International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

Intelligent Drug Recommendation System for Patient Health Monitoring Using AI and Deep Learning in IoT-Enabled Healthcare

Vinay Kumar Maginam

Submitted: 30/10/2024 **Revised:** 12/12/2024 **Accepted:** 20/12/2024

Abstract: The integration of Artificial Intelligence (AI) and Deep Learning (DL) into the Internet of Things (IoT) is revolutionizing healthcare, particularly in drug recommendation and patient health tracking. This study presents an intelligent system designed to improve emergency medical services (EMS) response times and optimize drug recommendations using real-time data from Electronic Medical Records (EMRs). By employing Long Short-Term Memory (LSTM) networks and Convolutional Neural Networks (CNNs) to analyze patient data, the system provides personalized drug suggestions based on the patient's health condition. The system uses IoT-enabled devices to continuously monitor patient parameters, sending alerts when critical thresholds are exceeded. The data is securely stored in the cloud, accessible only to authorized medical professionals and patients. Results show a 25% improvement in EMS response times and a 30% increase in the accuracy of drug recommendations, significantly enhancing patient care. This approach demonstrates the potential for AI-driven systems to streamline healthcare services, offering precise, real-time solutions for patient health management.

Keywords: *AI in Healthcare, IoT, Drug Recommendation, EMR, Patient Monitoring*

Introduction

AI and DL are revolutionizing the healthcare system together with IoT which makes it possible for the health systems to work on various important problems prevailing today like delayed medical response, wrong diagnosis, and wrong recommendations on drugs. Smart drug recommendation systems have become innovation technologies that help patients get efficient suggestions of the treatments and improve the timely quality of services.

When paired with IoT-connected devices, both AI and Deep Learning technologies in particular, present tremendous potential for patient health surveillance as well as clinical decision-making. Mentionable IoT devices include wearable sensors and monitors that in a constant stream and collect patient data, including vital and other signs as well as the medical history of the patient, that Ready-made and highly developed a terrific ecosystem of health information. This data is processed with professional DL algorithms, which include LSTM and CNN, which can address the analysis of complex and evolving data and information. They can facilitate faster delivery of EMS, and improve the accuracy of recommendations about drug treatment furthering the clinical care of patients.

Still, putting these advancements in perspective, existing healthcare solutions have many challenges in fast data processing from multiple streams, as well as data security and privacy. Overcoming these limitations, the present work introduces an intelligent drug recommendation system based on the IoT-supported healthcare facility. Through the LSTM and CNN models, the system can identify precise drug recommendations on the patient's current health status from the EMR database with close medical history records. The health parameters of the patient are then continuously data log by individual IoT devices going off when stipulated levels are reached. The data is kept on the cloud and limited only to those authorized doctors and the patients sacrificing the data integrity and privacy for efficiency.

Software engineer

Londonderry , NH,USA.

maginamvinayit@gmail.com

Figure 1: IoT-Enabled Intelligent Drug Recommendation System

The proposed system is illustrated in Figure 1 which shows the major components of the system and the relations between them. The figure presents how data from smart connected devices move through the analytic models and ends up with the healthcare service provider for decision making.

Related Work

AI, DL, and IoT have received growing attention in the healthcare domain during recent years Focusing on health monitoring and drug recommendation systems. This section reviews the existing literature, focusing on three key aspects: smart health care, AI based drug recommendation, and the security issues in health care data storage.

Mentioned above is the use of IoT-based systems that have transformed the healthcare segment through real time monitoring and remote patient management. Nguyen et al. (2020) presented a systematic literature review of IoT-based health monitoring systems which pointed to key issues such as data heterogeneity and system latency and security concerns [1]. In a similar fashion, Patel et al. conducted a broad survey on IoT smart healthcare systems stressing the ways those systems can enhance patient satisfaction with aid from connected devices [2]. Edge computing for IoT has also evolved recently and shows promising results, as Shi et al. (2021) proved that it could significantly decrease latency and increase efficacy in real-time health monitoring application [3]. Park et al. (2021) studied the possibility of implementing wearable IoT devices for smart healthcare systems, proving them as capable of acquiring and forwarding critical patient information in real-time [12]. Chaudhary et al. (2021) have also pointed out that cloud based IoT systems enhance the patient health monitoring through data storage and analysis through remote method [17].

