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THE RELEVANCE OF NATURAL LANGUAGE PROCESSING IN HEALTHCARE

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Abstract— **Over the years, there has been a growing acknowledgment of the significance of Natural Language Processing (NLP) in the healthcare sector. Natural Language Processing has proven useful in disease detection, capturing patient data in an unstructured format, language translation, and analyzing the grammar and meaning of information to make it comprehensible for Health Management Information Systems. Additionally, Natural Language Processing aids chatbot programs and provides language support for various regions. This study examines the potential and advancements of Natural Language Processing in healthcare, as well as its future prospects.**

Keywords— **Natural Language Processing, Healthcare, Relevance, Technology, Electronic health records**

I. INTRODUCTION

Advancement in information technology is transforming the way healthcare data are being processed. The healthcare industry has shifted from manually sourcing patient information to a more advanced and electronic approach. Today, mobile platforms are revolutionizing information systems, changing the way information is processed, removing distance barriers in accessing records, and enhancing the management of patients' information. The use of Android applications has become crucial in driving e-commerce. Consequently, many companies have embraced the internet as a business platform, leading to the demand for fast, engaging, dynamic, responsive, and reliable applications. This has led to remarkable innovation, particularly in the mobile web, enabling the development of features that were previously unattainable in mobile and desktop application development.

Electronic health records (EHR) systems have become generally utilized in hospitals over the past few years for patient history recording. The analysis of this vast amount of data is crucial for improving healthcare for patients. However, manually reviewing this data from different hospitals are both expensive and takes a lot of time, posing significant challenges. During patient visits, physicians record medical encounters on paper, which are then transmitted to nurses and other medical units for processing. These records are essential for business information processing in the healthcare sector and must be error-free.

Patient medical record are prone to errors due to the way they are being handled especially paper-based patient records. An observational study was completed in a University Clinic in which they found that 81% of physicians did not have access to all the information they wanted during a patient's visit (Tang, Fafchamps, and Shortliffe, 2014). Additionally, the manual method of using folder by doctors to diagnosis patient lacked tractability and context, leading to the need for Natural Language processing techniques and deep learning in enhancing clinical research and care. In order to extract information from the vast amount of Electronic Health Record stored in clinical narratives, there is need to use Artificial Intelligent (Natural Language Processing techniques). Artificial intelligence is the method of mimicking human intelligence into machines, especially computer systems and Natural Language Processing being one of the specific applications of AI focuses on the interaction between computers and human language. NPL has gained immense popularity in recent years, it is a technology that enables computers to understand, interpret, and generate human language, offering a multitude of possibilities across various industries. Healthcare, in particular, stands to benefit greatly from NLP, as it revolutionizes the processing and utilization of medical data.

NLP can be utilized to examine unstructured data within the EHR. Natural Language processing procedures has being used by scientist to recognize substantial clinical phenotypes when analyzing text and it also use to determine the grammatical relationships between phrases. To obtain a high sensitivity and positive predictive value in clinical records, Rule-based NLP techniques can be used. Capturing detailed patient information through free-text narratives remains advantageous and is likely to continue in EMRs for convenience and usefulness.

The healthcare field is experiencing extensive support from computer science, with AI being increasingly adopted. AI applications in healthcare, particularly those leveraging NLP, range from basic practices to specialized tasks. Natural

language processing (NLP) procedures focuses on evaluating text and speech in order to get meaning from it. Natural language processing (NLP) embraces the use of computer procedures to identify important elements in everyday language and be able to get meaning from amorphous input. NLP requires proficiency in computational linguistics, artificial intelligence and various machine learning specialties.

This article will explore the relevance of NLP in healthcare, specifically examining its potential benefits, applications, and challenges. By harnessing NLP techniques, healthcare professionals can effectively extract valuable information from vast medical records, enhance patient care and improve overall operational efficiency of health care industry. The integration of NLP in healthcare has the potential to revolutionize the industry, ultimately saving lives and enhancing health outcomes.

II. REVIEW OF RELATED LITERATURE:

To understand the current landscape of Natural Language Processing in healthcare, it is crucial to review the existing literature on the subject. Numerous studies have highlighted the significance of NLP in various healthcare domains, such as clinical documentation, disease surveillance, and sentiment analysis of patient feedback, diagnosis assistance, and drug discovery.

