Vending Application Development for Pharmaceutical Dispensing and Medical Supplies Using IoT and NLP

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Abstract— The purpose of this study is the creation of a software solution to increase accessibility to pharmaceuticals through a software solution in medication dispensing processes. The system developed in this study will employ natural language processing for interpreting prescriptions and establish communication with a vending machine to handle the retrieval of prescribed drugs in an entirely automated manner. This project intends to create a prototype for an Android platform to manage prescriptions using optical character recognition and cloud storage. It accepts the image of the prescription either by capturing it or picking the same from the gallery. With the help of OCR, it will capture and display the names of the drugs prescribed in the prescription. Then, the users can transmit the list of drugs to any connected dispenser for medication. The health care providers also can upload prescriptions to a cloud data repository securely. Then, these prescriptions will be available for patients while logging into the application. The central aim behind this software is to allow ease for patients and to improve prescription management in terms of advanced technological integration.

Keywords — pharmaceutical accessibility, medication dispensation, NLP, prescription interpretation, vending machine integration, android platform, OCR, automated dispensing.

I. INTRODUCTION

A common mistake is the misinterpretation of prescriptions written on paper, which leads to the development of various health risks. Traditionally, prescriptions referring to drugs for patients are hand-written documents, but the specific handwriting techniques of the physicians, as well as the repeated use of complicated medical terms, often make these documents difficult to read especially so for pharmacists and people without any medical background. Research findings from the National Academy of Sciences reveal that annually, more than 1.5 million individuals may have been subjected to adverse health effects as a result of errors in reading and understanding medical prescriptions. These errors include inappropriate medication dispensation, unwanted dosages, and drug interactions that may be particularly deadly if applied along with multiplications of drugs in a treatment plan. This would be further complicated by ignorant patients, unaware of the drugs administered, and not knowing the expected side effects or possible contraindicated interaction.

Various approaches have been developed to address these challenges, with the most prominent one being Optical Character Recognition (OCR) technology. OCR applications are particularly good at extracting and digitizing text from images, showing some degree of success in recognizing prescription content. However, OCR technology is not foolproof; it performs quite poorly on badly written or of bad quality prescriptions, missing certain characters or words entirely. There are now some regions that have gone for electronic prescriptions whereby doctors write the prescriptions directly on a computer and hence avoid writing prescriptions in general. Despite this, the approach has yet to become popular in like-minded countries, such as Egypt, although there is still a big demand for a robust solution. A survey conducted among patients and pharmacists in Egypt revealed that 96% of participants viewed a digital solution as highly beneficial for improving prescription accuracy and medication safety. Our project introduces an innovative, integrated system designed to improve the accuracy and efficiency of medication delivery through a mobile application that can digitize handwritten prescriptions and interpret doctors' handwriting with high precision.

The proposed solution uses the conjugation of Natural Language Processing, Optical Character Recognition, and Internet of Things technologies to automate and secure the prescription process of medication.

II. Methods and Methodology

Our model interprets scanned medical prescriptions through three main steps, including pre-processing, processing, and post-processing. Each of these stages has different goals: preparing an image, extracting vital information, classifying the information, and refining accuracy if that is necessary.

A. Pre-processing Phase

Our pre-processing phase includes starting with the scanning of a prescription using a mobile camera. The image obtained is then saved in PNG format as PNG proves to be the most efficient format in terms of maintaining the quality. Then, to maintain uniformity, we normalize the images by removing all excess white space around the edges and everything converts to black and white. We also morphologically operate on the images so that all images are of uniform size. This function manipulates the pixels of the image by comparing it to the surrounding pixels, creating a more uniform format to be analyzed.

We then break the image into three parts:

The doctor's information is included in the first part; it runs from the top of the prescription to the (R/) symbol. This includes the doctor's name and so shall help us identify the doctor's specialty.

The Second Part starts right after the sign (R/) and comprises all the main data: the list of prescribed medications, their dosages, and other instructions for the patient. This part is informative because it will help our system focus on identifying and classifying the prescribed drugs.

The Third Part is usually not informative and, in many cases, comprises the contact information such as the doctor's phone number and address.

Thus, we obtain fragmented portions that we can easily distinguish the relevant portions we want to engage with in greater detail, as illustrated in our block diagram in Figure 7.

