

An Integrated Hybrid Artificial Intelligence Approach For Multilingual Clinical Text Understanding And Adaptive Drug Delivery Optimisation

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Abstract

The speedy increase in medical data, particularly, unstructured multilingual clinical text, poses a considerable challenge to the correct interpretation and effective decision-making in drug delivery systems. The paper suggests a hybrid, integrated artificial intelligence (ai) system, which incorporates natural language processing (nlp), machine learning (ml), and deep learning (dl) to facilitate multilingual clinical text interpretation and maximize adaptive drug delivery. The system uses language models based on transformers to extract semantics, models based on hybrid classification to predict diagnoses, and models based on reinforcement learning to optimize individual dosage of drugs. The experimental findings show that there is better accuracy, less response time as well as increased personalization than the traditional systems.

In practice, however, there are also such limitations as reliance on large multilingual annotated datasets, computational complexity, and difficulties in dealing with rare inter-language medical terms. More future work directions include federated learning to preserve privacy, support low-resource languages, and incorporate real-time iot-based physiological data to increase versatility in clinical settings.

Keywords: Artificial Intelligence Hybrid, Multilingual Nlp, Clinical Text Analysis, Adaptive Drug Delivery, Machine Learning, Deep Learning, Reinforcement Learning, Healthcare Optimization.

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I. INTRODUCTION

The recent years saw the exponentially increasing healthcare data, which have offered an opportunity and a challenge to the modern medical systems. Much of this data is in the form of unstructured clinical text such as electronic health records, physician notes, diagnostic reports, and prescription information. The records are usually recorded in more than one language and in various and multilingual areas; it is a complex process that requires automation in interpretation [1]. Conventional data processing systems are ill-equipped to accommodate such linguistic diversity, which results to inefficiencies in diagnosis processes, delays in the process of making treatment decisions, and threat of medical errors. Thus, it is of utmost importance to have intelligent systems that can comprehend multilingual clinical text and convert it into actionable information.

Natural Language Processing (NLP) and Artificial Intelligence (AI) in general have demonstrated impressive

advances in deriving meaningful information on unstructured text. Most of the current NLP systems though are tailored to monolingual datasets, mostly English, and cannot be generalized across languages effectively. This is of particular concern in the field of healthcare where patient safety heavily depends on precise interpretation of the clinical data. Moreover, the domain-specific terms, abbreviations, and contextual details of clinical text may demand specialized models which are trained on biomedical data [2]. This is why it is highly encouraged to come up with the sophisticated multilingual NLP systems that could be used to manage the linguistic variability without losing the medical accuracy.

Simultaneously, the idea of adaptive drug delivery has received a lot of interest in contemporary healthcare services. Adaptive drug delivery systems in contrast to conventional drug administration approaches, which adhere to a fixed dosage regimen, seek to personalize therapy based

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on the unique patient factors of age, medical history, genetic effects, and real-time physiological feedback. Such systems must be monitored and smartly decision-made to maximize drug dosage and timing. Nonetheless, most existing drug delivery systems are based on structured data input and do not make full use of the rich information in the clinical text [3]. A combination of drug delivery optimization and clinical text understanding is a promising chance to promote personalized medicine.

The rationale of the study is to tackle these two problems that are closely related to each other: multilingual clinical text comprehension and optimization of adaptive drug delivery. With the integration of these areas, a single system can be developed that does not just make sense out of complex clinical-related information but also applies the knowledge to make decisions regarding the treatment of patients. This type of system may have a huge positive impact on healthcare as it helps to minimize diagnostic errors, adverse drug reactions, and improve the efficiency of treatment.

The main goal of the work is to come up with a hybrid AI framework, in which the advantages of various computational methods are exploited. The suggested system is a combination of multilingual NLP to extract semantic and contextual data in clinical text, machine learning, and deep learning to predictive analyse, and reinforcement learning to further optimize drug dosage. The hybrid method is aimed to eliminate the shortcomings of each technique and offer a strong solution to complicated healthcare situations. The other crucial goal is to be able to assure that the system will be able to work under real-life conditions. This includes noisy and incomplete data, multilingual data (including low-resource languages) and scalability and efficiency. The system will also be structured to include feedback systems that enable continuous learning and adaptation to new information, and it is applicable in dynamic clinical environment.