For instance, Smith et al. (2018) conducted a systematic review of NLP applications in the clinical domain. The study showcased the potential of NLP in automating clinical documentation tasks, extracting crucial information from electronic health records (EHRs), and improving the accuracy of disease diagnosis.

Similarly, Johnson et al. (2019) explored the use of NLP in disease surveillance, demonstrating its effectiveness in early detection and monitoring of outbreaks.

In his research work, Alexander (2017) aimed to improve clinical decision making by applying NLP and machine learning to EHRs in two tasks. The first task involved predicting CRT outcomes more precisely than the existing physician guidelines for suggesting the procedure. He used NLP features from free-text physician notes and structured data to train a supervised classifier for predicting CRT outcomes. The results showed a minor improvement over the current baseline, but he failed to predict CRT outcome with both high precision and high recall. These results reduced the clinical usefulness of the model, and confirmed previous work, which also could not identify reliable predictors of CRT response. The second task in the thesis was to identify breast cancer patient symptoms during chemotherapy from free-text physician notes. They manually labeled about 10,000 sentences, and trained a CRF model to predict whether a word indicated a symptom (positive label), explicitly indicated the absence of a symptom (negative label), or was neutral. The final model achieved 0.66, 1.00, and 0.77 F1 scores for predicting positive, neutral, and negative labels respectively. While the F1 scores for positive and negative labels are not very high, the model could be used, for instance, to collect better statistics about what symptoms breast cancer patients experience during chemotherapy and when they experience these symptoms during treatment.

Binggui, et. al (2022) conducted a research work on natural language processing. They believe that artificial intelligence (AI) technologies facilitate various smart health applications in different healthcare scenarios. As a fundamental technology driven by Artificial Intelligent, NLP has a vital part in smart healthcare because of its ability to analyse and comprehend human language. In their work, they surveyed an existing studies that relate to NLP for smart healthcare from the aspects of technique and application. They concentrated on extracting features and modelling for various NLP tasks in smart healthcare from a technical perspective. In the smart healthcare perspective, applications that use NLP technique in explanation mainly covers representative smart healthcare situations, such as physician clerking, hospital management, self-employed care, public health, and drug development. From the system developed, they demonstrated the potential and power of NLP for providing smart healthcare. They also discuss the challenges of current works in understanding human language, interpretability, and implementation of NLP systems for smart healthcare. Finally, they suggested integrating multiple NLP techniques, developing end-to-end applications, few-shot learning, and integrating multimodal and longitudinal data.

Gaurav (2019) gave a paper on natural language processing. He claimed that free-text allows clinicians to capture rich information about patients in narratives and stories. Care providers are likely to continue using free-text in Electronic Medical Records (EMRs) for the foreseeable future due to the convenience and utility it provides. However, this complicates information extraction tasks for big-data applications. Despite advances in Natural Language Processing (NLP) techniques, building models on clinical text is often expensive and time-consuming. Current approaches require a long collaboration between clinicians and data-scientists. Clinicians provide annotations and training data, while data-scientists build the models. With the current approaches, the domain experts - clinicians and clinical researchers - do not have provisions to inspect these models or give direct feedback. This forms a barrier to NLP adoption and limits its power and utility for real-world clinical applications. Interactive learning systems may allow clinicians without machine learning experience to build NLP models on their own. Interactive methods are particularly attractive for clinical text due to the diversity of tasks that need customized training data. Interactivity could enable end-users (clinicians) to review model outputs and provide feedback for model revisions within a closed feedback loop. This approach may make it feasible to extract understanding from unstructured text in patient records; classifying documents against clinical concepts, summarizing records and other sophisticated NLP tasks while reducing the

need for prior annotations and training data upfront. In the dissertation, he demonstrated this approach by building and evaluating prototype systems for both clinical care and research applications. He built the interactive tool for clinicians to train and build binary NLP models on their own for retrospective review of colonoscopy procedure notes. The results from the development and evaluation of these prototypes will provide insight into the generalized design of interactive NLP systems for wider clinical applications.

Harrison, et al (2017) stated that many hospitals use a series of paper forms to record their interactions with patients; while these have been highly successful, the world is moving digitally and there is need for paperless medical records. Using a project management methodology called Scrum that is supported by a usability evaluation technique called System Usability Scale (SUS) and a workload measurement technique called NASA TLX, a prototype web application system was built and evaluated for the client. The prototype used a varied set of input mediums including voice, text and stylus to ensure that users were more likely to adopt the system. This web based system was successfully developed and evaluated. This evaluation showed that the application was usable and accessible but raised many different questions about the nature of software in hospitals. While the project looked at how different input mediums can be used in a hospital, it found that just because it is possible to input data is some familiar format (e.g. voice), it is not always in the best interest of the end-users and the patients (Harrison, et al 2017).