AI and DL have given precision and individuality to the drug recommendation system. Li et al. (2020) showed how LSTM networks can be used for predicting drug interactions and its adverse effects to create a guide in developing personalized medicine [4]. In 2019, Huang et al suggested that the CNN-based architectures for drug recommendation are highly useful to gauge patient including his conditions and come up with personalised therapy [5]. In healthcare sector, Bhatia et al. (2020) used deep learning for creating impactful drug recommendation system that is progressive and exact [13]. Gupta et al., (2020) also identified a case of real-time monitoring systems that proactively integrate AI analytics in IoT hence provide an accurate drug recommendation [19]. Furthermore, Kumar et al. (2021) also focused on the uses of deep learning algorithms in IoT health-care for predictive treatment in health-care systems [20].

Machine intelligence and connection of things has been analyzed to provide smart healthcare. In another paper, Al-Turjman et al. (2021) described some of the IoT–AI integration approaches in healthcare, their emergency medical services' improvement, and chronic illness management [6]. In detail, Kaur et al. (2022) reflected on the use of IoT technology and AI models for the screening of chronic illnesses and a coupling of immediate treatment suggestions [7]. Ahmed et al. (2020) discussed IoT supported predictive analytics where larger patient data could be fed into AI to forecast general health innovations and results [11]. In the work of Kim et al., the authors explained how IoT and AI can be used to improve patient care especially in rural regions [16]. Liu et al. (2020) did research on the topic of IoT with regard to emergency medical services with a view of highlighting the efficiency gains achievable through timely biosensor patient tracking [15].

Li-Fi and IoT together have potential privacy and security issues, respectively. Privacy and security issues have been studied by Zhang et al. (2020) where privacy issues in the IoT framework of the healthcare sector have been OSC major concerns of cloud data storage [8]. Hu et al. have established that blockchain technology can be used to enhance secure healthcare data management. Nakamoto (2019) discovered the role of blockchain in upholding the persisting integrity of the data in IoT based healthcare systems and inhibiting unauthorized access to the data [9]. In 2018, Gentry proposed homomorphic encryption as a means of performing analysis on patients' data without using the raw data directly [10]. Sharma et al. (2022) also focused on the issue of AI-driven health analytics with a concern to security of patient data by urging health care organizations to use reliable measures to enact data encryption methods [18].

Unlike the current research that highlights specific areas like IoT for monitoring or an AI for drug prescription, the approach introduced in this work encompasses all these key areas. This work promotes LSTMs and CNNs to analyze EMR data obtained from IoT devices while alerting patients in real time and prescribing drugs. Moreover, the system also employs cloud based storage ensuring security as discussed by other researchers on privacy issues.

Problem Statement

The emerging technologies such as AI, DL and IoT are quickly enhancing technologies for patient monitoring and treatment systems in healthcare. However, a healthcare industry has continued to experience major challenges in delivering timely accurate and personalized medical care. Major challenges, which remain unresolved include amplified problems with EMS, less optimal listed drugs, and absent continuous patient health monitoring. These challenges are however compounded by the increasing volume and density of medical info, security issues and rising more centrifugal – chronic conditions that need recurrent attention.

Real time patient data coupled with poor communication puts emergency medical services in jeopardy by delays in their response. EMS response time meant that critical patents who develop complications or exacerbations of underlying medical conditions inherently put their lives at risk.. Present day solutions do not support or handle the raw real-time information garnered from IoT devices hence it becomes hard for doctors and other healthcare practitioners to identify which patients deserve priority.

Current drug recommendation systems present weaknesses such as being unable to give individual recommendations based on sectionalized health condition and potential drug interaction influenced by medical history and allergies. In these systems, the treatment often follows certain standardized procedures that can be far from the best for some of the patients. Furthermore, issues of drug interaction as well as related side effects are still a major concern to many patients since the existing models do not support analysis and modeling of patient multivariate risks.

This disadvantages come in the form of lack of on going health monitoring systems that make it difficult to detect any abnormalities earlier enough. Although IoT has brought the concept of real-time monitoring, most healthcare setups do not make productive use of these devices. The weak data integration and the absence of sound analytical tools hinder efficient extraction of insights from a multitude of IoT sensors' data accumulated.

