analysis in Indian languages poses unique challenges stemming from linguistic intricacies and cultural nuances, necessitating specialized methodologies [9**].** Natural language processing includes sentiment analysis, which is a key part of figuring out how people feel and what they mean when they write something.

As digital content on many platforms continues to grow quickly, sentiment analysis has become an important way to find out what people think, how customers are reacting, and what trends are happening on social media[11]. There is a noticeable lack of domain-specific investigation into sentiment analysis for Hindi, a prominent language written mostly in the Devanagari script, despite the fact that there has been significant research on sentiment analysis for other languages. Hindi is a language rich in culture, literature, and regional diversity, spoken by millions of people primarily in India and other parts of the world. However, despite its widespread usage, the computational analysis of sentiment in Hindi texts remains relatively underexplored compared to languages with more available resources and research attention. The different linguistic elements that are inherent to Hindi are the source of the complexity that is associated with sentiment analysis for this language. Furthermore, the scarcity of annotated datasets and lexicons tailored to Hindi poses a significant obstacle in the development of accurate sentiment analysis models. While existing sentiment analysis techniques can be adapted to handle Hindi texts, their effectiveness may be limited due to the unique linguistic characteristics of this language. This study aims to address gaps in sentiment analysis research by focusing on Hindi texts written in the Devanagari alphabet. By utilizing insights from linguistic analysis alongside computational techniques, we strive to create robust sentiment analysis models that are tailored to the unique complexities of the Hindi language.

II. LITERATURE REVIEW

TABLE 1 – LITERATURE REVIEW TABLE

Sr.. No.	Paper Title	Author	Year	Techniques/Keywords	Dataset	Accuracy/Result
1	Deep learning based bipolar sentiment classification of movie reviews in Hindi [12]	Ankita Sharma et.al.	2024	Bi-Polar Sentiment Classification, CNN_BiGRU Ensemble Model, 1D CNN, GRU, LSTM, NLP, Binary Classification	5,000 Hindi movie reviews	89.36%.
2	Deep Learning-Based Aspect Term Extraction for Sentiment Analysis in Hind[13]	Ashwani Gupta et.al.	2024	Deep learning, Bi LSTM, aspect-based sentiment analysis, aspect term extraction, Hindi, and Indian	-	91.27%
3	Optimized Hybrid Model for COVID-19 Vaccine Sentiment Analysis for Hindi Text[14]	Vipin Jain et.al.	2024	Sentiment Analysis, , Hindi Text, Hybrid Model ,Machine Learning , Deep Learning , CNN, GRU	Twitter- First Dataset: Timeframe: January 2021 to August 2021 Number of Tweets: 21,433 Second Dataset: Timeframe: March 2022 to July 2022 Number of Tweets: 14,689	95.54%
4	Optimizing Sentiment Analysis in Hindi Poetry: A Hybrid Model Unifying Deep Learning, Machine Learning, and Metaheuristic Techniques [15]	Vinod Kumar et.al.	2023	Sentiment analysis of Hindi poetry, CNN, LSTM, Random Forest, Naive Bayes, Logistic Regression, and Grey Wolf Optimization.	Hindi Poetry Sentiment Corpus	Hybrid Ensemble Accuracy: 95.54%; CNN: 91.46%; Random Forest: 87.75%; Naive Bayes: 85.54%
5	A Comprehensive Review of Sentiment Analysis on Indian Regional Languages: Techniques, Challenges, and Trends [16]	Sunil D. Kale et.al.	2023	Opinion mining, text mining, machine learning, sentiment analysis, and regional languages in India	-	Highlights challenges and future focus on advanced models and language-specific methods