III. NATURAL LANGUAGE PROCESSING

Natural language processing (NLP) is a branch of computer and specifically a branch of Artifical intelligence that is concerned to give machine (computer) the ability to understand human and speak human languages. Some applications of NLP include: Medical information extraction, healthcare text mining, transforming unstructured data found in texts into structured data, sentiment analysis, machine translation, using computer to automate the process of translating from one language to another, language to language translation etc. in the past , there are some factors that aid development of Natural Language Processing;

1. the accessibility of huge number of language data,
2. the improvement on machine learning procedures
3. Better understanding of human languages and its structure in social context.
4. Development of different computing devices

NLP is capable of rearranging text in order to make the text responsive for continuous analysis from machine learning or artificial intelligence techniques. Many of the text for continuous analysis can be patient billing, patient clerking and diagnosis, National Health care provider interactions or provider-provider interactions, or even social media discussions between patient and Healthcare provider. It transforms healthcare data into a textual data stream that may be paired with data streams from different hospital monitors example pulse oximetry, cardiac monitors, wearables, or laboratory tests. For some of hospital procedures like medical decision-making, developing tools for risk stratification, identifying postoperative complications after inpatient surgery from Doctors' notes and triaging patients by identifying syndromes, NLP has been successful in scaling up some of these procedures.

The most aspect use of NLP in healthcare industry is for translation of words or phrases into concepts. In recent times machines like computers are made to look past the sequence of letters to the concept denoted. Its task involves breaking down languages into what computer can understand through semantic and syntactic analysis. Syntactic analysis or syntactic identifies structure of text and relationship between words while semantic analysis identified the structure of sentences and meaning in languages. The sub tasks of syntactic and semantic analysis are:

1. Tokenization: break up a string of words into semantically useful units called tokens
2. Lemmatization transforming words back to its root as it appear in dictionary
3. Stemming each lemma (that operating on single word without considering the context)

Some Natural Language Processing machines can do only task 1 and 2 above. In Natural Language Processing procedure is a way of providing tools to digital devices that be able to do comprehension of languages. It can also do a deeper level comprehension than straight commands on language. This also means that different models of NPL work on variety of different linguistics which included:

1. Phonology - is concern on how sound are organize in words
2. Morphology – how content and structure of words are built from smaller units
3. Syntactic- concern with grammatical arrangement of words
4. Semantics relating to meaning in language
5. Pragmatic - relates to the way sentences are used in different contexts which contributes to its meaning

IV. AN OVERVIEW OF THE WHOLE PROCEDURES INVOLVES THE FOLLOWING STEPS;

Phonology and phonetic are concern on how words are comprehended as sounds while morphology refers to understanding of how words are constructed from smaller units of meaning called morphemes; meaning that words are split apart into smaller units. This process is referred to as tokenization. Tokenization, which involves splitting words from a sentences. The words are tagged with their different Part-of-speech (POS) through the body of each text. POS

tagging is the method of automatically assigning a parts of speech tag, such as noun or adverb, to each word in a sentence. These will resolve the issue of word vagueness, where the same word can have multiple tags, this is necessary for POS tagging. Hand-written rules is one of the rule based method that is used to disambiguate between tags and at the same time maximize the product of words likelihood and tag sequence probability, trained with manually labeled data.

Syntactic analysis is the study of how words can be joined to form correct sentences grammatically. It explores the relationships between words and assigns a syntactic structure to sentences using a parsing method. The structure of syntactic analysis is typically represented in the form of a tree. A parsing algorithm and grammar are required to perform syntactic parsing. The grammar determines the allowed structures of the language, while the parsing algorithm outlines how to generate the sentence structure based on the grammar. Parsing algorithms can be categorized as **bottom-up** or **top-down**. Top-down parsers attempt to construct a parse tree starting from the root node and moving towards the leaves. Conversely, bottom-up parsers begin with the words of the input and build the tree upwards. To address ambiguity, syntactic parsing is needed as single sentence can have many analyzing trees that adhere to the grammar. One approach to address this is the use of probabilistic context-free grammars (PCFG). In PCFGs, probabilities are assigned to each rule, and the probability of a sentence can be determined by multiplying the probabilities of the rules used in its parsing. The parsing algorithms can also be modified to incorporate probability information.