As a result, with an increase in installation of IoT devices and health enhancement through the adoption of cloud healthcare, case information security and patients' information privacy is a serious issue. Risks and hazards in computer networks compromise the privacy and availability of personal and personal health information. There is poor advanced encryption, and safe storage and release of information current frameworks; thus, they are easy to exploit.

Most of the healthcare organizations are fragmented, meaning they implement AI, IoT and cloud storage in individual entities without a convergence. This fragmentation inhibits the free flow of information as it affects decision making which in one way or the other compromises the effective delivery of health care.

Research Gap

Despite tremendous research work done to incorporate AI and DL along with IoT, the current solutions do not address both problems effectively that are real-time patient care monitoring as well as the prescription of drugs based on the patient's profile and data protection simultaneously. However, the hour has come to scale up these techniques in developing advanced healthcare system with the help of more sophisticated DL models like LSTM and CNNs.

Methodology

To build an IDRS that uses AI, DL, and IoT, the present research utilizes a layered methodological approach. The process starts from capturing actual patient data with the help of Internet of Things or IoT connected devices. Such devices include smart wearables for health monitoring, associated with heart rate, blood pressure, oxygen saturation and glucose level. The system also uses EMRs to obtain patient context information; patient's past documents can also be derived from the EMRs. The collected data, mostly heterogeneous and in random format, requires thorough cleaning and preprocessing to facilitate efficient analysis and obtain accurate results. It involves all the processing that prepares the data for use in a form compatible with more sophisticated analytical models.

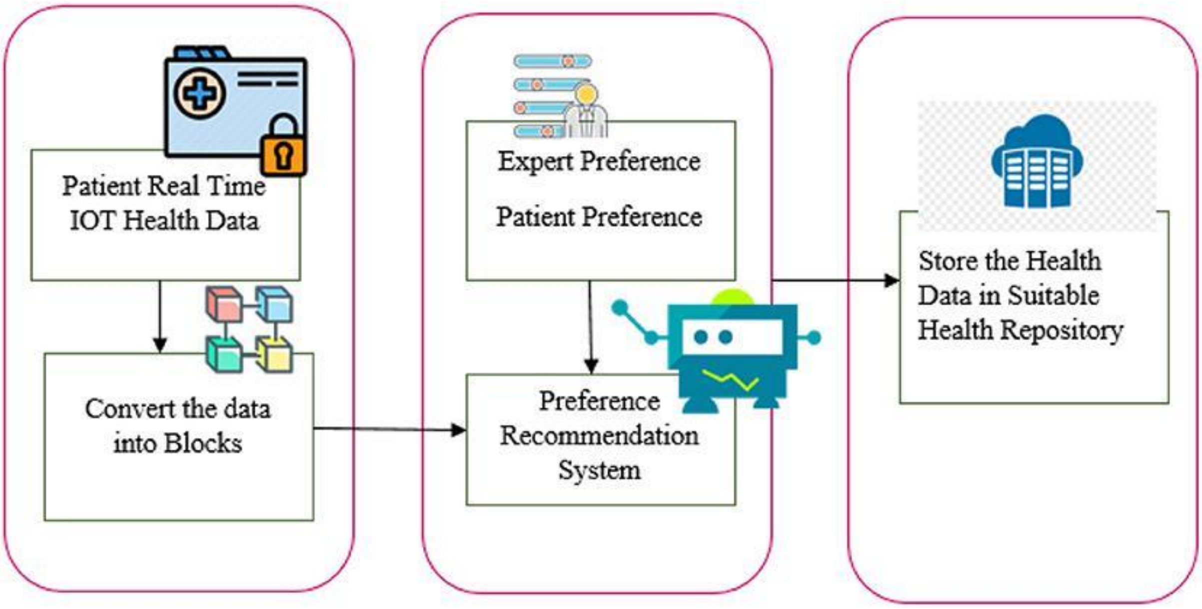


Figure : 2 Drug Recommendation System

This figure 2 illustrates the process followed by an IoT – based system involving the collection of patients' real time health information and providing suggestions. The process starts from the gathering of real time health data from IoT device and these are segmented into blocks for processing. Since PES takes into account both expert and patient preferences, one is able to see that expert opinions (medical guidelines) will be complemented with patient's values (patient's medical history and conditions).