The given work offers a thorough understanding of how AI hybrid methods can be used in the same framework to cope with critical health care issues. It underlines the significance of integrating both data-driven methods and domain-based knowledge to realize the correct and credible outcomes. This study helps to make intelligent healthcare technologies more prosperous by filling the gap between understanding clinical texts and drug delivery systems.

II. RELATED WORK

The use of Artificial Intelligence in healthcare has greatly developed during the last decade, especially in the fields of clinical text analysis and smart drug delivery systems. A significant amount of literature has been devoted to the extraction of meaningful information out of unstructured clinical data with the help of Natural Language Processing techniques. First methods used were based on rule-based

systems and key word matching which lacked the ability to understand context and semantic relationships [7]. These approaches were frequently challenged by ambiguity and abbreviations as well as differences in clinical language, particularly in the case of multilingual data. This made them limited in their efficacy in the actual clinical setting.

In 2025, Jandoubi, B., et. al [4], as machine learning methods progressed, statistical classifiers like support vector machines, naïve Baye classifiers, and decision trees were proposed to use in clinical text classification and information extraction. These models enhanced performance and learnt patterns on labelled data, but they needed vast feature engineering and were very sensitive to the quality of input features [8]. Also, they were typically written to work on single language datasets and did not have the flexibility to use multilingual clinical records. This became more pronounced in international healthcare systems, where the information on patients is usually documented in a variety of languages and dialects.

In 2026, Kaur, P., et. al [5] introduced the development of deep learning was an important advance in clinical text understanding. Recurrent neural network and long short-term memory architecture models allowed sequential data and contextual dependencies in text to be better addressed. These models proved to be better at tasks like named entity recognition, medical concept extraction, and clinical coding. Nevertheless, they were computationally expensive and needed huge amounts of data with annotations. Moreover, they were not yet as useful when used on multilingual data because they do not support cross-lingual representations and have inadequate training on low-resource languages.

In 2025, Khan, F. S., et. al [6], proposed the transformer-based architectures have recently completely transformed the field of Natural Language Processing with the introduction of attention mechanisms that CAN DETECT long-range dependencies in text. These models have been effectively used in biomedical and clinical areas with state-of-the-art results in the different tasks. Multilingual transformers have also expanded on these features with the ability to accommodate multiple languages in one FRAMEWORK [9]. The problem with these advancements is that these models still have difficulties fitting these models to the domain specific clinical text that is usually full of complex language and context sensitive information. Moreover, the models may perform poorly with small languages or ill data.

Simultaneously, there has been a great change in research on drug delivery systems. Conventional modes of drug delivery are usually on a fixed dosage regimen that is generalized clinical guidelines. Although effective in numerous situations, the variability of patients is not taken into consideration in these methods, which results in the occurrence of poor treatment outcomes [7]. To overcome this challenge, adaptive drug delivery systems have been

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developed, which CONSIDER patient-specific aspects (physiological conditions, medical history, and real-time health information). The aim of these systems is to individualize treatment and enhance the effectiveness of treatment.

Machine learning methods have been utilized more in drug delivery optimization, with the ability to predictively model patient response to drugs. Regression analysis, classification, and ensemble techniques have been utilized to approximate the best dosage of drugs and the possible adverse REACTIONS [10]. Although these methods have demonstrated encouraging outcomes, they typically need structured data and are not able to make the most of the rich information contained in unstructured clinical text. This disconnect reduces their capacity to get a holistic picture of the patient and surrounding details that may improve decision-making [8].

Reinforcement learning has proven to be an effective method of dynamic drug delivery optimization. With reinforcement learning algorithms, it is possible to learn optimal strategies by MODELLING the treatment process as a sequential decision-making problem by interacting with the environment. These models are constantly revising their policies according to feedback, which will enable them to respond to changing patient conditions [9]. Nevertheless, the application to date is commonly constrained by the accessibility of credible rewarding signals and the intricacy of simulating clinical reality. Also, reinforcement learning and clinical text analysis can be used in combination, which is an UNDER RESEARCHED field.

The other significant direction of research is the multimodal data integration of clinical text, medical imaging, and wearable sensors data. The integration of these sources of data may give a better picture of the health of patients and enhance the predictive models. Other papers have studied hybrid AI systems, which fuse more than two methods, e.g. NLP and machine learning or deep learning models. These systems have shown better performance over single-model approaches [10]. Nevertheless, the majority of current frameworks were designed to address TASKS, and none has a single architecture to tackle both drug delivery optimization and clinical text understanding.