Semantic analysis focuses on the meaning of individual words and how they come together to form the meaning of a sentence. There are several methods to representing this meaning in NLP, such as First Order Logic, Semantic Networks, Conceptual dependency and Frame-based representation languages. Ambiguity is also encountered at the semantic level. To address this ambiguity, there are two main groups of methods: machine learning methods that use features predictive of word senses (such as bag of words or collocational features), and methods that utilize lexical resources like dictionaries or syntax information. Pragmatic refers to how sentences are used in different contexts and how it influences sentence interpretation. As previously mentioned, ambiguity exists at multiple levels of analysis in NLP, posing a significant challenge.

V. NATURAL LANGUAGE PROCESSING (NLP) IN HEALTHCARE

The healthcare industry is experiencing rapid growth and is incorporating technology and its application into different practices in order to improve service delivery. This integration allows for more accessible healthcare, particularly in rural areas through E-Health services. However, there is a large amount of data being collected, such as Electronic Health Records (EHRs), clerking, diagnosis, monitoring data, healthcare operations, management data and sensor information, which is mostly unstructured and of poor quality. This renders the data effectively useless. Natural Language Processing (NLP) is an effective solution for addressing these issues by parsing and extracting critical data strings from unstructured data. NLP has already been successfully used in various healthcare operations globally. The main reasons for implementing NLP in healthcare include managing the increasing amount of clinical data, supporting value-based care and population health management, improving clinical documentation and computer-assisted coding efficiency, enhancing patient and healthcare provider interactions, empowering patients with health literacy, and improving the quality of healthcare.

As a result of its successful applications, NLP deployment in healthcare technologies has been on the rise in recent years. For example, NLP techniques were utilized by the Department of Veterans Affairs in the USA to review billions of EHR documents for indications of mental health issues in veteran patients. Another study achieved 100% accuracy in predicting the onset of psychosis in high-risk youths using an analytics algorithm that leverages NLP. Applying NLP techniques to medical records was found to improve the accuracy of identifying reportable cancer cases by 22.6%, as compared to manual review. NLP also offers potential benefits such as effective decision-making by physicians, reducing physician burnout, addressing the increasing demand for healthcare services, and efficiently managing healthcare claims.

1. Natural Language Processing for Smart Healthcare

Smart healthcare is a healthcare system that exploits emerging technologies, such as artificial intelligence (AI), blockchain, big data, cloud/edge computing, and the internet of things (IOT), for realizing various intelligent systems to connect healthcare participants and promote the quality of healthcare (Tian,et. al2019). Major participants in smart healthcare can be classified into three categories, i.e., the public, healthcare service providers, and third-party healthcare participants. Related to the participants, representative smart healthcare scenarios include smart homes, smart hospitals, intelligent research and development for life science, health management, public health, rehabilitation therapy, and etc. Figure 1 shows the major participants, emerging technologies, and representative scenarios of smart healthcare.

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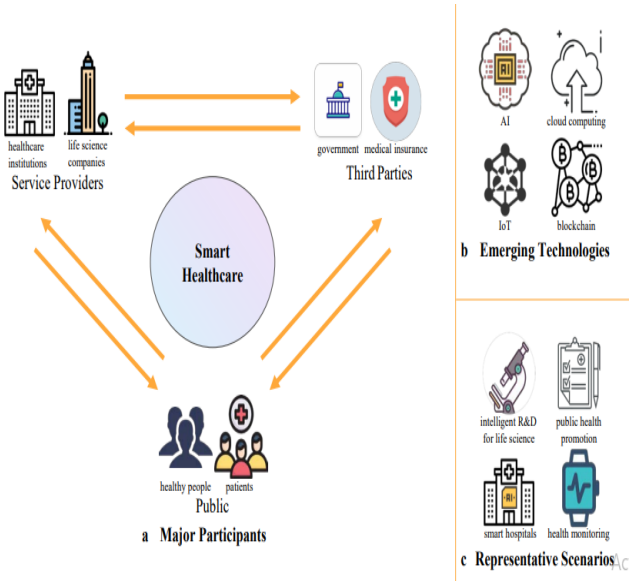

Figure 1: Smart healthcare (Tian,et. al2019)

Figure 1a is the major participants in smart healthcare include the public, healthcare service providers, and third-party healthcare participants. Figure 1b is example emerging technologies enable smart healthcare applications include artificial intelligence, blockchain, cloud computing, the internet of things, and etc. figure 1c is representative smart healthcare scenarios include intelligent research and development for life science, public health promotion, smart hospitals, health monitoring, and etc.

