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Harnessing NLP for Automation and Intelligence Across Sectors

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Abstract

Natural Language Processing or NLP is a vital subset of Artificial Intelligence or AI which enables machines to interpret, understand, and communicate using human language in a remarkable way. From the traditional rule-based approaches to the modern advanced deep learning techniques such as transformers, neural networks, and hybrid models, NLP has been evolving year by year. This study reflects on various applications of NLP, including sentiment analysis, machine translation, analysis of electronic health records (EHR), identification of cybersecurity incidents, and training. The study also recognizes recent advancements in NLP, particularly in its convergence with AI and machine learning models, that have significantly improved its accuracy and effectiveness. While NLP holds great promise in several domains, heterogeneity of data, language model bias, ethical considerations, and computational complexity are some of the challenges still arising. The conclusion suggests that NLP has the ability to revolutionize sectors like healthcare, education, finance, and cybersecurity to provide automated, intelligent, and scalable solutions. The study also addresses potential research areas in the future that are focused on making NLP models more inclusive, ethical, and efficient.

Keywords: NLP (natural language processing), AI (artificial intelligence), deep learning, EHRs, BERT, GPT

INTRODUCTION

Natural language processing (NLP), a significant area of artificial intelligence (AI), examines how people and computers communicate using natural language.

Programming and Natural Language Processing

In the subject of computer science, languages are both well-established fields with a lengthy history of research. Despite the fact that they are both focused on the same thing, "languages", over the years, they have seldom interacted at all. This has prompted the incorporation of more complex NLP techniques, such as transformer-based models and deep learning, which use massive datasets to better comprehend context and semantic linkages. NLP methods have not only enhanced the accuracy of sentiment analysis but also provided the possibility for large-scale, real-time processing. Additional knowledge from social media could be revealed by enhancing these methods, which would also provide sentiment analysis with the status of a key decision-making tool across numerous industries.

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Numerous applications are made possible by the combination of EHRs with NLP, from enhancing clinical research to bettering patient outcomes through personalised medicine. In order to identify patients who are at high risk for specific illnesses, for example, NLP-driven analysis of EHRs can use pattern recognition and predictive modelling. This allows for preventive actions that may lessen problems. Furthermore, clinical practice's constant

learning and adaptation are facilitated by the constant flow of data from EHRs, which is crucial for changing healthcare delivery and bringing it into line with evidence-based practices.

NLP has enormous potential to revolutionise education. Teachers may establish more effective, inclusive, and engaging learning environments by incorporating NLP technology into their online courses and classrooms. NLP is changing how knowledge is taught and learnt, from intelligent tutoring programs that adjust to students' learning preferences to automated essay scoring that offers immediate feedback.

Sophisticated Natural Language Processing (NLP) methods have become effective instruments for dealing with these issues. Names and addresses may be understood and standardised across many forms and languages using NLP techniques, especially those based on deep learning. In order to convert inconsistent data into a standardised format, methods like tokenisation, fuzzy matching, entity identification, and semantic parsing are essential. The structure and growing popularity of common natural language processing (NLP) tasks (e.g., CoNLL, MUC, CLEF, PAN) show how essential tool evaluation has always been in the NLP community.

For example, phishing attempts frequently use carefully constructed messages that instil anxiety or a feeling of urgency, leading the target to act rashly and without doing adequate due diligence. Usually, these messages include subliminal linguistic clues, like inflated urgency or inconsistent tone or language, that might point to false intent. Through the analysis of vast amounts of harmful and valid information, NLP-based AI systems may be trained to recognise these indications and make the distinction between communications that are trustworthy and those that are not. Furthermore, AI models are especially well-suited to identifying new phishing tactics due to their capacity to continually learn and adapt using machine learning techniques. AI systems are capable of being updated in real-time when attackers modify their strategies, guaranteeing that they continue to be proficient in identifying novel social engineering techniques (Figure 1).

RELATED WORK/LITERATURE REVIEW

Within artificial intelligence, NLP is a discipline aiming to help computers understand and handle human languages. Deep learning and a large amount of both annotated and unannotated data have propelled natural language processing forward significantly in domains including machine translation, question-answering, and machine reading comprehension over the last 5 years. Used frequently in current NLP systems, we will define several fundamental neural network-based modelling approaches in the modelling section including word embedding, sentence embedding, and sequence-to-sequence modelling.