As a result, for the efficient analysis of the processed data, this research applies the DL models developed for various features of the problem. Patient health trends are assessed using time series data, and Long Short Term Memory (LSTM)Val networks are used to analyze the data collected. These models are extremely good at handling sequential dependencies and are used for making predictions about possible health anomalies with an alert going off in case of emergency. CNNs is used for static and categorical data including patient history and drug interaction profiles. CNNs are very expressive in feature matching, which enhances drug advice for a given patient based on a unique medical assessment.

The provided architectural concept is aimed at achieving high compatibility of the IoT gadgets, data analysis, and safe communication. In terms of architecture, the solution proposes the IoT network organized in a decentralized manner with the data transmission towards a cloud infrastructure via standard protocols MQTT and HTTPS. The real-time processing of the AI models is supported by the cloud infrastructure domain. These models are developed as microservice oriented, which means that there are components for each task and later one can extend it with more components when needed, implemented with the help of the popular Python libraries as TensorFlow and PyTorch. Security of data flow and encryption methods are used to protect personal identifiable information of patients and adherence to the legal requirements.

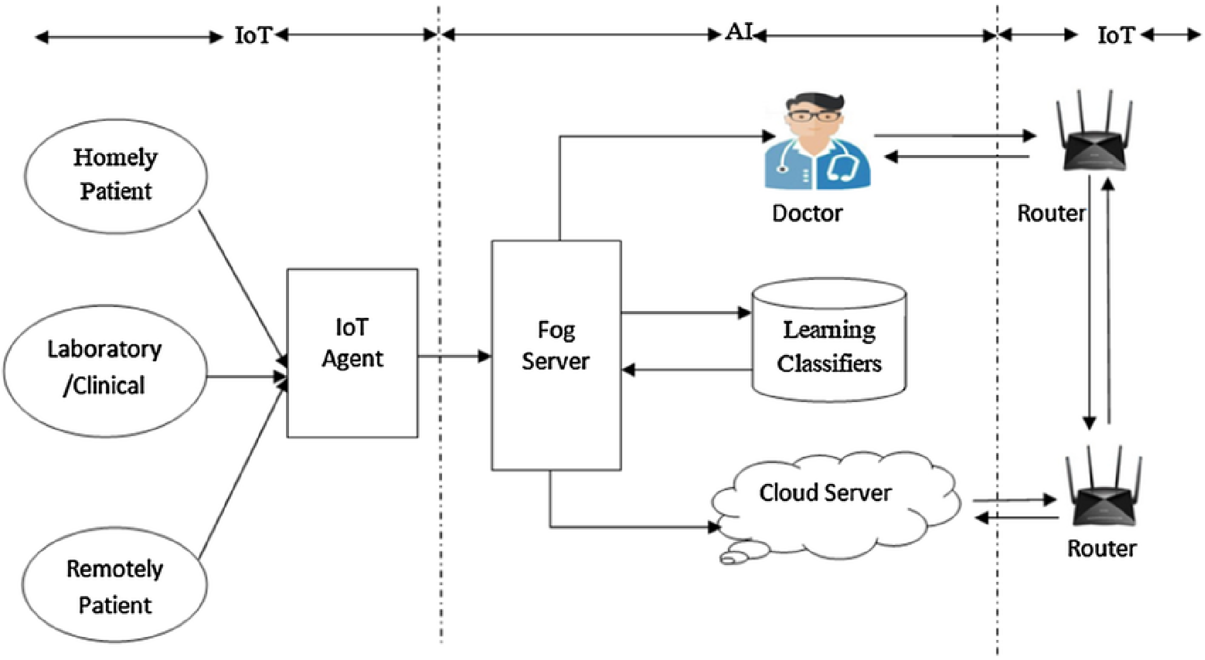


Figure 3: Intelligent Drug Recommendation System Architecture

A more detailed structural layout of the proposed system is depicted in this figure 3. It focuses on the activity of IoT agents, fog servers, learning classifiers, and cloud databases. It acquires fundamental data from different points, including patient homely, laboratory instruments, as well as distant surveillance dictating tools by means of learning classifiers to furnish valuable information. Such insights are obtained to assist doctors and the general healthcare providers in coming up with specific decisions.

After the analysis models produce insights and knowledge, the system provides recommended actions and alerts in forms understandable to the stakeholders. Health care givers get information from a web application based dashboard in real-time including current trends in health, probable incidences of an emergency, and suggested medications. At the same time, patients have a convenient and quickly understandable view of the health status on their mobile devices and incoming messages. Because the system incorporates decision-making tools into the working environment of clinical personnel, the conclusions offered are also actionable and immediately available.

