Oxygen: A Distributed Health Care Framework for Patient Health Record Management and Pharmaceutical Diagnosis

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***Abstract*— With the COVID-19 pandemic, the world is confronting various healthcare issues, and healthcare automation is more crucial than ever. The pandemic has revealed the limitations of existing digital healthcare systems to manage public health emergencies. There is no registered population for many healthcare institutions in Sri Lanka, as a result, there is a communication gap. Electronic Health Record systems (EHRs) are becoming popular to share patient details but accessing scattered data across several EHRs while safeguarding patient privacy remains a challenge. Most of these medical records are in printed format and manually entering those into EHR systems is time-consuming and error prone. Not only that pharmaceutical error is a critical healthcare problem, but it is even riskier to visit doctors for pharmaceutical diagnosis during a pandemic. This research introduces a Blockchain-based patient health record system, an Optical Character Recognition (OCR) and Natural Language Processing (NLP) based Medical Document Scanner, a Drug Identifier based on Image Processing and a Medical Chatbot powered by NLP as four novel approaches to address these issues. Altogether with the results, this research aims at introducing a solution for the limitations in healthcare while providing a distributed healthcare framework for the healthcare community worldwide.**

Keywords*— Digital Healthcare, Machine Learning, Natural Language Processing, Blockchain, Image Processing, Optical Character Recognition*, *Healthcare Transformation*

I. INTRODUCTION

The world is facing numerous challenges in the field of healthcare due to COVID-19. The pandemic has had an unforeseen worldwide impact in terms of healthcare systems generating difficulty for healthcare workers in identifying and monitoring mass populations. The pandemic has exposed the importance of the digitalization of the healthcare industry and the limitations of the existing systems. As a result of COVID-19, research institutes and governments have been obliged to reconsider healthcare delivery solutions to maintain service continuity when people stay at home and conduct social distancing.

In recent years researchers are focusing more on the use of Blockchain and Machine Learning (ML) approaches for digital transformation in the healthcare field. The amount of digitally stored patient data has grown significantly. According to the statistics, many people visit hospitals for pharmaceutical diagnoses, but it is riskier to visit doctors during a pandemic.

According to World Health Organization (WHO), physical distancing helps to minimize the spread of COVID-19 and avoiding spending time in crowded areas will break the chain of transmission. Therefore, there should be a solution for the patient who is unknown or illiterate, to learn everything about the tablets, their usage, adverse effects, etc. while staying at home. So that it raises public awareness and minimizes the number of visits to doctors during the pandemic [1]. Hence the authors have proposed a system that can provide remote Drug Identification for patients while giving reminders to take medication on time based on the latest prescriptions with the help of a user-friendly medical conversational Chatbot.

But in the healthcare field, electronic medical records are extremely sensitive confidential information that must be exchanged frequently. One of the most difficult aspects of a centralized method of storing health records is safeguarding patient privacy and system transparency. Illegitimate access to sensitive patient information, such as identification details, as well as misuse of patient information and clinical records, leads to data breaches [2]. Here the authors have introduced a Blockchain-based component as a better solution by enabling decentralized data storage for sharing and accessing scattered patient records while protecting users' privacy.

Storing data in Blockchain need the data to be in electronic format but most of the medical documents are in printed format, hence the conversion of the existing patient data into electronic health records has become a challenging task. Converting these data into Electronic Health Records (EHR) and entering these details into Blockchain often needs to follow the manual data entering procedure which is often time-consuming and error prone. The authors have addressed this issue by proposing an approach to extract textual data from the captured images of the Clinical Laboratory Test Reports through a medical document scanner.

To overcome these limitations and produce accurate results, "Oxygen" delivers a unique Web and Mobile based solution to provide healthcare services to meet the challenges that the healthcare domain confronts due to its limitations.

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II. LITERATURE REVIEW

For the past few years, several studies have been conducted on the digitalization of the field of healthcare. The research studies that have been done on the use of Blockchain [3] and Machine Learning-based technologies [4] to provide healthcare services are highlighted in this section.