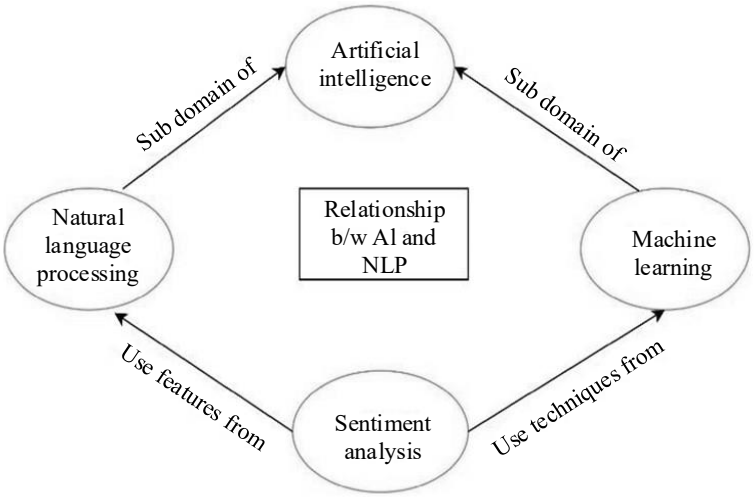

Figure 1. Relationship b/w AI and NLP.

Commonly used learning techniques for NLP models will be presented in the learning section, including supervised, semi-supervised and unsupervised learning, multitask learning, transfer learning, and active learning. Even if it has not been fully studied yet, we see logic as a fresh and intriguing road for neural NLP [1].

NLP has great promise for making computer interfaces more user-friendly, since people will (in theory) be able to speak to the computer in their own language, rather than needing to learn a computer command language. In the world of programming, however, the need for a formal programming language to talk to a computer has always been taken as a matter of course. We want to challenge this assumption. Our belief is that modern Natural Language Processing techniques can make natural language able to (at least partially) express programming abstractions, thus making programming much more accessible to non-expert users. To demonstrate the feasibility of Natural Language Programming, this study tackles what are considered some of the most difficult cases: steps and loops. We look at a set of English descriptions used as programming exercises and develop various ways of converting linguistic forms into program forms, that we refer to as programmatic semantics [2].

Active learning aims to reach high performance with a reduced number of training samples. It accomplishes this by repeatedly engaging an oracle to label newly chosen samples in a human-in-the-loop fashion. This method has seen a rise in popularity due to its wide-ranging applicability; however, survey papers on it, particularly regarding deep active learning (DAL), are still limited [3].

The quick and widespread creation of user opinions on social media platforms, especially Twitter, has made them essential resources for gauging public opinion. The ability to understand public views, emotional reactions, and patterns through sentiment analysis of Twitter data has drawn a lot of interest. This technique is useful in fields like public health, marketing, politics, and customer service. We provide a comprehensive study of sentiment analysis research utilising natural language processing (NLP) models in this work, with an emphasis on data from Twitter. Machine learning, deep learning, and hybrid models are among the approaches and methodologies that we cover, along with their benefits, drawbacks, and performance indicators. Transformer-based architectures like BERT, GPT, and others are among the important NLP models that are frequently used, according to the review. Furthermore, the impact of sentiment lexicons, feature extraction strategies, and preprocessing techniques on sentiment analysis efficacy is evaluated in this study. Insights into new patterns, a thorough review of present approaches, and recommendations for future advancements in the field of sentiment analysis on Twitter data are all intended to be provided by findings [4].

Large language models (LLMs) have developed into intelligent agents with their own objectives and methods for interacting with humans, moving beyond simple tools [5]. This progression gave rise to a new paradigm in natural language processing (NLP), known as human-model cooperation, which has shown impressive results in a variety of NLP tasks in recent years. We begin by providing a comprehensive analysis of human-model cooperation in this work, examining its tenets, formalisations, and unresolved issues. Specifically, we present a novel taxonomy that offers a cohesive viewpoint for summarising current methods. We also go over possible frontier regions and the difficulties that come with them. We see our work as a first step towards additional groundbreaking studies in this field [6].

When it comes to NLP applications like machine translation and text classification, transformer-based models have produced impressive results. However, their resource requirements and computational complexity make them difficult to scale and make accessible. To overcome these drawbacks, this study suggests a hybrid quantum-classical transformer model that incorporates a quantum-enhanced attention mechanism. The model improves computational efficiency while capturing complex token dependencies by utilising variational quantum circuits (VQC) and quantum kernel similarity [7, 8].