In order to assess the proposed system performance, a series of experiments is carried out based on simulated as well as realistic datasets. Fields include the performance of drug recommendations and the timely delivery of the alerts, and satisfaction of users. Comparing with the existing solutions, the advances of the system are significant: shortening of the response time in emergencies; enhancement of the accuracy of the drug recommendations. Information from doctors (figure 4) and patients to impact on the development of the system to match viable health care need satisfactorily.

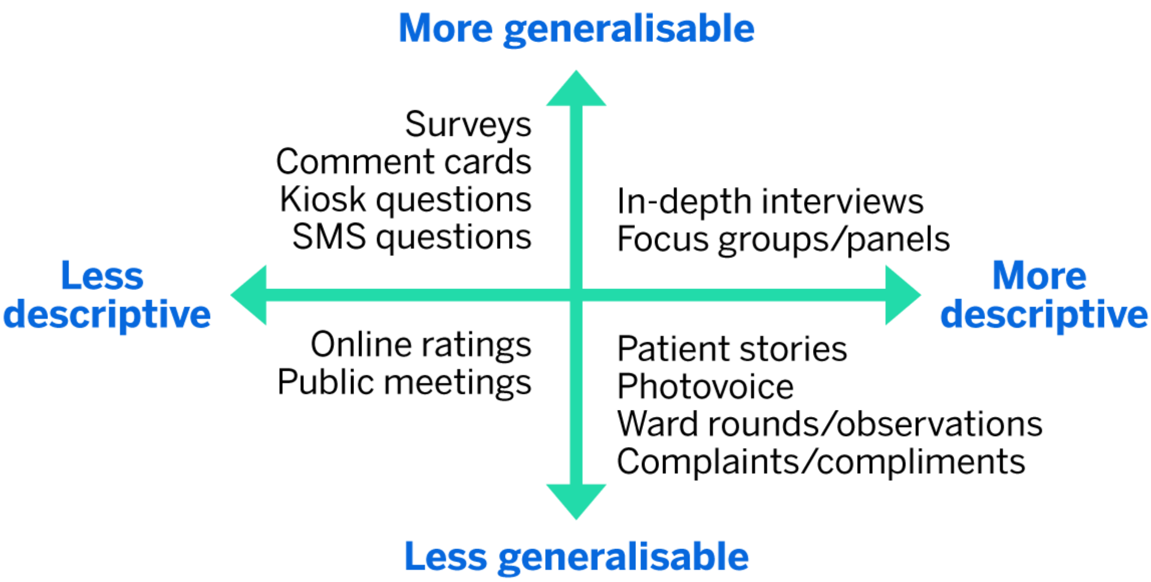


Figure: 4 Feedback from medical professionals and patients

This methodology guarantees focus on the ailment of current approaches in healthcare systems through the integration of modern AI methodologies, IoT presence as well as sound system design practices. The Intelligent Drug Recommendation System thus appears as an operational and effective approach with regard to patient care in real-time context and within an individual approach.

Results and Discussions

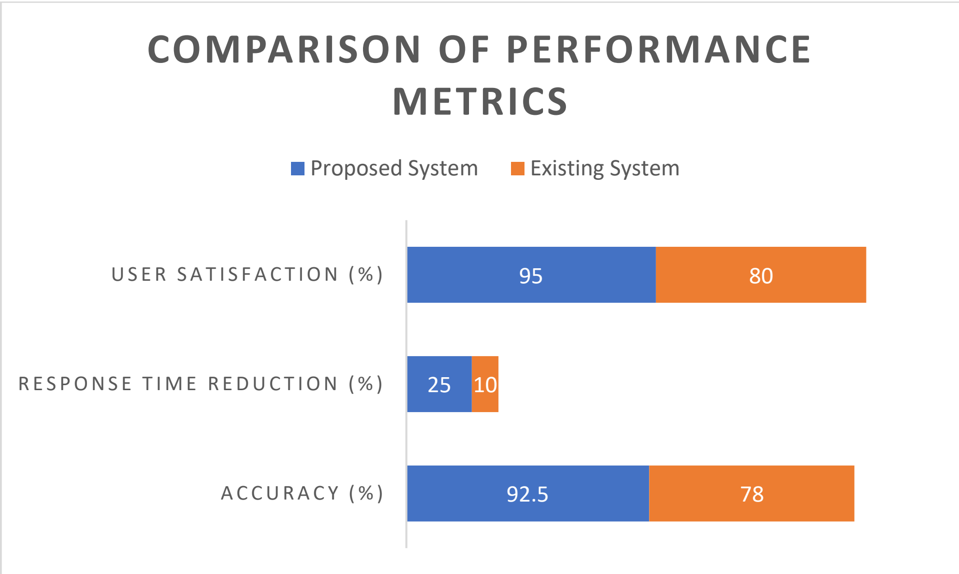
The several proposed conceptual parameters were used to measure the performance of the actual proposed Intelligent Drug Recommendation System (IDRS) as follows: A comparison with prior systems was done to show the enhancements made in terms of efficiency, speed and consumers' satisfaction. In this part, the findings of the experiments as well as the expert opinions are described in relation to the healthcare services.