A. Blockchain Component

According to [5], the authors have shown that the cost of data breaches in the healthcare industry is projected to be over $380 per record. This article emphasizes the significance of the security of healthcare records and patient-centric distributed healthcare solutions and demonstrates that Blockchain not only provides decentralization, but also data confidentiality, real-time access, and data authentication and authorization. Blockchain technology can be a superior option in biomedical research and teaching, as well as in keeping electronic medical health records [6] [7]. They also indicate that while various Blockchain prototypes have been produced to date, not enough research has been done to solve the difficulties that Blockchain technology offers, such as security and privacy. Latency and interoperability are two issues that need to be addressed, and more studies should be done in these areas. The study [8] found that lack of interoperability and sharing are some common issues in handling medical data. The Blockchain's security is dependent on the private key, and if the private key is lost, the storage's security is also compromised. However, those concerns were not addressed in this study. Previous research work [9] has focused on the interoperability of the data exchange between business entities and the study focuses on how the transition takes through five mechanisms including data liquidity, data aggregation, digital access rules, patient identity, and data immutability.

The studies demonstrate that Blockchain technology may be used as a platform for digital exchange and that healthcare data can be stored in many systems, necessitating several interactions between institutions.

B. Medical Document Scanner

Optical Character Recognition (OCR) [10] is a technique in computer vision technology that detects and identifies the text in an image and transforms it into meaningful information that the computer or any other device can easily comprehend [11] [12]. According to [13] the authors have suggested a text detection approach with the use of a patch-based training strategy and a concatenation structure that can combine the features of the deep and shallow layers in the Neural network. This study was carried out to improve the accuracy of multilingual text recognition. Overall, the research study can be considered a success, but the suggested patch-based strategy was designed specifically for the Chinese language and Latin characters, and the authors did not use any method to extract only the key entities from the captured documents. In the work [14], encouraging results can be produced when a variety of image processing algorithms are applied to text detection, and they proposed a modular strategy for text detection. However, the proposed module is hindered by blurring and low resolution and several other problems occur while computing the stroke width when the image is poorly captured. A key challenge in OCR is the failure of the current algorithms to correctly extract text in the documents where text is skewed or distorted and the authors of [12] developed a deep neural network-based self-supervised pre-training model as a solution for this. This bi-directional encoder has been designed to predict concealed text and fill in gaps in non-transcribable areas of the page. The only problem is that this module has not been trained with domain-specific data sets.

As a result of the reviewed studies, it is apparent that textual extraction from printed documents is a significant requirement in the healthcare domain, and researchers should spend more time in this area to develop better solutions.

C. Drug Identifier

Many medications utilized in hospitals and emergency clinics are hard to recognize on an everyday premise except if they are self-evident. Several researchers have attempted to overcome those problems using image processing techniques. The first model in pill identification and recognition was proposed by Lee and his associates [15]. The gathering fostered computer vision [16] for distinguishing illicit medications using tablet design, size, shape, and imprint. In this arrangement, a given image is contrasted with a set of images put away in a display, following three principal steps: pre-processing, edge detection, and component vector development. The authors of [17] proposed a technique to distinguish damaged and missing tablets with an edge recognition strategy. This technique says that tracking down the edges of tablets by taking the center. The authors of [18] proposed a system that distinguishes defective tablets by utilizing the “Feature Extraction Technique”. This technique includes image handling procedures to distinguish the faulty tablets and included extraction methods to see the faulty ones. Later [19] proposed a model for recognizing the remedy of medications and it has effectively resulted in the United States 568 of the most related tablets and has shown a precision of 91.13% in naturally recognizing the right drug.

As a result of the reviewed studies, it is clear that drug identification is a significant requirement in daily wellbeing, and research teams should find better solutions to improve that area.