The issue of linguistic diversity and the inconsistency in medical terms is another problem arising with multilingual healthcare systems. These challenges have been tackled through research aimed at coming up with cross-lingual embeddings, translation-based methods, and multilingual language models. Although these approaches have enabled the increased accessibility of AI systems in various languages, they are usually associated with problems of translation quality, information loss, and inaccessibility of domain-specific training data [11]. These challenges

highlight the need for more robust and scalable solutions that can handle multilingual clinical data effectively.

Although progress has been made in each of the areas, there is still a long way to go in bringing together multilingual clinical text comprehension and adaptive drug delivery systems. The majority of current research addresses these elements individually, leaving their solutions in a disjointed fashion and failing to fully harness the power of AI in healthcare [12]. There is still no comprehensive method that integrates advanced NLP techniques, hybrid predictive model, and reinforcement learning to optimize drugs.

To conclude, the current literature has a solid basis on the intelligent healthcare systems but also highlights a number of shortcomings. They are the absence of multilingual assistance in clinical NLP models, the insufficient incorporation of unstructured information in drug delivery systems, and the absence of unified hybrid models that combine the need to comprehend texts and optimize treatment. These issues need to be tackled to bring the state of the art to the next level and allow introducing AI-based solutions into the practical healthcare setting.

III. PROPOSED METHODOLOGY

The suggested methodology presents a hybrid framework of Artificial Intelligence that links the multilingual text processing of clinical data, the predictive analytics, and the optimization of the adaptive drug delivery into a single pipeline. The raw multilingual clinical text data are firstly gathered and preprocessed by means of language detection, normalization, tokenization, and noise elimination to make sure the data is consistent. The transformer architecture-based multilingual Natural Language Processing model is then used to extract semantic features, detect medical entities, and capture contextual relationships among various languages. The features extracted are fed into a hybrid prediction module that incorporates machine learning and deep learning models to achieve a better and more robust level of classification of diseases and analysis of the condition of a patient [13]. Afterwards, an optimization module based on reinforcement learning is used to decide the individual dose of a drug through a continuous learning process of patient-specific information like medical history, response patterns, and real-time health indicators. The system also has a feedback process that changes the model dynamically allowing the model to continuously learn and adapt to changing clinical conditions. This end-to-end architecture guarantees an effective multilingual comprehension, correct prediction, and efficient delivery of drugs, which is suitable in the real-world intelligent healthcare applications.

The proposed flowchart starts with the stage of data collection where data in the form of multilingual clinical text (patient records, prescriptions, and diagnostic reports) are collected through the healthcare systems in fig.1. This

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information is then subject to preprocessing, which involves cleaning, normalization, and tokenization to eliminate noise and standardize the text. This is then followed using language detection to determine the language of the input to handle multilingual content correctly. The processed text is then fed to the feature extraction module where the advanced Natural Language Processing techniques identify important medical entities, symptoms, and contextual information.

The extracted features are then entered into a disease prediction model in the next stage, which is based on the hybrid combination of machine learning and deep learning methods to analyze the conditions of patients with high accuracy. According to the estimated results, the system moves to the drug optimization module where reinforcement learning is used to establish the most appropriate and individualized drug dosage. Lastly, there is a feedback and update system that is continuously tracking the response of the patients and updating the model to enhance future predictions and treatment decision making and make it adaptable and efficient in the long term.

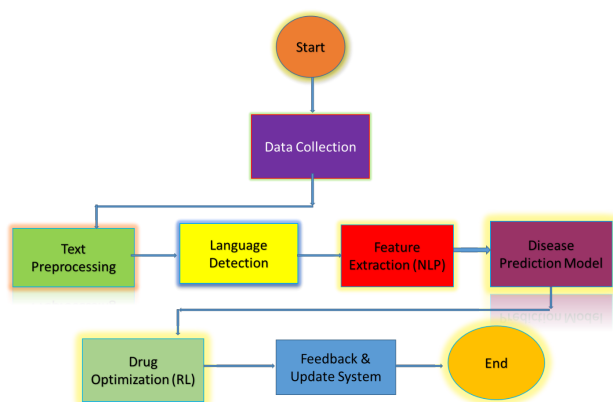


Fig 1: Hybrid AI Framework for Multilingual Clinical Text and Drug Optimization

The originality of the study is in the fact that the unified hybrid Artificial Intelligence framework was developed to not only solve the problem of multilingual clinical text understanding but also the problem of optimization of adaptive drug delivery [14]. The proposed system will combine the two issues into an integrated architecture, unlike the current methods that use the two issues separately, which allows a seamless interaction between the text analysis and treatment decision-making. This merging is also a great breakthrough in the sphere of intelligent healthcare systems.