Human capital (HC) is the collective tacit knowledge that is embedded in people's minds. HC is acknowledged as a crucial resource that fosters innovation and strategy renewal. As people move into and out of HC, they carry their abilities, skills, and implicit knowledge, demonstrating the temporary nature of HC. Given that HC is a major contributor to long-term competitive advantage, this instability emphasises how crucial it is for businesses to actively develop and nurture it. This study makes the case that neuro-linguistic programming (NLP) has a great deal of promise for improving and developing HC in a variety of settings. NLP was developed at the University of California in the 1970s and asserts that the three primary representation systems: visual, auditory, and kinaesthetic (VAK), are used to encode subjective experiences [9].

Significant gains in educational results are being made as a result of the revolution in teaching and learning methods brought about by the incorporation of Natural Language Processing (NLP). This study examines how NLP technologies are revolutionising a number of facets of education, such as automated evaluation, intelligent tutoring programs, and personalised learning. Teachers are now able to provide individualised learning experiences that are catered to the particular requirements of every student by utilising cutting-edge NLP techniques like sentiment analysis, machine translation, and text summarisation.

NLP-powered automated grading systems improve students' learning by giving them timely, consistent feedback while also relieving teachers of some of their administrative duties. Additionally, NLP-enabled intelligent teaching systems may have interactive conversations with students, providing in-the-moment support and encouraging a deeper comprehension of challenging ideas. The introduction of NLP in education presents a number of ethical and practical issues, including data privacy and algorithmic bias. This study demonstrates how NLP may be used to develop more inclusive, effective, and efficient learning environments through a thorough analysis of recent research and case studies, eventually changing the face of teaching and learning [10].

Natural Language Processing (NLP) has developed extremely fast and become central component in several areas, such as human-computer interaction (HCI), artificial intelligence, and multimodal systems. In the case of 3D interfaces, NLP can revolutionize the way people interact with computer models, allowing for more intuitive, flexible, and natural virtual environment manipulation. The emphasis is on how NLP can facilitate collaboration, enhance user experience, and make it possible to have more dynamic, contextual interactions in 3D environments. The challenges that include the intricacies of natural language understanding, the sophistication of human communication, and the technological needs to achieve seamless integration will also be addressed. In addition, the study will make suggestions for future directions in NLP for 3D interfaces, proposing a vision of more intelligent, adaptive, and human-oriented modelling environments [11, 12].

In today's environment, sentiment analysis has become a crucial tool for making investing decisions. It processes unstructured text data, such as news articles, analyst reports, and social media updates, to provide beneficial insights into market mood.

NLP's revolutionary influence on sentiment analysis is discussed in the study, which highlights how it can process massive amounts of financial language and extract useful information for investors. The use of NLP in finance has revolutionised sentiment analysis through the use of advanced techniques including transformer-based algorithms like BERT, tokenisation, and word embeddings. NLP technologies facilitate a deeper understanding of investor mood and market trends by deciphering complex financial jargon and implicit emotions. By facilitating sentiment scoring, predictive modelling, and real-time evaluation, these technologies give traders and portfolio managers a competitive edge when developing data-driven trading strategies. The effectiveness of sentiment analysis driven by NLP in improving risk management, investment planning, and decision accuracy are important lessons learnt. The study also compares traditional and AI-powered approaches, demonstrating how NLP is more suited and scalable for handling high-dimensional financial data [13].

The growing amount of clinical documentation, biological literature, and electronic health records (EHRs) during the last few years has presented both a burden and an opportunity to enhance healthcare. Natural language processing (NLP) techniques used in biological text mining may effectively replace valuable insights gleaned from unstructured biological data. The study examines how NLP models support data-driven medicine, which prioritises simple tasks like text categorisation, connection extraction, and named entity recognition (NER). We demonstrate how domain-specific natural language processing (NLP) models, such BioBERT and ClinicalBERT, are taught to handle the intricacies of biological language, including confusing terms and technical jargon. Pharmacovigilance, clinical decision assistance, and drug recovery and discovery are just a few of the medical applications for biomedical text mining. NLP models streamline the identification of important patterns from extensive biological records, enabling more knowledge-based decision-making, better patient outcomes, and accelerated personalised medicine research [14].