D. Medical Chatbot

According to the [20], Text-based Chatbots in the Light of Recent Technologies are gaining popularity in the modern world, notably in businesses and health care, because they can automate administrative work and provide services that go beyond the constraints of people. A Contextual Chatbot for Healthcare Purposes was proposed by a group of researchers by employing ML and Artificial Intelligence (AI) [21] methodologies to store and manage the preparation models, allowing the Chatbot to produce a better and more appropriate response when the client asks questions from the Chatbot [22]. Kidwai, B., and R.K. Nadesh [23] explored how innovation has altered, how patients communicate with professionals as well as how medical treatment is delivered. To improve the current medical service, a Chatbot can be planned and built using highly Artificially Intelligent programs and good decision-making algorithms. It can assist the client in providing an accurate description of their condition based on the symptoms provided. The AI will be given precise information about the symptoms as well as medicine that may be given to treat a specific illness.

III. METHODOLOGY

This section emphasizes the four key components each interconnected as depicted in Fig.1 below. The following sub-sections offer a detailed analysis of the techniques as well as a summary of the individual functionality of each component.

A. *Blockchain Component*

The proposed Blockchain component is a web-based application. The most typical issues with centralized EHR systems were resolved by this component. Due to its decentralized structure and high security, Blockchain technology is increasingly being used in applications today. Since it is holding sensitive patient data, it is necessary to safeguard patients' privacy. This component focuses on storing, accessing, and sharing patient details among healthcare professionals. Transactions are executed on the Ethereum test network.

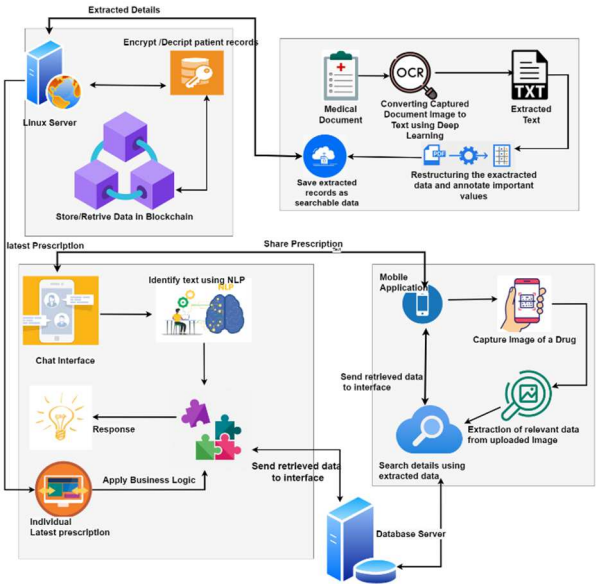

Fig. 1. System Overview Diagram of the proposed system

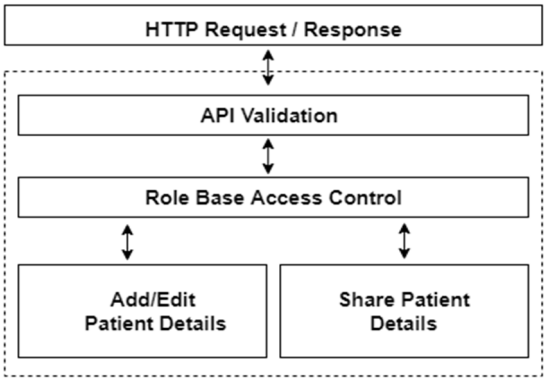

Fig. 2. System Overview Diagram for Blockchain Component

Storing patient details- Storing patient details in EHR is most critical thus it is storing patient-sensitive information. The authors have employed Blockchain technology to solve the problems associated with centralized storage. The patient's NIC and the hash value of the patient's data object were saved in the Ethereum network. Solidity in the Smart contract was used to store the details.

Accessing Patient Details- Only authorized users have access to manipulate data to prevent unauthorized access. The reliability of the data was also strengthened by this approach. Role-based access control mechanisms were used to limit unauthorized access and to set permissions to perform only the relevant transactions. To perform the role-based access mechanism the authors used a separate smart contract. When obtaining patient data, hash values were retrieved from the Ethereum network and converted to the JSON format. The authors performed API key validations to validate the HTTP requests.