Natural language processing (NLP) is a branch of computer science and artificial intelligence that deals with the representation, automatic analysis and understanding of human language in machines. NLP has emerged as a popular research area and has drawn wide attention from many research communities in recent years. As human language is a common form of data input for intelligent systems, NLP allows machines especially computers to comprehend human language, interact with humans, making it vital to support smart healthcare. The main forms of natural language are speech recognition and text, where text includes reading books, articles, text recording, dictionaries etc, while speech recognition takes place between man – machines and man-man discussions. NLP has been evolving for several years ago since the early origin of artificial intelligence in the 1950s. Methods to perform NLP are generally classified into three categories: rule-based approaches, statistical approaches, and deep learning-based approaches (Young, Hazarika, Poria, and Cambria, 2018). From the 1950s to 1980s, NLP research mainly concentrated on rule-based approaches, which demanded expertise in both computer science and linguistics to design rules that suit human language. However, even well-designed rules are quite restricted for covering human language due to its flexibility and complex patterns. Since the 1980s, statistical NLP systems have been developed by extracting features from corpora using statistical and machine learning algorithms and have gradually replaced rule-based NLP systems due to their superiority in performance and robustness. With the early application of the neural probabilistic language model (Bengio, 2013) and the fast development of deep learning since 2013, neural NLP, by using neural networks and large corpora for automated feature learning, has dominated current research and achieved SOTA performance of many NLP tasks (Young, Hazarika, Poria, and Cambria, 2018). In smart healthcare, NLP is used to process text data and is related to human-machine/human-human communication. The text data can be divided into 2 categories: clinical text and other text data (Young, Hazarika, Poria, and Cambria, 2018). Clinical text comes from all clinical scenarios and mainly consists of unstructured text records from electronic health record (EHR) systems, such as medical notes, diagnostic reports, electronic prescriptions, and etc. Other text data include all text that occurs in other healthcare scenarios, e.g., surveys in population screening and articles for evidence-based reference. Communication is frequent in all smart healthcare situations, such as patient-relative communication in clinical inquiry and human-robot interaction in rehabilitation therapy, along with applications such as machine translations and user interfaces for rehabilitation robots.

2. Natural Language Processing for Medical coding and Billing

The 3M 360 Encompass System is a healthcare application that utilizes natural language processing in medical coding for the purpose of computer-assisted coding (CAC). The process of extracting billable details from clinical notes and converting them into standardized medical codes refers to as Medical coding. By keeping track of the latest regulations, the company, which has a team of more than 150 coding experts, ensures that it remains current. This system aids coders by compiling and evaluating patient documentation, as well as providing automatic suggestions for tags and comprehensive tools for reviewing and approving. In the past, this task was typically carried out by a human coder. However, manual coding is time-consuming and susceptible to mistakes, resulting in the healthcare provider potentially missing out on claiming the complete amount of compensation they are entitled to. NLP-based computer-assisted coding (CAC) systems have the ability to extract data from medical notes and patient electronic health records (EHRs) regarding various treatments and procedures that were administered. These systems can then generate appropriate insurance codes to support the accuracy and validity of insurance claims.

3. Natural Language for Analyzing the Emotions of patients

The utilization of natural language processing (NLP) in the healthcare field assists healthcare professionals in gathering

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and evaluating customer feedback and viewpoints from various social media platforms. NLP tools have the capability to handle a large number of reviews, enabling the assessment of patients' overall sentiment towards the quality of care they received. These tools are capable of identifying specific elements that may cause frustration for patients, categorizing them based on how often they occur, and subsequently initiating enhancements to address the most frequently expressed negative feedback. For example, if someone says, "I spent half an hour on hold trying to speak to a doctor," it suggests that they had a negative encounter with medical doctor on duty. Healthcare facilities can utilize healthcare NLP to make use of sentiment analysis in processing survey results. Instead of depending on social media, they can create specific surveys, distribute them to patients, and employ NLP solutions to automatically evaluate each response.