Given how quickly the healthcare industry is changing, the combination of AI and NLP has the potential to completely transform data analysis and decision-making. The current approaches to illness diagnosis, personalised medicine, treatment recommendations, and resource optimisation in the Internet of Medical Things are rather varied and include methods such as data-driven solutions, rule-based solutions, and machine learning techniques. However, the majority of these systems have limitations when it comes to managing complicated clinical situations in terms of accuracy, scalability, and adaptability. For the benefit of IoMT, this study examines the synergistic advantages of NLP technology and AI optimisation methods. The solution we propose below combines modern data analytics techniques with natural language processing (NLP) capabilities to improve personalised medicine, streamline illness detection, offer treatment suggestions, and maximise resource allocation [15].

Web-based systems provide appropriate experimental settings for building and reusing pipelines for natural language processing (NLP). However, because there are few appropriate experimental platforms for building and reusing NLP pipelines, systematic testing of NLP tools in an open research web-based context remains a challenge. This study introduces TextFlows, an open-source web-based platform that makes it simple to build, share, run, and reuse natural language processing pipelines. By combining seven open source, publicly available part of speech (POS) taggers from well-known NLP libraries and testing them on six annotated corpora, it shows how simple it is to use TextFlows for the systematic testing of new NLP modules [16].

By extracting insightful information from Electronic Health Records (EHR), Natural Language Processing (NLP) is revolutionising healthcare decision-making. With an emphasis on how NLP may improve clinical processes, patient outcomes, and the integrity of healthcare decision-making, this study introduces the integration of NLP in EHR systems. In this study, both structured and unstructured EHR data are analysed using advanced natural language processing (NLP) approaches, such as BERT and spacy, to determine patient outcomes, treatment patterns, and diagnoses. The study shows how NLP-based analysis might improve clinical decision support systems by contrasting it with conventional data analysis techniques. Despite the promise, there remain obstacles, such as the importance placed on data quality, model interpretability, and interaction with current healthcare systems [17].

These days, phishing and frauds are commonplace and highly skilled social engineering tactics that pose a serious risk to both people and businesses. Social engineering attacks take advantage of trust and get sensitive information without authorisation by manipulating human psychology. The rule-based and pattern-based nature of these assaults makes traditional defensive strategies like email filtering and heuristic scanning insufficient for identifying and stopping them.

Applications of Artificial Intelligence (AI), especially Natural Language Processing (NLP) methods, have become more popular for detecting and preventing social engineering assaults. By automatically processing text-based data in emails, texts, and online chats, NLP-based AI systems present a possible answer [18, 19].

The technique to be suggested includes preprocessing text input, tokenisation, and the use of deep learning architectures such as bidirectional LSTMs for classification purposes of various kinds. Finding the best accurate estimating models with the least amount of uncertainty around possible validation loss is the aim. The study often discusses natural language processing (NLP) in a variety of contexts, such as text categorisation, sentiment analysis, and language comprehension. The results demonstrate how effectively our proposed NLP models complement one another. Long-term memory and natural language processing (NLP) complement one another [20, 21].

The fields of Deep Learning and Natural Language Processing have witnessed unparalleled breakthroughs in the past 10 years. Recent developments in the use of deep learning techniques for text analysis make reference to the contributions neural networks have made to machine translation, sentiment analysis, and text production. Furthermore, the creation of complex models with contextual awareness and interpretative depth has been made possible by the growing availability of large-scale datasets and high-performance computing capacity [22].

RESULTS AND DISCUSSION

The research highlights the following key aspects of NLP development and application as illustrated in Table 1.

Table 1. Aspects of NLP development.