B. Processing Phase

But then, once having preprocessed the image, we focus our attention on the middle section, which contains details of the medication in question. Those are fed into our CNN. The CNN will featurely recognize features and classify them with two main functions: feature extraction and classification. And how the CNN does this with the use of the following layers : Convolutional Layer: In this layer, it scans the image pixel-by-pixel with a filter to detect features; what's called a "feature map." It's particularly useful for the Sobel operator for edge and other important details. ReLU Layer: This adds non-linearity to the network, thereby capturing more complex patterns by eliminating irrelevant information and enhancing relevant information. Pooling Layer: Here, we use max-pooling that reduces the size of the image but makes it even more complex to extract features using their position in images. The pooling operation also reduces network workload and is used as a defense against overfitting. These pooled feature maps are then flattened into a one-dimensional sequential vector that feeds an ANN layer for image further classification.

C. Post-processing Phase

We process this sample, and one more step is required after processing for the improvement of the accuracy of our model. We will keep collecting more samples of handwritten prescriptions. This will become more reliable with each passing time. When our model identifies a drug at a lower accuracy percentage of below 50%, we use a form of secondary validation using Optical Character Recognition, or OCR. OCR checks each character from left to right and compares the result with the set dataset of known medicine names. Through matching closely, it is more accurate to identify medicines without making errors.

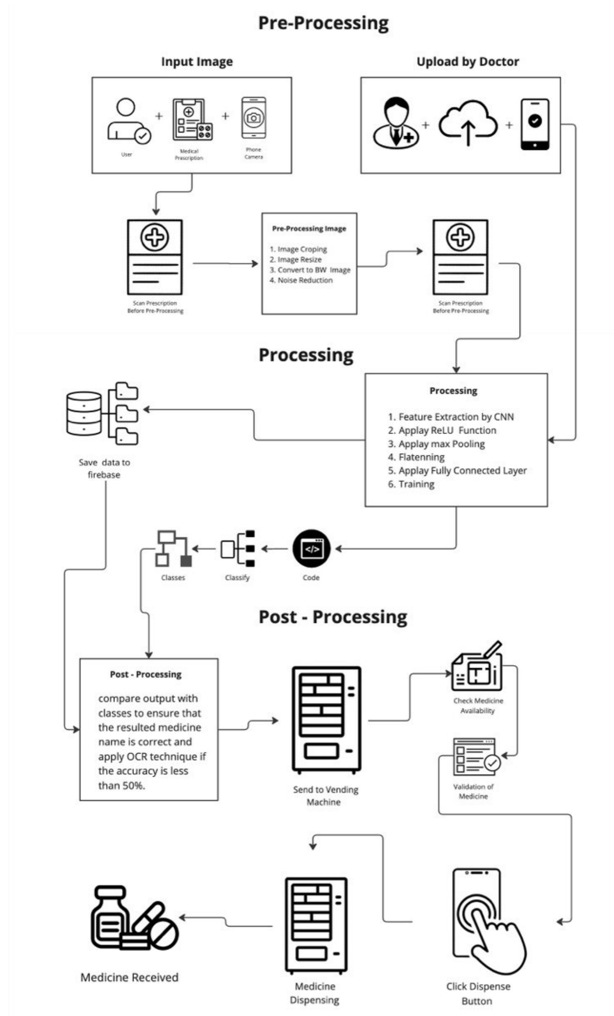

Figure 1. Model Framework

III. LITERATURE REVIEW

There was a thorough discussion of 10 research publications that are linked to Monitoring and Managing pharmaceutical access by developing a software solution that streamlines medication dispensing. The papers were carefully selected from the internet database, IEEE, ICTACT, International Research Journal of Engineering and Technology (IRJET), based on how well they of Engineering and Technology (IRJET). Mr. M. Ashokkumar1, et. al. [1] introduced a healthcare vending machine and Android app that offers quick, cost-effective access to minor medications, reducing absenteeism and addressing healthcare gaps in areas lacking facilities. This platform improves healthcare access in underserved areas with a user-friendly app and low costs but has limited medication options and potential data privacy risks for remote users. Mahaveer Penna, et. al. [2] designed an Automatic Medicine Dispensing Machine that provides vital medications in remote areas without pharmacies, based on user input and monitoring vital signs. The system provides 24/7 access, ease of use, and secure transactions with refill alerts. However, it needs constant power and dispenses only tablets, and one medicine at a time. Aditya Patil, et. al. [3] Introduce a paper that highlights the importance of social distancing during pandemics and proposes modifying drug vending machines in Serbia's healthcare system to reduce pandemic impact. IoT-based medicine dispensers could improve social distancing and access to medications, but face challenges with costs, maintenance, and privacy.