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4. Language Technology for AI Chatbots and Digital Transcription

Although there is currently no existing solution, it is highly likely that speech recognition applications will assist humans in modifying clinical documentation. In today's digital world, there is a wide range of chatbots and personal virtual assistants available, and the healthcare industry is no exception to this trend. Presently, these assistants possess the capability to identify symptoms and evaluate patients to determine the most suitable healthcare professional. Startups in the emerging field of chatbots include BRIGHT.MD, which has developed Smart Exam, a virtual physician assistant that utilizes conversational Natural Language Processing (NLP) to gather personal health information and compare it with evidence-based guidelines, providing diagnostic recommendations for healthcare providers.

VI. IMPROVING NATURAL LANGUAGE PROCESSING CAPABILITIES IN HEALTHCARE

Improving healthcare data in natural language processing has posed difficulties. In case the NLP system generates excessive suggested conclusions or incorrect artificial conclusions in the electronic health record, users will disregard its intelligence, resulting in a decrease in overall business productivity. NLP software for healthcare should prioritize data conclusions that contain minimal noise and provide the most reliable guidance for healthcare providers. Healthcare organizations can take a few steps to improve the capabilities of their Artificial Intelligence and NLP systems. Firstly, it is important for them to concentrate on creating strong sets of data that can be used to train models. By making sure that the training data is extensive and precise, medical experts can generate models that are more capable of dealing with common scenarios. Secondly, healthcare establishments should make an effort to enhance their knowledge of how their intended audience uses language by conducting surveys among patients and medical personnel. This enables them to develop more user-friendly systems that align with the way individuals communicate in healthcare environments.

VII. CHALLENGES OF NATURAL LANGUAGE PROCESSING IN HEALTHCARE

The implementation of natural language processing (NLP) in healthcare presents numerous advantages. However, incorporating this technology into your medical practice may come with its own set of challenges.

a. Language requirements within the healthcare sector vary Medical professionals, such as doctors, adopt a specific writing style when it comes to documenting clinical notes and other medical records. This style often utilizes specialized terminology, acronyms, and abbreviations, and lacks detailed context. Complicating matters further, around one-third of the clinical abbreviations found in the Unified Medical Language System Metathesaurus possess multiple meanings. Words that are completely spelled out can still cause confusion. For example, the term "discharge" can have two distinct meanings: being released from a hospital or the release of bodily fluids, which depends on the context. If you wish to expand the use of NLP in the healthcare sector beyond your clinic and utilize it to examine patient responses on social media, you must acquaint it with the particular acronyms and symbols that individuals employ to convey their feelings instead of words. "If you obtain pre-made NLP algorithms that are designed for general purposes, it will be necessary to retrain these algorithms for use in healthcare environments.

b. Not enough training data exists for medical facilities to adequately supply accurate and comprehensive data that accurately represents the intended population.

c. Hospitals face challenges regarding ethical considerations and potential moral risks when utilizing AI. These challenges include determining the ultimate decision-maker for selecting the appropriate treatment and identifying the party accountable in case the treatment proves ineffective.

d. Enhancing natural language processing in healthcare information has been a challenging endeavor. In the event that the NLP system generates excessive erroneous or contrived findings in patients' electronic health records, users will ultimately dismiss its capabilities, leading to diminished productivity in the overall business. To refine NLP software for healthcare, the emphasis should be on delivering precise data conclusions with minimal distortion.

VIII. FUTURE OF NATURAL LANGUAGE PROCESSING IN HEALTH CARE

Despite not being fully developed yet, the healthcare industry is committed to improving natural language processing (NLP). Organizations are making substantial investments in cognitive

computing and semantic big data analytics initiatives that make use of natural language processing (NLP). In the long run, NLP tools have the potential to close the divide between immense data quantities and the limitations of human cognition. This will have positive outcomes for precision medicine as well as administrative duties such as billing and reimbursement. However, the success of NLP relies on accurate algorithms tailored to healthcare and user interfaces that are user-friendly. If these goals are achieved, it could lead to new opportunities for big data analysis in the future.

In conclusion, Natural Language Processing holds immense potential in revolutionizing the healthcare industry. The objective of this article is to examine the relevance of NLP in the healthcare sector, with a focus on its advantages, uses, and difficulties. By extensively studying relevant literature, we can acquire knowledge about the present condition of NLP in healthcare and its impact on patient treatment, clinical decision-making, and operational effectiveness. This article will contribute to the growing body of knowledge on NLP in healthcare, paving the way for future advancements and implementations in this crucial field.

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