Sharing Patient Details- Here the authors shared the healthcare details among the healthcare professionals. This can be utilized by authorized entities by registering to the system. Patient data was shared among authorized entities via REST APIs.

B. *Medical Document Scanner*

The Medical Document Scanner component comprises three fundamental processes as given in Fig 3. In the first process image pre-processing techniques are used to improve the overall quality of the image. In the second process, Textual data is extracted from the captured images of the Clinical Laboratory Test Reports using the OCR process. In the third process, important Named Entities are extracted from raw data using techniques in Natural Language Processing (NLP).

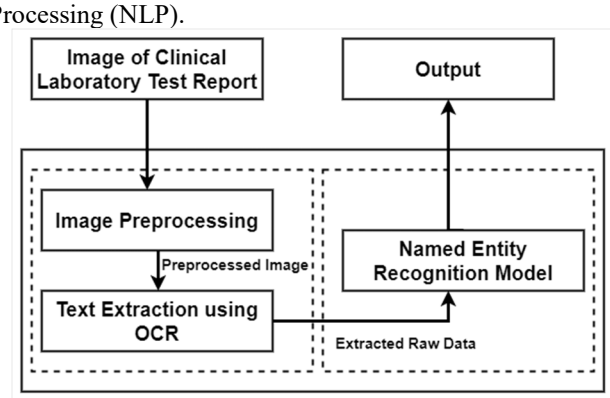

Fig. 3. System Overview Diagram for Medical Document Scanner

Image Pre-processing – Due to skewing, noise, and uneven lighting, photographs captured by mobile phones typically have a lower quality. To ensure that the system produces accurate results, the images must first be pre-processed. The OpenCV library was used by the authors to read and resize the image with aspect ratio and employed OpenCV's Details Enhancement Technique for image enhancement. Finally, the document's location was determined using the find contours approach and applied the Magic Color technique to increase the brightness and contrast after wrapping the document.

Text Extraction using OCR- The objective of this process is to capture the text present in images and convert them into text format. For OCR, the authors have used Pytesseract which is an OCR Tool for Python. Python-tesseract serves as a wrapper for Tesseract-OCR Engine, and it can read and extract text in images.

Important Named Entity Recognition -Following text extraction, the text was cleaned using several methods before being given to an NLP model for training. For Entity Extraction Spacy library was utilized together with the Named Entity Recognition (NER) which is a technique in NLP. Important values and entities were then retrieved from the extracted data. The data from the image was extracted and converted into a data frame and the named entities from the

model were obtained. Then each word was tagged, token data frames were joined with Pytesseract data, and finally, the bounding box image annotating the important values was obtained.

C. Drug Identifier

The proposed system for drug identification is a mobile application component that will be communicated with the cloud-based server with REST APIs. Shape, colour, and imprint are three qualities that any strategy used to distinguish pills. Here the component is divided into four significant parts according to the functionality.

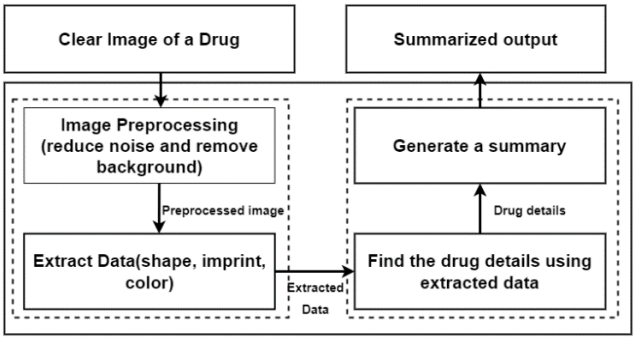

Fig. 4. System Overview Diagram for Drug Identifier

Gathering Data set for training the module – For playing out that task with next to no mistakes the image handling model should prepare very well utilizing various kinds of images with various resolutions. So, assembling a sample dataset is the primary job and for satisfying that should accumulate numerous and more drug images and related information for that specific medicine by utilizing previous research or getting information from the related sites [24] [25].