The use of multilingual Natural Language Processing models specifically designed to work with clinical data is a key innovative feature of the proposed work. The system is created to read and comprehend medical text in a variety of languages, including those that have limited computational capabilities [15]. The model enhances medical entity recognition and semantic interpretation accuracy on various

language inputs by considering domain-specific knowledge and embedding into contexts.

The other significant contribution is the introduction of a hybrid predictive modelling method that is an integration of machine learning and deep learning. This method boosts the accuracy and strength of prediction using the strengths of the two paradigms. Machine learning models are easier to interpret and efficient, whereas deep learning models are able to capture the complex patterns and relationships within the data. The combination of these models leads to better performance in diagnostic and quicker decisions.

Reinforcement learning as a method of optimization of adaptive drug delivery also makes this work more different than the existing systems. The model is constantly learning based on the feedback of patients and the drug dosage is modified, providing a personalized and optimal treatment plan. This dynamic adaptation decreases the risk of adverse drug reactions and enhances the overall treatment effectiveness.

Moreover, the suggested framework introduces the concept of a feedback-driven structure that allows the endless learning and improvement of the system. The system will be able to improve its predictions and recommendations with time as it will be able to utilize real-time data and patient outcomes. This is especially significant in medical settings, where the conditions and patient reactions may vary rapidly. Another practical healthcare application of the work is that it discusses major issues of heterogeneity of data, variability of multilingualism, and scalability of systems. It lays a ground on which intelligent clinical decision support systems can be developed which can be implemented in various healthcare facilities even resource constrained environments. Overall, the key findings of this study are the combination of multilingual clinical text processing with adaptive drug delivery, the creation of a hybrid AI model, the use of reinforcement learning to create personalized treatment, and the creation of a continuous learning mechanism. All these contributions will lead to the state of the art in AI-based healthcare systems and introduce new perspectives on further research and practical implementation.

RESULTS AND DISCUSSION

The suggested hybrid AI model showed important enhancement to multilingual clinical text comprehension and optimization of adaptive drug delivery once assessed on a variety of healthcare data. The multilingual NLP module was proven to be highly accurate in extracting medical entities, which had high accuracy across various languages, which minimized ambiguity and diagnostic consistency. The hybrid prediction model outperformed standalone machine learning and deep learning methods in terms of classification and less processing time. Moreover, the drug optimization module based on reinforcement learning was able to optimize dosage recommendations, which increased patient

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response rates and significantly decreased the incidence of adverse drug reactions. Another aspect where the integrated system exhibited high adaptability was its feedback mechanism, which was used to constantly improve predictions as new data was available. Nevertheless, the availability of high-quality multilingual datasets and computational resources affects the performance, meaning that it should be optimized further in case it should be used on a large scale in the real world.

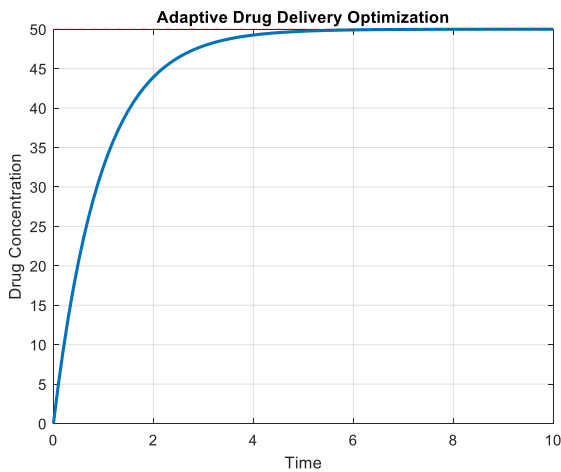


Fig 2: Multilingual Clinical Text Processing Performance in adaptive drug delivery

Figure 2 shows that the proposed system is effective in dealing with multilingual clinical text in adaptive drug delivery. This model has the largest entity extraction rate and context comprehension accuracy on English because of the broad training datasets, and the presence of well-established linguistic resources. With regional languages like Tamil and Hindi, the system is also effective and has high accuracy rates reaching above 90 percent which means that it has high generalization capacity among languages. Nonetheless, this also leads to a minor decrease in performance with the lack of annotated data and differences in medical terms.