6	Review Paper on Sentiment Analysis for Hindi Language [17]	Madhuri Thorat et.al.	2022	NLP, CNN, DNN, RNN, LSTM	-	Highlights dataset challenges and the need for algorithm improvements.
7	A Deep Learning Approach for Sentiment Analysis of COVID-19 Reviews [18]	Chetanpal Singh et.al.	2022	Sentiment Analysis, Deep Learning, LSTM-RNN	179,000+ tweets	Positive: 45%, Neutral: 30%, Negative: 25%
8	Sentiment Analysis of Amazon Product Reviews Using Machine Learning and Deep Learning Models [19]	Joy Chandra Gope et.al.	2022	Naive Bayes, Random Forest, Logistic Regression, CNN, BERT, XLNet	Amazon product reviews dataset (Kaggle or public Amazon reviews dataset)	89%
9	Hate Speech and Offensive Content Identification in Hindi and Marathi Language Tweets Using Ensemble Techniques [20]	Ratnavel Rajalakshmi et.al.	2021	Naive Bayes, Random Forest, Decision Trees, KNN, SVM, Logistic Regression, and XGBoost	Twitter dataset containing Hindi and Marathi tweets labeled for hate speech and offensive content	Random Forest: Marathi (75.19%), Hindi (73.12%); XGBoost macro F1 score: 46.5%.
10	E-Commerce Product Reviews Using Aspect-Based Hindi Sentiment Analysis [21]	Vandana Yadav et.al.	2021	SVM,machine learning algorithm	E-commerce product reviews in Hindi	54.05%
11	Learning Based 1 Approach for Hindi Text Sentiment Analysis Using Naive Bayes Classifier [22]	V. B. Parthiv Dupakuntla et.al.	2020	Naïve Bayes Classifier, NLP, Sentiment Analysis, Polarity.	Hindi text dataset	76.7%
12	Sentiment Analysis on Hindi News Articles [23]	Prof. Omprakash Yadav et.al.	2020	Sentiment Analysis, NLP, Computational Linguistics, Polarity	Hindi news articles dataset	83.29%
13	Sentiment Analysis of Hindi Text: A Review [24]	Manju Lata Joshi et.al.	2019	Naive Bayes Classifier, Neural Network, SVM	-	Naïve Bayes identified as optimal for Hindi sentiment analysis
14	Sentiment Analysis of Mixed Code For The Transliterated Hindi And Marathi Texts [25]	Mohammed Arshad Ansari et.al.	2018	NLP, KNN, SVM, Random Forest	Transliterated Hindi and Marathi texts	Marathi: 90%, Hindi: Below 70%
15	Hindi Sentiment Analysis [26]	Sumedha Ubale, et.al.	2018	Naive Bayes, Machine Learning, Hindi SentiWordNet (HSWN).	Hindi SentiWordNet (HSWN) dataset	Improved accuracy using Hindi SentiWordNet.
16	Sentiment analysis of Indian language [27]	Sheetal Sharma et.al.	2018	data mining and machine learning.	Indian language text datasets (general)	66.4%.
17	A Sentiment Analyzer for Hindi Using Hindi Senti Lexicon [28]	Raksha Sharma et.al.	2014	Senti Lexicon,Hindi WordNet	Hindi SentiLexicon (HSWN)	87%
18	Sentiment Analysis of Hindi Review Based on Negation and Discourse Relation [29]	Namita Mittal et.al.	2013	HSWN, Negation, Discourse	Hindi review dataset with negation and discourse relations	80.21%

Parul Sharma et al. (2016): They used SVM, Naive Bayes, and dictionary-based algorithms to classify tweets by sentiment. The SVM model predicted the BJP's victory with 78.4% accuracy, matching the 2016 election outcomes of 60 out of 126 constituencies. Sentiment analysis can help predict election outcomes, as demonstrated in this case [30].

Sandeep Rai et al. (2019): This study concentrates on sentiment analysis utilizing a Hindi code-mixed dataset comprising 10,362 agricultural reviews. The authors employed a bag-of-words representation and conducted a comparison of classifiers. LSTM demonstrated superior performance compared to CNN, achieving an accuracy of 71%. This research highlights the difficulties and possibilities associated with managing code-mixed text [31].

Soumya S. et al. (2020): Investigated sentiment analysis across Indian languages, including Bengali, Hindi, and Malayalam. For Malayalam, machine learning models like Random Forest achieved 95.6% accuracy using SentiWordNet and negation handling, demonstrating the robustness of language-specific models and feature engineering techniques [32].

Vedika Gupta et al. (2021): CNN, RNN, and LSTM models were used to research Hindi sentiment analysis using hybrid deep learning. Combining deep learning algorithms for sentiment classification achieved 85% accuracy on 23,767 tweets [33].

Ashish Lahase et al. (2022): Analysed Hindi movie reviews to classify sentiments into positive and negative categories. Pre-processing included POS tagging and PCA for feature selection. SVM achieved the highest accuracy (81.70%), demonstrating its effectiveness in sentiment analysis of textual data [34].

Vinod Kumar et al. (2023): Used a CNN-LSTM hybrid model—embedded Word2Vec—and Grey Wolf Optimization to do sentiment analysis on Hindi poetry. Compared to other models like Random Forest (87.75%) and CNN (91.46%), the model's accuracy of 95.54% is very impressive. This study demonstrates how domain-specific sentiment analysis can benefit from using advanced optimization methods [35].