Implement a dependable communication strategy between the application and cloud base server – In this project correspondence between the application and cloud base servers is one of the significant errands. Authors made REST APIs on related technology or framework. At the point when a client transfers an image from a versatile application, the image should move to the server right away without any mistakes to make a solid and dependable association. Here the authors used the flask library to develop the APIs.

Create a solid decision-making process in the cloud base server –To satisfy that task authors made a procedure that separates information from an image during image handling. The framework contracts that information with the current data set and finds a similitude with a higher rate that will be useful to give precise and solid results to the client. And, for the data extraction from the image authors utilized Contours, Colorgram, Webcolors, NumPy, OpenCV, and Pandas libraries.

Create an application to Conduct all the related functions to the image processing component – Society ought to have user-friendly applications that assist in utilizing without any platform difficulty. To overcome that, the authors developed an app that has an easy-to-understand interface that incorporates the core functions using a cross-platform mobile development framework to develop to break the platform barrier.

D. Medical Chatbot

The proposed system includes a user-friendly smart healthcare Chatbot which is based on techniques in machine learning and natural language processing to assist patients. The Chatbot is capable of understanding user input and response appropriately. The main function of the proposed Chatbot is to interact with the user and collect information about the user's prescription and remind them to take the medicine at the required times. Once the latest prescription details of the patient are acquired from the Blockchain component, the Chatbot will analyse the names of the medications provided in the prescription and answer the patient's queries regarding the most important medications in general. The mobile application is developed using React Native and NodeJS. The user-friendly interfaces of the mobile app enable users to easily interact with the app. The Drug Schedule Management System determines when to take medications. The Drug Schedule Management System will generate a timetable that can send real-time reminders to patients to take their medications on time, which is typically important for patients staying at home. This component can be divided into four sub-components based on functionality.

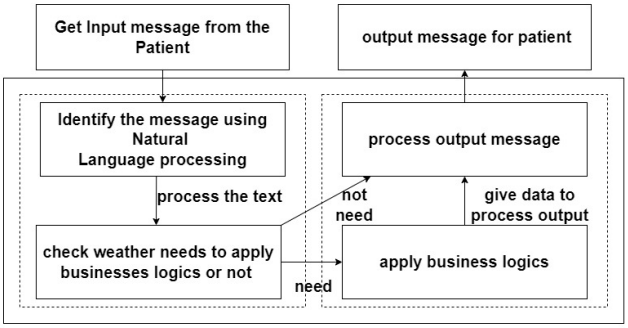

Fig. 5. System Overview Diagram for Medical Chatbot

Design a user-friendly smart healthcare Chatbot to assist patients in acquiring their information- The suggested Chatbot is capable of responding appropriately to the patient's prescription details stored inside the Blockchain.

Identify the user input and give an appropriate response to patients' messages- The authors used NLP and ML to recognize the messages and provide appropriate responses. Here the Chatbot is trained to increase its accuracy.

Use Blockchain to obtain pertinent data - Use Blockchain to get patient prescription information because it is important to establish a connection with the system which stores Patient Details together with the prescription details.

Manage Medication Timetable Management System- This step is used to send reminders to patients to take the medication on time as prescribed.

IV. Results and Discussions

Descriptive information related to the proposed system is presented below.

A. Blockchain Component

Fig 6. shows the transaction history of all the transactions performed by the system through the Rinkeby Testnet. Fig 7. Shows the Transaction details of a successful transaction. All

patient details are encrypted before adding to the Blockchain. Data will be received as a JSON object.