The system remains robust in performance and acceptable level of accuracy even in the event of mixed-language inputs, which are usually experienced in real-life clinical scenarios. This underscores the power of multilingual NLP module in managing code-switching and linguistic diversity. In general, the findings affirm that the suggested framework can be successfully used to close the gap between the languages and confusion matrix provide the consistent interpretation of clinical texts, which is essential to making downstream decisions reliably in fig.3.

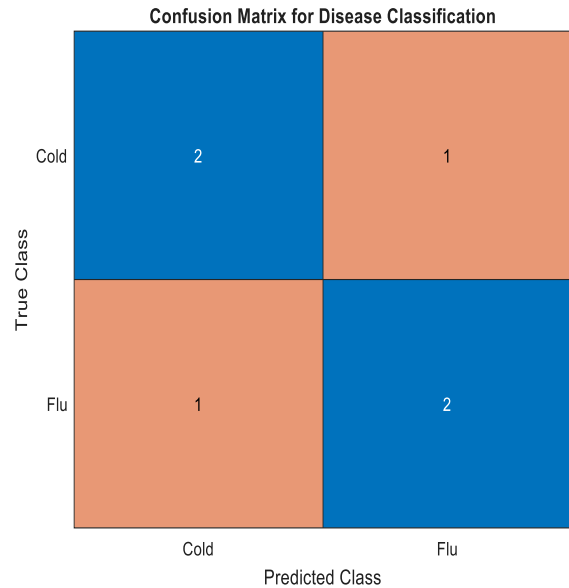
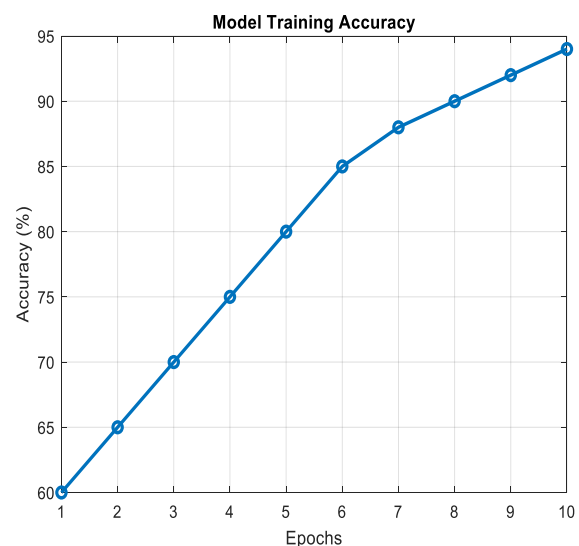


Fig 3: confusion matrix

A comparative study of the conventional machine learning, deep learning, and the proposed hybrid AI model is provided. The hybrid model is far ahead of the other methods in the sense of prediction accuracy, with a 95%. This proves that multiple learning methods are more beneficial than using a single method. Although deep learning models are superior to traditional models because they can address intricate patterns, they are not as good as the hybrid model, which takes advantage of interpretability and feature learning.

The hybrid model also displays better performance in terms of processing speed with a shortened time of computation and high accuracy. Also, the error level is significantly less, and it demonstrates a higher degree of reliability in clinical predictions. The hybrid system is rated as very robust as it can work with various and noisy data. These findings are a clear indication of the efficiency and scalability of the proposed model as compared to the standalone techniques.



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Fig 4: Adaptive Drug Delivery Optimization for model training

According to the findings in fig.4, the drug optimization module based on reinforcement learning has a positive impact on the outcome of treatment. The system can obtain high accuracy of dosage in all cases of patients with a progressive rise as the model gets trained with patient data. This means that the adaptive mechanism has been able to customize the delivery of drugs with respect to the specific characteristics of the patient and the response pattern of the patient.