Reference no.	Year	Category	Findings
[3, 8, 22]	May 2024, Jan 2025 Nov 2024	Machine Translation	Deep learning models such as transformers significantly improve translation accuracy, better than traditional statistical methods.
[4, 13]	Feb 2025, 2024	Sentiment Analysis	Transformer-based models like BERT and GPT achieve higher accuracy in real-time sentiment detection.
[14, 15, 17]	Dec 2024, Nov 2024, Dec 2024	Healthcare Applications	NLP in EHR analysis enhances patient diagnosis, predictive modelling supporting better clinical decision-making.
[19]	Nov 2024	Cybersecurity	NLP-powered AI detects phishing attacks by analysing linguistic patterns and suspicious text-based behaviours in real-time, strengthening digital security.
[1, 2, 10, 18]	Jan 2020, Feb 2006, Dec 2023, 2024	Education	NLP-driven intelligent tutoring systems personalize learning experiences, provide automated assessments, and enable language-based student assistance.
[16]	Dec 2024	Finance	NLP enhances financial sentiment analysis, assisting investors in making data-driven decisions based on market sentiment and economic trends.
[6, 7, 9, 11]	Jan 2025, Feb 2025, Jun 2024, Oct 2015	Human-Computer Interaction	NLP enables more natural and conversational AI interfaces, improving virtual assistants, chatbots, and customer service automation.
[5, 24]	Jan 2025, Feb 2025	Law	The study highlights the importance of document retrieval, case entailment document drafting, and client advice.
[12]	Jan 2025	3D-Models	NLP allows users to interact with 3D environments through spoken commands, queries, and instructions.
[20, 21] [23]	Apr 2025,	Language Techniques	NLP as a key technology enabling computers to comprehend and generate human language, has made significant progress.
	Apr 2025	API Security Monitoring	The pivotal role of Natural Language Processing (NLP) in bolstering API security monitoring.

An important step towards safeguarding private information and user confidence is the incorporation of natural language processing into API security solutions. Businesses may establish an active security posture that not only protects their digital data but also complies with legal requirements by using an NLP technique for API security monitoring. Adopting new approaches like natural language processing (NLP) will be crucial as the web continues to change in order to handle the dynamic threat landscape and improve API security in a complicated and interconnected world [23].

Speech recognition, machine translation, sentiment analysis, and text summarisation are just a few of the activities that fall under the umbrella of natural language processing (NLP). More complex human-computer interactions are made possible by NLP systems' ability to handle and analyse enormous volumes of textual data by utilising methods from linguistics, machine learning, and deep learning. As NLP technology develops, it is revolutionising sectors including healthcare, banking, entertainment, and customer service by providing game-changing answers to practical issues and improving user experience [24].

One of the biggest challenges in the cloud is effectively protecting the vast amount of health data and Electronic Health History (EHHs). To diagnose patients, doctors require their medical information, including multimedia big data analytics. Patients may effectively maintain their medical records using online EHH. By storing EHH on the cloud, this may be accomplished effectively.

Goals: By creating a multi-layered encryption system, the research seeks to effectively secure patients' private information in cloud storage. Before being saved in a cloud environment, EHHs are encrypted using the Fernet and Fully Homomorphic Encryption (FHE) techniques.

Sentiment Analysis Accuracy Over Different Approaches

A pie chart in Figure 2 displays the accuracy percentage of different sentiment analysis models, such as rule-based, machine learning, and deep learning models.

Year-Wise Reference Contribution

The year-wise reference contribution is illustrated in Table 2 and Figure 3, representing the number of papers analysed by publication year.

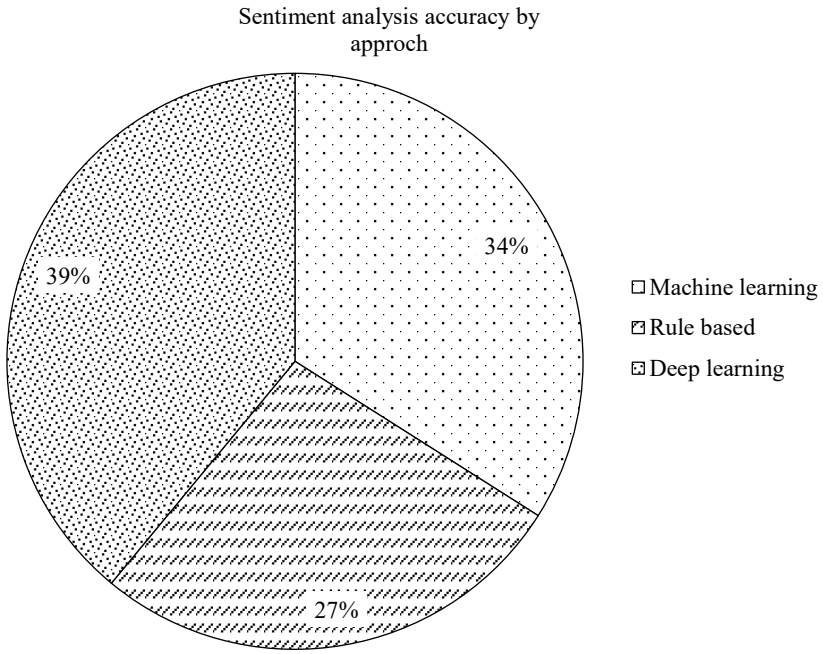

Figure 2. Pie Chart displaying sentiment analysis.