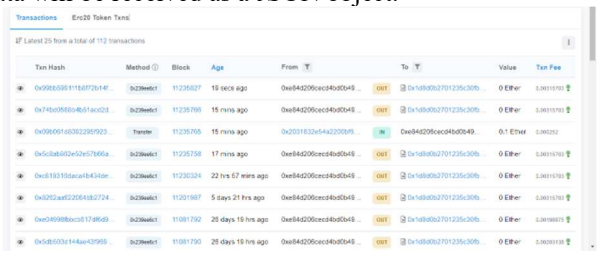

Fig. 6. Transaction history of the Rinkeby Testnet

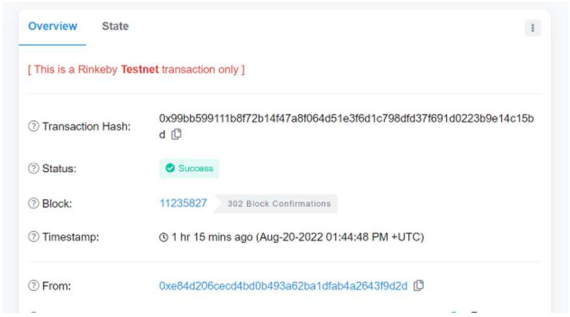

Fig. 7. Successful transaction details

B. *Medical Document Scanner*

The outcomes of the medical document scanner component are displayed in Fig. 8 below. When an image of the Clinical Laboratory Reports is uploaded, an image with bounding boxes drawn around the important named entities will be received as the output. The extracted text is displayed next along with the corresponding tag or entity.

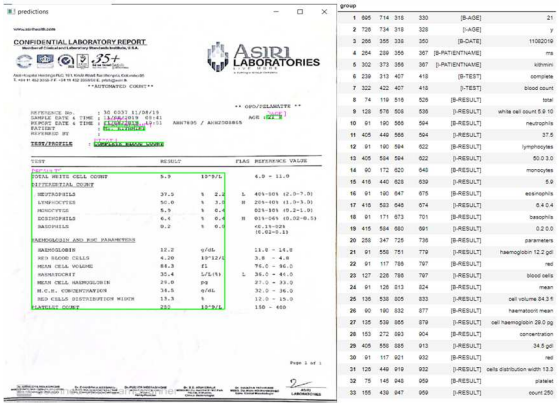

Fig. 8. Bounding Box Image and the Recognized Named Entities

TABLE I. COMPARISON RESULTS OF THE MEDICAL DOCUMENT SCANNER

Test	Recall	Precision	F1-measure
[14]	0.380	0.827	0.520
Ours	0.889	0.895	0.892

Our system can correctly identify entities at a precision(ENTS_P) of 89.52, with a recall(ENTS_R) of 88.97 and an F1 score(ENTS_F) of 89.25 shown in Table I. The quality of the uploaded image has a significant impact on the scanner's accuracy. Therefore, the accuracy of the picture can be greatly increased by employing more image pre-processing techniques.

C. *Drug Identifier*

The outcomes of the drug identification component are displayed in Fig. 9 below. When an image of the Drug (Fig. 9) is uploaded through the APIs, extracted data such as shape imprint, colour, and shape will be received as the output.

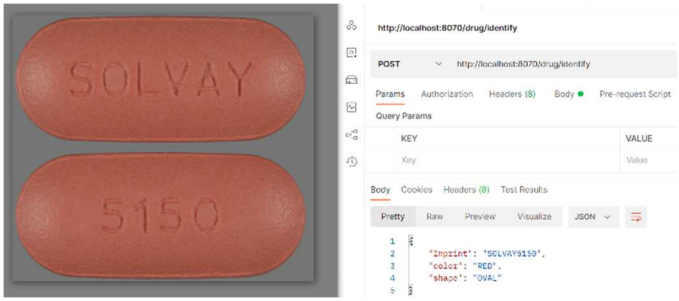

Fig. 9. Input Image of the Pill and the Output JSON which shows the details of the Pill

TABLE II. COMPARISON RESULTS OF THE DRUG IDENTIFIER

Projects	Identify drug using image [Y/N]	Provide a detailed summary of drugs [Y/N]	Provide side effects of drugs [Y/N]
[15]	Y	N	N
[26]	Y	N	N
Ours	Y	Y	Y

When compared with the existing products, this system can successfully identify drug images and provide a summary and the side effects of the drug. Using various image processing techniques, the quality of the pill images can be enhanced to produce better results and outcomes.