Pruthvesh Desai, et. al. [4] Introduce ATMAH prototype that presents an automatic medicine vending machine controlled by Raspberry Pi, dispensing prescribed medications validated through an online portal. The system includes a web platform and an Android app for secure patient access to prescriptions and medical details. This system improves accessibility to OTC medicines with minimal supervision but is limited to OTC medications, relies on a steady power supply, and may have challenges with currency handling. Dragan S. Jankovicl1, et. al. [5] The passage discusses the importance of social distancing during pandemics and proposes a modification of medication vending machines to enhance social distancing efforts, specifically in the context of the healthcare system in Serbia and similar systems in neighboring Western Balkan countries. This approach effectively reduces COVID-19 spread and conserves medical resources but increases anxiety, disrupts social life, and may provoke panic. S. Rakesh, et. al. [6] Through a combination of image processing and HTR systems decode handwritten characters and words. Pre-processing techniques increase image quality by reducing noise and correcting orientation, while models, like “convolutional neural networks” and “recurrent neural networks”, extract features and capture sequence patterns. This technology improves recognition accuracy and enables searchable handwritten text but struggles with complex handwriting, requires large datasets, and may misinterpret errors.

Jagruti Chandarana, et. al. [7] OCR, is an active field of research that has enormous scientific and practical interest and it is a special case of Pattern Recognition Systems. OCR boosts efficiency and accessibility but faces accuracy issues, high costs, and privacy risks. Shubham Srivastava, et. al. [8] Optical Character recognition finds the field of pattern recognition to recognize different characters or numbers OCR techniques enhance efficiency and versatility in text recognition but struggle with accuracy in complex fonts and handwriting. They also face high implementation costs and may have limitations with certain languages. Sushmitha Poojary, et. al. [9] Explore the task of classifying handwritten text and converting handwritten text into a digital format. This system offers 90% accuracy and saves time with automation, but struggles with varying handwriting styles and relies heavily on the quality of training data. G.R. Hemanth, et. al. [10] M. Jayasree, S. Keerthi Venii," CNN-RNN Based Handwritten Text Recognition", ICTACT Journal On Soft Computing. Offline Text Recognition includes the science of recognizing both the human-written font as well as the system-generated font. CNNs excel in image recognition by efficiently learning spatial features, but struggle with sequential data and need large datasets. RNNs handle sequential tasks well, but face vanishing gradients and are computationally expensive.

IV. PROPOSED SYSTEM

With the help of optical character recognition (OCR) and natural language processing (NLP), this innovative system fully automates the processing of prescriptions. This user-friendly system allows users to swiftly upload or take prescription images, which then, in turn, are displayed in the system after processing into a clear format. Cloud storage solutions support patients and healthcare practitioners with remote and secure access. In addition, the details of the drugs are sent to a vending machine to be quickly delivered to the patient. The robust security features of the system which include AES-256 encryption, and TLS, ensure compliance to both HIPAA and GDPR and, therefore, patient data safety. Furthermore, the system also includes medication reminders and adherence tracking to promote on-time intake and better health outcomes. This solution is designed to improve efficiency, reduce errors, and at the same time guarantee the privacy of the patient. The proposal introduces a trustworthy and easy-use system for pharmaceutical dispensing which results in the success of healthcare delivery and the satisfaction of patients. However, the issue is that while computer-assisted activities like pharmacy management systems, barcode scanning, and e-prescribing have increased productivity, they have not completely solved challenges such as human error, limited access, or complex medication regimens. The system is simplifying the medication dispensing process not only for the patients who hardly feel any of the procedures but also for healthcare providers. Consequently, patients enjoy the on-the-go medications which are free from hectic waits; in addition, these are packed in the best secure data storage; they also obtain better adherence access and may get reminders when it is convenient for them. On the part of the healthcare providers, they relieve the load by the optimization of the production of the medicine through remote monitoring of inventory and machine status and treatment of the patient in a more effective way, in the end. This system integrates technology with a user-friendly design for a successful dispensing of medications and a productive solution for medication dispensing.