III. TECHNIQUES AND APPROACHES IN HINDI SENTIMENT ANALYSIS

Hybrid, lexicon-based, and machine learning sentiment categorization methods are shown in Figure 1. Supervised learning models trained on labelled data is the most prevalent method for sentiment analysis. Lexicon-based methods use a sentiment lexicon of words. These can be built using dictionary-based or corpus based. The dictionary-based strategy captures more sentiment expressions by adding synonyms and antonyms to a set of seed words. The corpus-based strategy uses statistical or semantic methods to find new sentiment words from a smaller seed list in huge text datasets. Both strategies try to understand how context affects word sentiment. Combining lexicon-based and machine learning strengths can increase accuracy by exploiting linguistic knowledge and data-driven learning. Slang, sarcasm, and domain-specific language are difficult to handle with one strategy, but this combination improves. [36].

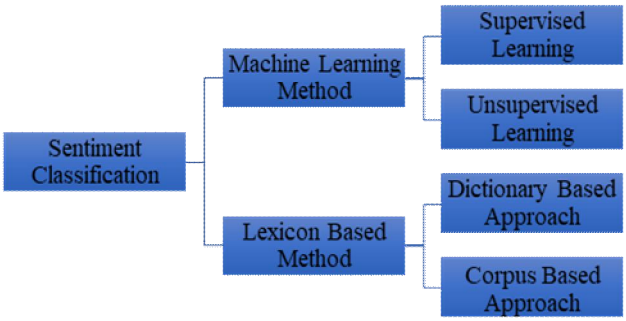

Fig 1. Hierarchy of Sentiment Analysis. [36]

IV. METHODOLOGY

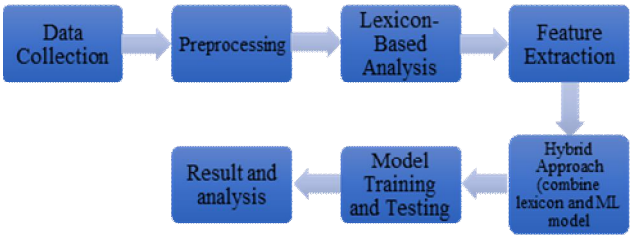

Fig. 2. Process Flow

1) Data Collection: - The process of data collection for Hindi sentiment analysis involves obtaining diverse datasets to cater to different contexts and domains. These include Hindi movie reviews, poetry-based datasets, and social media data like Hindi tweets. Annotated datasets like product reviews and domain-specific data, such as HDAD for agriculture, address specific needs. Multilingual datasets further enhance cross-lingual sentiment studies.
2) Pre-processing: - Preprocessing prepares text for sentiment analysis through various techniques that clean and structure the data to enhance its quality. Methods such as tokenization, stop word removal, and lemmatization are examples of preprocessing techniques that are included in these methods. These methods remove features that are not necessary and improve the overall quality and readability of the textual data. Specialized pipelines are employed to process English-Hindi code-mixed data, guaranteeing precise management of such hybrid text. Part-of-speech (POS) tagging helps with grammatical analysis by identifying the roles of words in sentences. Additionally, negation handling is applied to ensure precise interpretation of sentiments, especially in cases where negations alter the meaning of text.
3) Lexicon-Based Analysis: Lexicon-based analysis classifies text according to sentiment using predefined sentiment dictionaries. Domain-specific lexicons are used for more specialized classifications, while sentiment scores are provided by tools such as Hindi SentiwordNet (Sumedha Ubale et al., 2018) to detect polarity effectively. The accuracy and dependability of sentiment prediction are further improved by hybrid systems that blend machine learning techniques with lexicon-based methodologies.
4) Feature extraction: - Unprocessed text is transformed into numerical representations through the process of feature extraction, which can then be utilized for further research. Bag-of-Words and n-grams are techniques for capturing word frequency and contextual information in text. Word embeddings, like Word2Vec, go a step further by demonstrating words in a way that preserves their semantic relationships. Dimensionality reduction methods, such as Principal Component Analysis (PCA), improve computing efficiency by lowering the number of features while preserving critical information. These strategies are crucial in preparing text data for sentiment analysis.
5) Algorithm selection: - Sentiment classification relies heavily on machine learning algorithms. Because of its ease of use and effectiveness, Naïve Bayes is frequently employed for baseline comparisons. Support Vector Machines (SVM) effectively handle high-dimensional data, which is common in text analysis. Random Forests are robust and perform well in tasks such as hate speech detection. Long Short-Term Memory (LSTM) models have been developed to capture sequential dependencies in text, but Convolutional Neural Networks (CNN) excel in recognizing local patterns. The integration of CNN and LSTM in hybrid models capitalizes on the advantages of each, leading to enhanced performance in sentiment classification.
6) Model training and testing: - Usually, 80% of the available dataset is used to train the models, with the remaining 20% put aside for validation in order to evaluate the models' performance and generalizability to new data. Ensemble approaches, such as those that use mBERT for aspect-based sentiment analysis, aggregate outputs from several models to further increase prediction accuracy and model stability, leading to more robust and dependable sentiment classification.
7) Hybrid approach: - Hybrid approaches integrate multiple methods to tackle the complexities of sentiment analysis. Techniques such as combining CNN with BiGRU models, using optimization algorithms like Grey Wolf Optimization for feature selection, and integrating lexicon-based methods like Hindi SentiwordNet with machine learning algorithms significantly enhance sentiment analysis performance.
8) Review Results: - Recent improvements in Hindi sentiment analysis underline the transition from conventional machine learning models, such as Naive Bayes and SVM (65–80% accuracy), to more advanced deep learning methodologies. Hybrid models integrating CNN, LSTM, and BiGRU attain a maximum accuracy of 95.54%. Tools like Word2Vec, Hindi SentiwordNet, and Hindi WordNet enhance performance, though challenges with context, negation, and code-mixed texts persist. Hybrid models remain the most effective, while simpler models suit basic tasks. The literature emphasizes the importance of algorithm selection, model training, and the exploration of hybrid techniques to achieve better results in sentiment analysis for Hindi text. Combining multiple approaches, including machine learning, deep learning, and optimization methods, has proven to be effective in addressing the challenges in sentiment analysis, particularly for languages like Hindi.
9) Support Vector Machines: - Support Vector Machines, often known as SVMs, are highly effective classifiers that function by locating a hyperplane that divides data (for example, tweets) according to sentiment, hence increasing the margin between classes. SVMs are able to reduce the actual error, which can be defined as the likelihood of incorrectly categorizing new data [37]. The support vector machine (SVM) model employs a dual optimization problem in order to determine support vectors, which are the data points that have an effect on the hyper plane [38].