D. *Medical Chatbot*

The Chatbot interfaces and the outcomes are shown in Fig.10 and the accuracy of the developed medical Chatbot component is shown in Fig.11

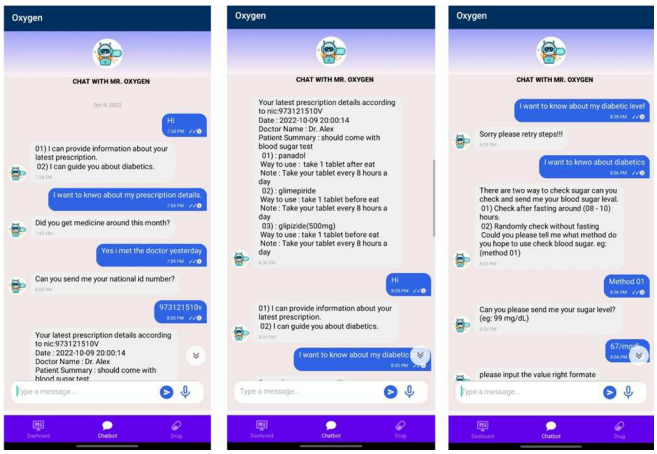

Fig. 10. Chatbot Interfaces

Fig. 11. The outcomes and the accuracy of the Medical Chatbot

V. CONCLUSION AND FUTURE WORK

Covid19 has had a significant impact on the healthcare industry, and the pandemic has shown limitations in the current digital healthcare systems. In this research, these issues are solved by proposing an approach using Blockchain and Machine Learning-Based Healthcare framework which offers healthcare services to patients and medical professionals. The system includes a Blockchain-based component for securely storing and accessing patient data, an OCR and NLP-based medical document scanner to prevent the errors that are due to manually entering data, an Image Processing-based drug identification module for remote pharmaceutical diagnosis, and an NLP and ML-based virtual Chatbot in healthcare assistance. This research demonstrates that the system's overall objective was successfully attained using these techniques and technologies. In terms of future work, the system can be expanded by improving accuracy by incorporating more data for training.

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REFERENCES

[1] N. L. Delgado, N. Usuyama, A. K. Hall, R. J. Hazen, M. Ma, S. Sahu and J. Lundin, "Fast and accurate medication identification," *NPJ digital medicine,* vol. 2, no. 1, pp. 1-9, 2019.

[2] D. Tith, J.-S. Lee, H. Suzuki, W. M. A. B. Wijesundara, N. Taira, T. Obi and N. Ohyama, "Application of Blockchain to Maintaining Patient Records in Electronic Health Record for Enhanced Privacy, Scalability, and Availability," *Healthcare informatics research,* vol. 26, no. 1, pp. 3-12, 2020.

[3] M. Nofer, P. Gomber, O. Hinz and D. Schiereck, "Blockchain," *Business & Information Systems Engineering,* vol. 59, no. 3, pp. 183-187, 2017.

[4] M. Aurangzeb, C. Eckert and A. Teredesai, "Interpretable Machine Learning in Healthcare," *2018 ACM international conference on bioinformatics,* pp. 559-560, 2018.

[5] H. V. M, S. Danai, U. H. R and M. R. Kounte, "Health Record Management through Blockchain," *Third International Conference on Trends in Electronics and Informatics (ICOEI 2019),* pp. 1411-1415, 2019.

[6] C. C. Agbo, Q. H. Mahmoud and J. M. Eklund, "Blockchain Technology in Healthcare: A Systematic Review," *Healthcare,* vol. 7, no. 2, p. 56, 2019.

[7] M. Imran, U. Zaman, Imran, J. Imtiaz, M. Fayaz and J. Gwak, "Comprehensive survey of iot, machine learning, and blockchain for health care applications: A topical assessment for pandemic preparedness, challenges, and solutions.," *Electronics,* vol. 10, no. 20, p. 2501, 2021.

[8] Y. Zhang, M. Cui, L. Zheng, R. Zhang, L. Meng, D. Gao and Y. Zhang, "Research on electronic medical record access control based on blockchain," *International Journal of Distributed Sensor Networks,* vol. 15, no. 11, p. 1550147719889330, 2019.