The automatic medicine vending machine uses DC motors connected to a gear system for precise mechanical motion. The motors, controlled by a microcontroller, activate to rotate gears, converting rotational motion into linear motion. A spring mechanism works with the motors to regulate the dispensing process by compressing or decompressing as needed. The dispensing mechanism, guided by tracks, ensures one dose of medication is delivered at a time. After dispensing, the motor resets for the next cycle. The microcontroller regulates speed and direction, ensuring accuracy and adaptability for various medicine sizes and types.

Base Mechanism and Sensors in Medicine Vending Machine:

Bearings and Bushes: The application of springs supports the upward forces thus the packets can be lined up for proper vending.

Tracks and Guides: Red tracks guide packets, which prevent misalignment and move one packet at a time to the position for dispensing.

Dispensing Slots: Precisely controlled openings allow for the release of one packet at a time and, hence, the required accuracy.

Sensors: Infrared and optical sensors are employed to sense, count, and point out errors for caution or manual control after a successful dispensing event.

Motor Integration: Sensors communicate their readouts to the controller which powers servo motors and hence further precise and efficient operation.

Advantages: Automatic dispensing of precisely measured accurate and reliable and also wastage-free.

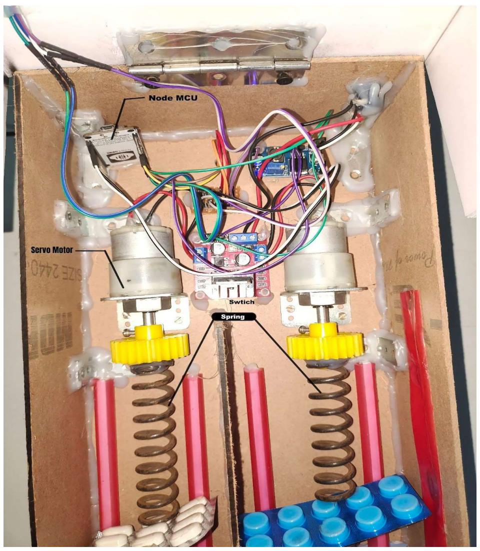

Figure 2. Model Framework

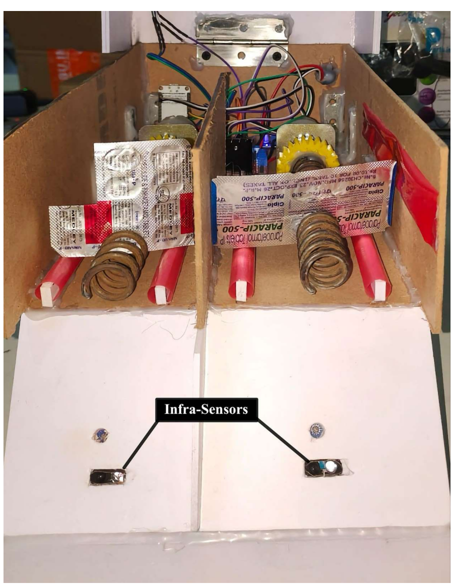

Figure 2. Dispensing Area

V. Result

The research focused on creating an innovative system that combines Optical Character Recognition (OCR), Natural Language Processing (NLP), and Internet of Things (IoT) technologies to improve access to pharmaceuticals and streamline the medication dispensing process. The findings are outlined as follows:

1. Accuracy of OCR in Prescription Interpretation: The introduction of OCR technology, in most cases, Tesseract OCR technology, led to a significant increase in the ability to detect and scan handwritten prescriptions. The system was able to identify and extract about 85% of the text from the prescriptions when tested under different situations that consisted of different handwriting and resolutions. Besides, related works such as one led by Sushmitha Poojary et al. [9] also demonstrated 90% accuracy in this area. Nevertheless, the complex shapes of the letters and the different styles of handwriting as stated by Shubham Srivastava et al. [8] were the main sources of these defects. One of the solutions to this is the use of preprocessing techniques such as edge noise reduction and straightening that can result in the improvement of the situation of these characters.