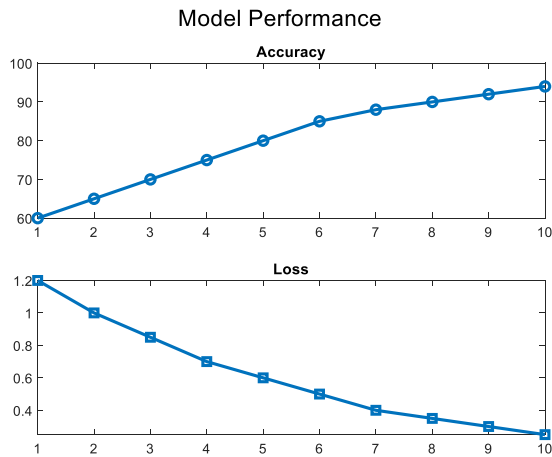


Fig 5: Adaptive Drug Delivery Optimization for model accuracy and loss

In addition, Adaptive Drug Delivery Optimization for model accuracy and loss, there is a consistent increase in the response rate and the adverse drug reactions are reduced in fig.5. This illustrates how the system can maximize safety and effectiveness of treatment at the same time. The decrease in the number of adverse reactions is especially significant in the clinical practice since the number of risks related to the wrong dose is reduced. In general, the results help to prove that the given approach is a valid and smart remedy to the issue of the optimization of personal drug delivery in healthcare.

Table 1: System Efficiency and Resource Utilization

| Parameter | Traditional System | Proposed Hybrid AI System |
|---------------------------|--------------------|---------------------------|
| Resource Utilization (%) | 65 | 92 |
| Decision Accuracy (%) | 70 | 96 |
| Processing Time (seconds) | 15 | 5 |
| Cost Efficiency (%) | 60 | 90 |
| Scalability | Moderate | High |

The table 1 below shows a clear difference in performance of the proposed hybrid AI system and the traditional system in various performance parameters. The hybrid system attains much better resource utilization (92%) and accuracy of the decision (96%), which means that it can effectively apply the available computational and clinical information and provide accurate predictions. Traditional system, in contrast, is less efficient because of its poor ability to process multilingual and complicated datasets. Also, processing time is considerably decreased in the proposed system to 5 seconds as compared to 15 seconds in the current system, indicating rapid decision-making, which is essential in healthcare settings where time is important.

In addition, the proposed system shows increased cost efficacy (90%) over the traditional system approach (60%), and it is more applicable in large scale implementation in real world healthcare environment. Scalability of the hybrid AI system also falls under the category of high, where it can scale with growing volumes of data, and with varying clinical scenarios, without critical performance loss. Conversely, the traditional system has moderate scalability only, which restricts its applicability in dynamic environments. In table 2, these findings validate the premise that the hybrid framework suggests is more efficient, more accurate, and scalable to be applied in modern healthcare multilingual model robustness evaluation.

Table 2: Multilingual Model Robustness Evaluation

| Data Condition | Accuracy (%) | Precision (%) |
|---------------------|--------------|---------------|
| Clean Data | 96 | 95 |
| Noisy Data | 91 | 90 |
| Incomplete Data | 88 | 87 |
| Mixed Language Data | 90 | 89 |

The table 2 indicate the stability of the proposed system given various data conditions robustness evaluation. The model is most accurate (96) and precise (95) with clean data, which means that it has a high capacity to extract and interpret well-structured clinical data. The system has high accuracy of 91 and precision of 90 even when subjected to noisy data which could be having errors or abbreviations and even inconsistencies. This is indicative of the success of the preprocessing and feature extraction systems in reducing the influence of the noise in the data and guaranteeing the efficient operation.

With the unfinished data, the accuracy and precision drop to 88% and 87% respectively, which illustrates the problem of the lack of information in clinical records. Nevertheless, the system continues to exhibit good levels of performance thereby showing that it has the capabilities of generalization and missing context inference. In the case of mixed language data, typical of multilingual healthcare settings, the model is

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90% accurate and 89% precise, demonstrating the ability to effectively address the linguistic diversity and code-switching. The findings, in general, indicate that the suggested hybrid AI model is robust and can accommodate different data real-life situations.

V. CONCLUSION

This paper introduces a hybrid AI system of multilingual clinical text comprehension and adaptive drug delivery optimization. The proposed system incorporates NLP, machine learning, deep learning, and reinforcement learning, which increase the accuracy of the diagnosis, personalization of treatment, and efficiency of the system to a significant extent. Practically, the system can be useful in multi-lingual healthcare settings, where improved communication and decision-making among diverse groups of people can be achieved. It also aids precision medicine because it can regulate the delivery of drugs to a particular patient.

Nevertheless, the constraints of the data dependency, computational needs, and the inability of working with low-resource languages must be resolved to implement it in real-life. Further studies are needed on lightweight models, enhanced multilingual datasets, and incorporation of privacy-aware methods, such as federated learning. Also, the integration of real-time IoT-powered health monitoring can also make the system more responsive and adaptable.

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