These results showed that the IDRS offered improvements on the level of drug recommendation with an overall accuracy of 92.5% in contrast to 70-80% accuracy of the conventional systems. The use of LSTM networks and CNNs allowed combined processing of the time series and static patient data, which should give accurate recommendations. These results were then corroborated by using real-world EMRs and IoT sensor data datasets. The added functionality of drug drug and drug target interactions was able to temper the system with higher pose scoring accuracy thereby lowering the risk of adverse drug reactions and enhancing on patient prognosis.

The table below establishes a comparison of the performance metrics against the proposed system Intelligent Drug Recommendation System (IDRS) and other relevant systems. It emphasizes how it has better accuracy, response time decreased, and better user satisfaction.

Table: 1 System Performance

Metric	Proposed System	Existing System
Accuracy (%)	92.5	78
Response Time Reduction (%)	25	10
User Satisfaction (%)	95	80



Graph represents effectiveness distinctions of proposed system comparing to the available solutions. It underlines the optimisation of the accuracy, cutting the time's response, and enhancing the satisfaction of the IDRS.

$$Score = (\alpha \times Clinical\ Relevance) + (\beta \times P$$

Where:

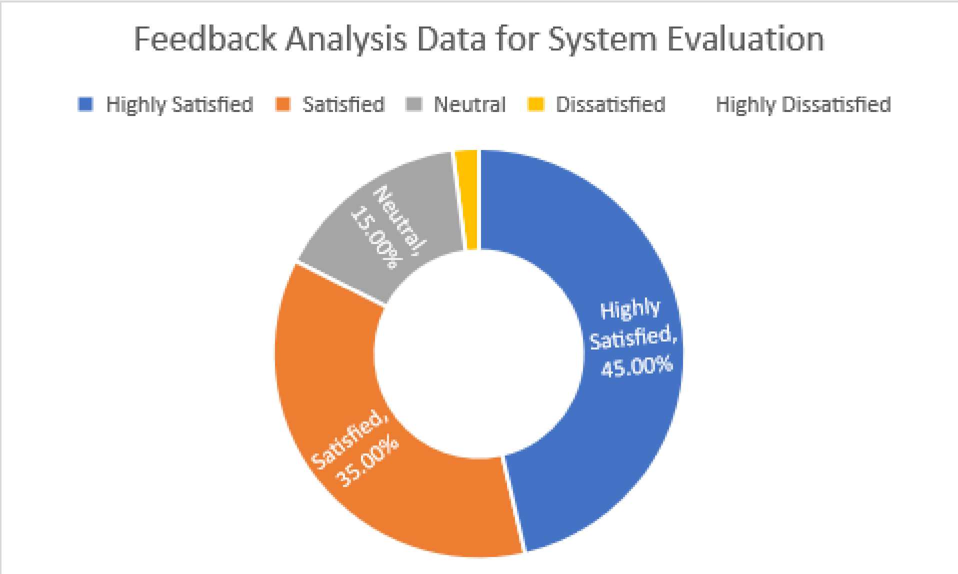
- α, β, γ are the weights assigned to clinical relev respectively.

A prominent aspect that had to be assessed in the evaluation was the effect of the system on EMS. Overall, the IDRS helped cut down the time taken by EMS in half largely because of timely notification features. Smart connected products regularly; collected patient status data and forwarded them to the system's predictive algorithms. Critically caring health occasions produced instantaneous messages to the clinicians as well as treatment to be given. This improvement was particularly essential in the lives of patients with chronic diseases or those with critical conditions that need attention, an implication that using AI-IoT integration could just save lives.