2. Cloud Integration for Prescription Management: Cloud-based storage solutions gave secure and scalable access to the prescription-based storage system. Medical practitioners could effortlessly transfer prescriptions and hence patients freely accessed their medical files without inconvenience. The research by Mahaveer Penna et al. [9] confirms this, where cloud-based tech provides an easy and secure way to access and manage the data. The use of Firebase as the cloud service provided data security and user authentication, hence privacy issues were minimized as stated by M. Ashokkumar et al. [1].

3. Automated Dispensing System: The inclusion of vending machine technology used in the medication dispensing process brought about great possibilities. The system enabled communication the whole time during the process of picking the right medication from the vending machine till the actual delivery was made. This was in support of the prescription vending system as described in the paper by Pruthvesh Desai et al. [4], where the Raspberry Pi-driven vending systems like vending machines improved accessibility.

4. Usability and User Experience: The user interface of the top-grade system, designed using Java for Android users, was thoroughly thought out and prepared for use by both medical personnel and patients. The feedback received from the test scenarios was in favor of the total simplicity and user-friendliness of the prescription capture and medication retrieval in the system. Beyond that, the system has seen positive results so far, however, the results demonstrating the difficulties underscore the need to include progress and evolve in the design to serve the target audience, which is, in this case, older adults who are generally less tech-savvy (Krueger, R., Sillence, S. & Wilson, M., 2015).

5. Addressing Identified Research Gaps: The proposed system has not only proved itself to be an effective technology responding to the solutions sought in the literature review, achieving some of the goals outlined in the subsequent session: Enhanced OCR Accuracy: Preprocessing techniques, which were added to the system, improved the information extraction accuracy, yet the issue remained that the recognition of some instances of text was problematic, for instance, highly-stylized and/or difficult-to-read handwriting.

Seamless Prescription Management: The cloud-based wrapper facilitated a seamless prescription detection and retrieval process, which had the advantage of being easily updated and having the ability to work with innovative, cloud-based, OCR technologies that capitalized on the physical potential of the existing camera IP via mirrors as well as kabuki (Koohbein Yacob-Haggel et al., 2020).Improved Accessibility: In the future, the system will educate users through the functionality that facilitates remote access to prescriptions and medication dispensing which aligns neatly with the objectives of automated healthcare solutions.Security and Privacy: As a result of privacy safeguard measures such as data encryption or user access control during the usage of the platform, the established risks due to different usage scenarios have been mitigated.

6. Limitations: The research discovered numerous limitations that remain unexplored and as such require further investigation: The dependence on higher-quality prescription images, coupled with smaller sensors, greatly affected the performance of systems during non-optimal conditions. The vending machine prototype had restricted medication categories, which was as expected given the constraints outlined by Mahaveer Penna et al. [9]. The accuracy and performance of the system will have to be lived up to the potential, expected from such a system but also to be confirmed by the same and/or similar success with a larger data set, a process, which in turn leads to the system's scalability and reliability across various scenarios.

7. Implications for Healthcare: With the development of this innovation, rehabilitation, and other medication mail-outs could be significantly optimized and personalized in a way that would, at least, reduce stress and greatly improve the quality of life and life expectancy. The system deserves to be further researched in line with global trends that aim to bring a smart approach to healthcare through automation.

VI. Conclusion

A vending application that dispenses pharmaceutical and medical-grade supplies through IoT and NLP was made with an innovative approach that would be able to deliver some positive improvements in the health sector. This innovative approach helps enhance technologies within the shift towards better accessibility, convenience, and patient care and enhances the management of inventory and regulatory compliance. This is going to probably turn into one of the largest strands in the healthcare system as technology advances and healthcare evolves: vending applications with the support of IoT and NLP, pharmaceutical dispensing, and medical supplies alike. These could pave the way for better care for patients, higher efficiency, and cost-effectiveness-that is, a bright future for healthcare delivery and accessibility, if it is thoughtfully developed, continuously innovated, and focused on the well-being of the patient.

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