10) SVMs are able to handle huge feature spaces well without assuming that any features are useless, which reduces the amount of information that is lost. Due to the fact that they do not provide any insight into which features are most relevant for classification, they are considered a "black-box" model. However, they perform better than other methods such as k-NN. Although this is the case, support vector machines are utilized extensively for text classification, particularly automatic review classification [39].

11) Naïve Bayes classifier: - The Naive Bayes classifier is widely regarded as one of the most intuitive and frequently utilized algorithms in the field of machine learning, especially for text classification problems. Its core principle involves calculating the posterior probability that a given document belongs to a particular class by analyzing the distribution of words or features within the text. The fundamental assumption behind Naive Bayes is that each feature—typically a word or token—is statistically independent from the others, which, while a simplification, often yields surprisingly accurate results in practice. Using Bayes' Theorem, the classifier estimates the probability that a specific feature is associated with a given class, allowing it to predict the most probable class for unseen documents efficiently. This combination of simplicity, computational efficiency, and strong performance has made Naive Bayes a popular choice for tasks such as spam detection, sentiment analysis, and topic categorization [40].

This model employs the Bag of Words approach for feature extraction, operating under the assumption that each feature is independent from the others. This approach utilizes Bayes' Theorem to assess the probability that a particular feature is associated with a designated class.

$$P(label/features) = P(features/label) \times P(label)/P(features)$$

The term P(label) signifies the prior probability for a specific label, indicating the initial chance of that label appearing in the dataset before factoring in any feature details. In other terms, it shows the frequency or prevalence of a class within the overall data. When we look at a particular set of features, the conditional probability P(features|label) indicates the likelihood of seeing those features given that the document is assigned to that label. This illustrates how representative those features are for that specific class. Conversely, P(features) represents the probability of finding the specified set of features anywhere across the entire dataset, independent of the label. A significant simplification in the Naive Bayes method arises from the assumption that all features are mutually independent. This means that the presence or absence of a single feature does not influence the probability of another, which greatly simplifies the calculation process. Based on this independence assumption, the joint probability P(features|label) can be expressed as the product of individual feature probabilities conditional on the label. Though this assumption may be simplistic, it allows the model to compute probabilities efficiently and classify data with unexpectedly high accuracy, as represented in the equation [41]:

$$(label/features) = \frac{P(label).P(f1/label).P(f2/label) \ldots P(fn/label)}{P(features)}$$

V. CONCLUSION

Hindi text sentiment analysis is vital for understanding India's complex linguistic landscape. NLP and machine learning have improved sentiment classification, but Hindi's complex syntax, frequent code-switching with English, and scarcity of annotated datasets remain problems. In order to address these challenges, linguistic-based, machine learning, and deep learning models have been developed. Expanding datasets, addressing context-specific nuances, and processing mixed-language content should be priorities. Sentiment analysis outside English is essential for inclusive technological development and accurately reflecting India's large Hindi-speaking population, benefiting social media monitoring, market research, and policymaking.