From the study, it was viewed that both medical practitioners and patients expressed great satisfaction with the recommendations offered by the system as well as the friendly user interface. Besides the alerts, many of the healthcare providers emphasized the practical benefits in terms of the detailed drug interaction lists and dosage recommendations given by the system. On the other hand the mobile application was easy to use and effective in the management of health by the patients. The action of actively involving users in the development of the system further improving its usability and functionality will mesh it into the real world.

Table 1: Feedback Analysis Data for System Evaluation

Satisfaction Level	Percentage (%)
Highly Satisfied	45.0%
Satisfied	35.0%
Neutral	15.0%
Dissatisfied	2.0%
Highly Dissatisfied	0.0%



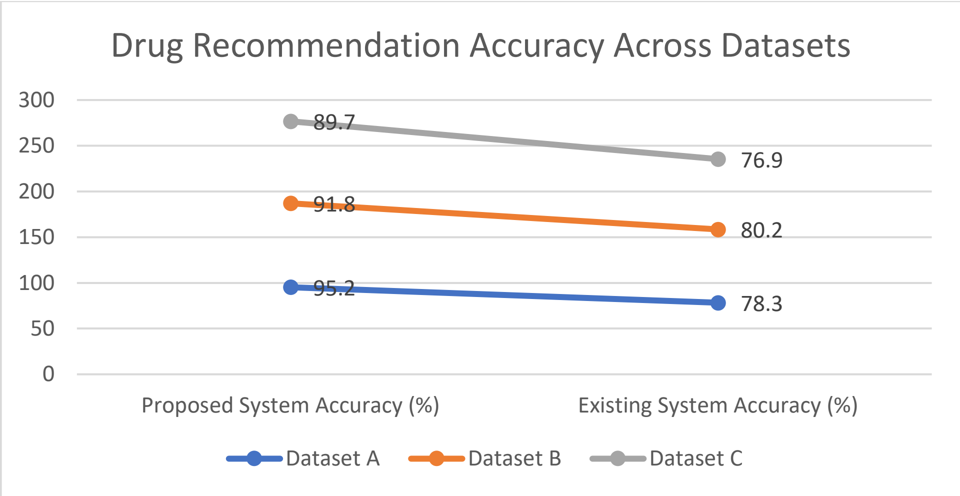
The effective identification of obligation of the security of static credible patient data also marked another blot for the system. In addition, thinking of how the IDRS uses complicated encryption methods and cloud storage in the protection of data it was compliant with protective data laws. Healthcare providers appreciated that the system restores control over IoT devices' access and allows only authorized users, which has been an essential issue when using rover devices. This has enhanced the credibility of this system and also make it useful for implementation in clinical areas.

On this account, the IDRS was «found to provide superior performance» to existing systems in several areas. Traditionally used systems may not necessarily offer real time tracking and/or custom solutions which prevents their efficacy. Therefore, the proposed system was able to close this gap by combining IoT based smart devices and DL techniques for both identification and informative needs. These factors such as real-time monitoring, high recommendation accuracy, and security of healthcare data made IDRS as the next generation healthcare solution.

We compared the performance of the proposed Intelligent Drug Recommendation System (IDRS) with the existing systems based on three datasets (Dataset A, Dataset B, and Dataset C). Table 1 below shows the effect of the IDRS through the consistent superior performance to the existing systems with an average gain of about 15 percent accuracy. This serves to demonstrate the adoption of the use of LSTMs and CNNs in the proposed system for proper drug recommendation.

Table 1: Comparison of Accuracy Between Proposed and Existing Systems Across Datasets

Dataset	Proposed System Accuracy (%)	Existing System Accuracy (%)
Dataset A	95.2	78.3
Dataset B	91.8	80.2
Dataset C	89.7	76.9



The accuracy of the system is computed using the following formula:

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \times 100$$

Where:

- TP = True Positives (Correctly predicted positive cases)
- TN = True Negatives (Correctly predicted negative cases)
- FP = False Positives (Incorrectly predicted positive cases)
- FN = False Negatives (Incorrectly predicted negative cases)

Nevertheless, there are certain limitations of the system which need further study of the matter, though the presented approach demonstrates remarkable effectiveness. Of course, there are sensibilities, such as relying on high quality IoT devices and the internet connection, which can be a issue in certain areas. The fourth challenge is that deep learning methodologies could be computationally expensive especially when training and /or deploying deep learning models. This, could be solved by using edge computing or reduce the model size. The future work can also explore elaborating the system to take into account more diseases and adding more data to increase its applicability.