Table 2. Paper analysis table.

Year	Number of papers
2018	1
2020	1
2021	1
2022	1
2023	1
2024	7
2025	9

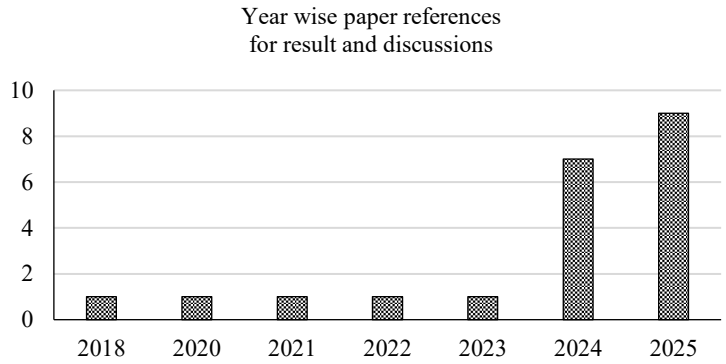

Figure 3. Bar Graph showing distribution of papers for references.

Table 3. Domain Table with NLP Usage.

Domain	Extent of NLP usage (%)	Description
Healthcare	85%	NLP is widely used in EHR analysis, clinical decision support, predictive modelling, and drug discovery.
Education	75%	NLP powers intelligent tutoring systems, automated grading, and personalized learning experiences.
Finance	65%	Used in financial sentiment analysis, risk assessment, fraud detection, and chatbot services.
Cybersecurity	70%	NLP helps detect phishing, spam, fraud, and social engineering attacks using pattern analysis.
E-Commerce	80%	NLP enables recommendation systems, sentiment analysis, chatbots, and search optimization.

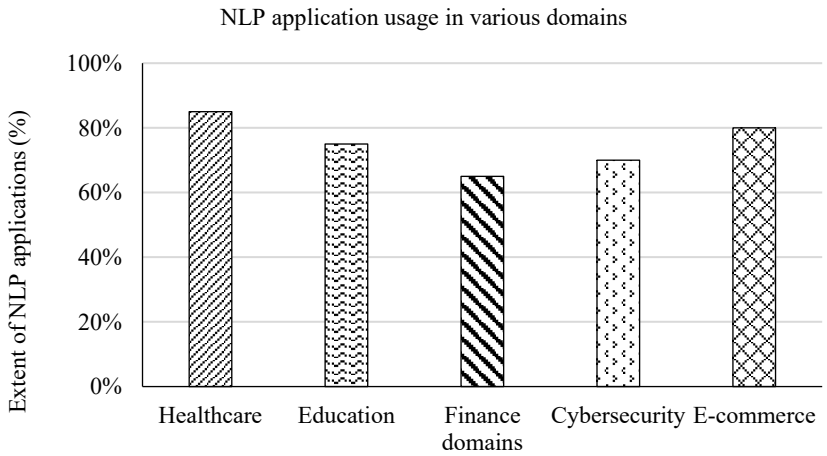

Figure 4. NLP application usage in different fields.

NLP Application Usage in Various Domains

A bar chart representation in Figure 4 shows the extent of NLP applications in fields such as healthcare, education, finance, cybersecurity, and e-commerce (Table 3).

CONCLUSION

This study concludes that NLP has seen remarkable advancements, particularly through deep learning techniques, which have significantly improved its accuracy, efficiency, and application scope. NLP's integration with AI has enabled automation in fields such as healthcare, cybersecurity, finance, and education, making processes more streamlined and effective. However, several challenges remain, including ethical considerations, data biases, high computational costs, and model interpretability issues. Addressing these challenges will be crucial for the continued growth and responsible implementation of NLP technologies. Future research should focus on making NLP models more accessible for low-resource languages, improving explainability in AI-driven NLP applications, and enhancing ethical AI practices to ensure unbiased and transparent language processing. Overall, NLP continues to be a transformative force, revolutionizing industries and making human-computer interactions more seamless, intelligent, and intuitive.

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