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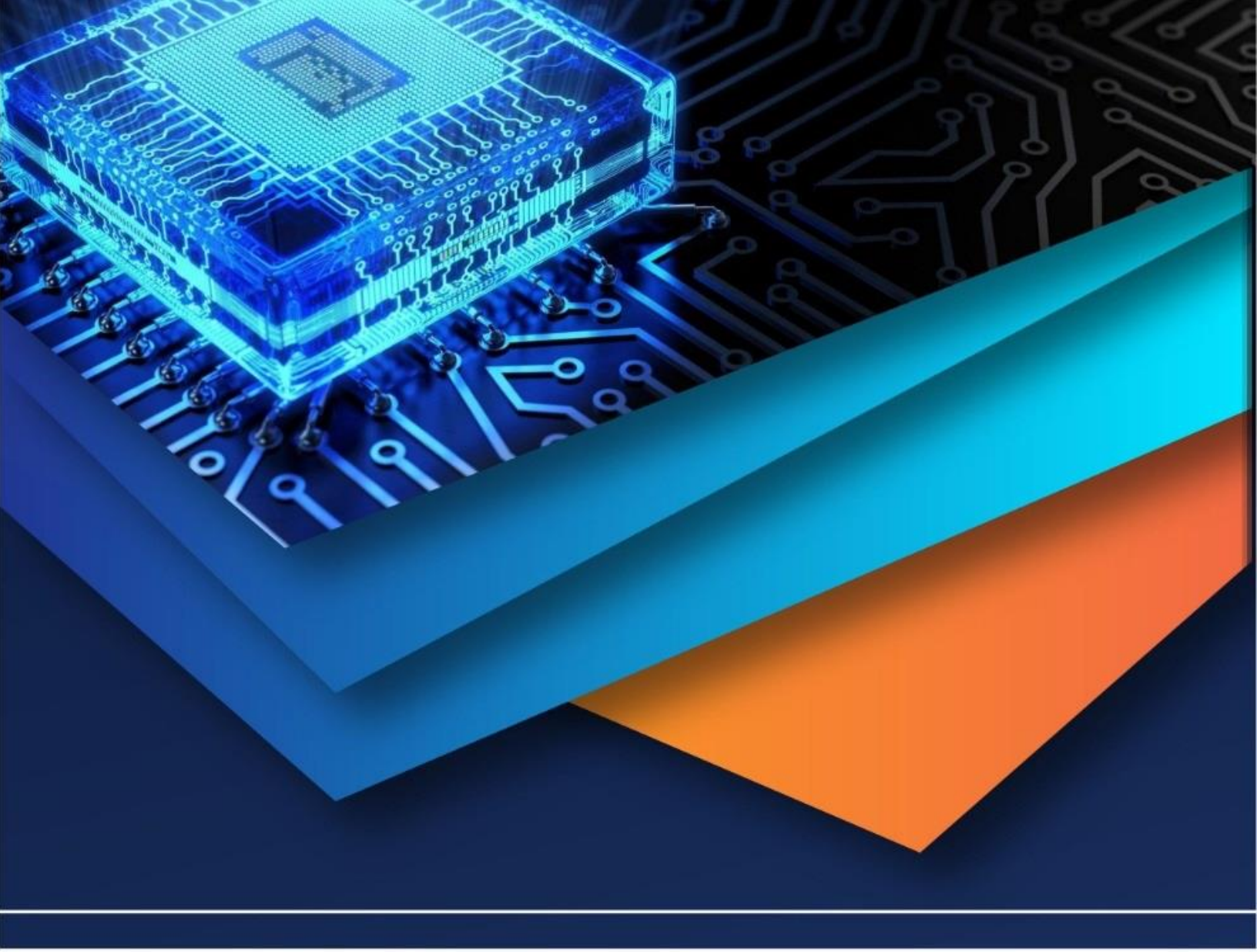

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