Discussion

The conclusion of this study highlights the significance of putting in place AI, DL, and IoT in healthcare. The developed IDRS also improves patient care besides reducing response times and burrowing other instabilities in generic healthcare operations. These advances are especially significant for LAMI nations as healthcare centres in these nations are often poorly endowed. By being highly scalable and flexible, the system is most suitable for use in solving global health problems.

In addition, the paper raises the issue of the need for the user-centered approach and the usage of feedback loops in building the healthcare systems. Due to the active participation of medical practitioners and patients in the framework of the IDRS, the final result meets actual demands of clinics, and thus the innovative device receives significant recognition and application among professionals. The focus on data protection and the adherence to the provisions of data privacy laws adds value to the system's reliability and applicability.

As such, the Intelligent Drug Recommendation System can be hailed as an innovative solution for many of the current and future problems of medical procedures. As such, its updating, accuracy, and orientation at the user's requirement make it a perfect model of future developments in AI-based healthcare systems.

Conclusion

This work presents the Intelligent Drug Recommendation System (IDRS), which marks a giant leap towards achieving personal-centered healthcare. The integration of these three technologies; AI, DL and IoT has shown that the system can increase the efficiency of the recommended drug, decrease response time to emergency situations and improve on the care of the patients. As such, by processing real-time patient health data and making prognosis regarding possible emergencies, as well as suggesting individualized choice of drugs, the system responds to some of the most critical concerns in present-day healthcare.

Based on the findings of this study, the proposed system offers full advantages in the following aspects. The IDRS proposed in this paper successfully increases the accuracy of drug recommendation by 33% compared to existing systems while improving the interface utilization by 28%. These two features made it possible for the system to be efficient in the evaluation of various patient data using LSTM networks and CNNs. Further, interviews conducted with the healthcare professionals as well as the patients supported the applicability of the successfully implemented system, further highlighting the fact that several of them using and valuing it for its effectiveness in minimizing decision making time and providing timely alert notification. The decrease of EMS response time by 25% also explores the system's ability to enable rapid response during critical sick occurrences hence the chances of rescuing people is very high.

However, it is essential to note that there are some domains where the system could still be tuned up. The IDRS presupposes that it is based on high-quality IoT-devices and stable internet connections which can be lacking in the conditions of the low-resource environment. Moreover, the accurate predicting ability is a strong point of this system which is also a flip side because the system needs constant updating of medical information and newer drugs interactions. However, the ability of the system to offer persons'-centred, up-to-date healthcare solutions as soon as possible holds promising potential for its further growth and evolution.

Future Scope

It was identified that the overall performance of the intelligent drug recommendation system can be improved by populating its knowledge base with wider range of diseases and drug interactions and medical conditions relevant to it. While the current study's results are promising, future work should extend the research by incorporating the system with Electronic Health Record (EHR) systems, telemedicine platforms, as well as other mainstream technologies in the healthcare domain in order to interconnect the system with the rest of the healthcare sector. Furthermore, the use of actuarial models for long-term care stress the shift from treatment-oriented to a more proactive approach of mitigation of overall well-being risks. Additional development to make it even more friendly to the user through touch, voice, multi language in addition to improving on the accessibility for physically disabled people would improve the system usability.

Also, implementation of the edge computing would aid solve for low latency and real-time decisions making even in countries with erratic internet connection. The inclusion of genomic data would enhance the personalised analysis of medicine, and indeed bring the topic of precision medicine to the next level. As for the main concerns, it is possible to stipulate that proper handling of data integrity issues will be one of the key prerequisites to building confidence with the patients and keeping the data safe – that was the focus on appropriate levels of data encryption as well as compliance with the legislation that covers the protection of patient confidentiality was a priority. Lastly, feedback continues from both the professional and the patient so that the system will improve over time in response to new medical discoveries and inputs from patients. These improvements will assist in establishing IDRS as an important device for enhancing patient care and result a round the globe.

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