[9] W. J.Gordon and ChristianCatalini, "Blockchain Technology for Healthcare: Facilitating the Transition to Patient-Driven Interoperability," *Computational and structural biotechnology journal,* vol. 16, pp. 224-230, 2018.

[10] S. MORI, C. Y, SUEN and K. YAMAMOTO, "Historical Review of OCR Research and Development," *Proceedings of the IEEE,* vol. 80, no. 7, pp. 1029-1058, 1992.

[11] B. Jahan and M. A. Naeem, "Offline optical character recognition (OCR) method: An effective method for scanned documents," *2019 22nd International Conference on Computer and Information Technology (ICCIT),* pp. 1-5, 2019.

[12] S. Karthikeyan, A. G. S. d. Herrera, F. Doctor and A. Mirza, "An OCR Post-correction Approach using Deep Learning for Processing Medical Reports," *IEEE Transactions on Circuits and Systems for Video Technology,* vol. 32, no. 5, pp. 2574-2581, 2021.

[13] W. XUE, Q. LI and Q. XUE, "Text detection and recognition for images of medical laboratory reports with a deep learning approach.," *IEEE Access,* vol. 8, pp. 407-416, 2019.

[14] A. C. Özgen, M. Fasounaki and H. K. Ekenel, "Text Detection in Natural and Computer-Generated Images," *In 2018 26th signal processing and communications applications conference (SIU),* pp. 1-4, 2018.

[15] Y.-B. Lee, U. P. and A. K. Jain, "Pill-id: Matching and retrieval of drug pill imprint images.," *In 2010 20th International Conference on Pattern Recognition,* pp. 2632-2635, 2010.

[16] A. Luongo, Computer vision: algorithms and applications, Springer Science & Business Media, 2010.

[17] Shilpa and A. Bhatia, "Enhanced Center of Mass Technique for Detection of Missing & Broken Pharmaceutical Drugs.," *IJIRST-International Journal for Innovative Research in Science & Technology,* vol. 3, no. 1, 2016.

[18] S. Ramya, J. Suchitra and R. K. Nadesh, "Detection of broken pharmaceutical drugs using enhanced feature extraction technique.," *International Journal of Engineering and Technology,* vol. 5, no. 2, pp. 1407-1411, 2013.

[19] J. J. Caban, A. Rosebrock and T. S. Yoo, "Automatic identification of prescription drugs using shape distribution models.," *In 2012 19th IEEE International Conference on Image Processing,* pp. 1005-1008, 2012.

[20] B. Borah, D. Pathak, P. Sarmah, B. Som and S. Nandi, "Survey of textbased chatbot in perspective of recent technologies.," *In International Conference on Computational Intelligence, Communications, and Business Analytics,* vol. 1031, pp. 84-96, 2018.

[21] P. Hamet and JohanneTremblay, "Artificial intelligence in medicine," *Metabolism 69,* pp. S36-S40, 2017.

[22] P. Kandpal, K. Jasnani, R. Raut and S. Bhorge, "Contextual Chatbot for healthcare purposes (using deep learning)," *In 2020 Fourth World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4),* pp. 625-634, 2020.

[23] B. Kidwai and N. RK, "Design and development of diagnostic Chabot for supporting primary health care systems," *International Conference on Computational Intelligence and Data Science (ICCIDS 2019),* vol. 167, pp. 75-84, 2020.

[24] U.S. National Library of Medicine, "The National Library of Medicine Data Distribution," U.S. National Library of Medicine Data Distribution, [Online]. Available: https://www.nlm.nih.gov/databases/download/data_distrib_main.html. [Accessed 29 January 2022].

[25] DrugBank Online, "DrugBank online: Database for Drug and Drug Target Info," [Online]. Available: https://go.drugbank.com/. [Accessed 29 January 2022].

[26] R. Maini and H. Aggarwal, "Study and comparison of various image edge detection techniques," *International journal of image processing (IJIP),* vol. 3, no. 1, pp. 1-11, 2009.