Deep Learning to Aid Prescription Processing & Inventory Management for Local Pharmacies through Smartphone Application

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***Abstract*— Deep learning applications are potentially improving the accuracy of treatment protocols and health outcomes through algorithmic process. But in Bangladesh, most of the prescriptions provided by doctors to patients are still handwritten. Due to this, one of the most common and preventable medical errors is the medication error. Slight mistakes in prescriptions can lead to the consumption of incorrect medicines and doses in patients. Usage of digital prescriptions or also known as e-prescription can reduce medication errors dramatically. First of all, it omits the possibility of illegible handwriting. Thus, the local pharmacists can provide the correct medicines and doses to the patients. The research findings indicate the proper use of the deep learning technology to develop a model that converts the handwritten prescription into a digital prescription. This paper also points out the algorithms used to calculate the error rates of the deep learning model. This paper is conducted to show how deep learning can hugely contribute to reducing medication errors and how we use this advanced technology to directly connect the local pharmacy stores to fulfill patient's extensive medical needs. The smartphone application helps to provide appropriate healthcare services to the patients and also has an efficient inventory system for the local pharmacies. This paper also discusses the importance of integrating an inventory system into an overall pharmacy workflow. Moreover, the impact it brings to automate the dispense system and maintain supply and demand data for multiple inventories through the application.**

Keywords*—Deep learning, OCR, Inventory management system, logistical support, mobile application, pharmacy, e-prescription, healthcare*

1. Introduction

In the past ten years, mobile phones have gone from being simple communication devices to be fully functional pocket-sized computers. The ability to perform full-fledged computer functions on a mobile device has paved the way for implementing advanced technologies like deep learning, AR, VR, etc. in a portable dimension. In fact, most of the latest smartphones have dedicated cores built into their SOC to perform this type of specific task [1]. At the same time, growing access has evoked an explosion in the number of ML-based application users in smartphones. Because of this phenomenon, handwritten prescription processing with the usage of deep learning is very effective when it comes to digitalizing prescriptions.

Also, the number of smartphone users worldwide is well above 3 billion right now and it is predicted to reach 6 billion within the next few years [2][3]. The number of smartphone users among healthcare professionals and the general public is increasing at a nearly geometric pace [4][5][16]. Healthcare functions on mobile applications have been proven extremely helpful for patients as well as for their caregivers [6][7][17]. Also, patients can use these applications to track their health records, and their caregivers can provide consultations based on the health records.

Everyone should have access to the medical services they need but unfortunately, health services can be very costly sometimes. Now, enabling more competition in the pharmaceutical marketplace can benefit the general public. Many regions are not under regulation by the government for the price of pharmaceutical products directly. Research shows competition determines the market price [8]. That means more competition among pharmacies can benefit the general public by offering a product at a lower market price, more discounts, free consultants, etc.[8][9].

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There are a lot of aspects that need to be considered in order to make this app appealing for users to download and use this app on a regular basis. Even though the app consists of very advanced and complex technologies, the general user of the app must be able to use the app without any additional instruction. The simple design of the application in terms of features is a key point in the process of development of the application.

A huge number of smartphone users are already using healthcare functionality-based applications to avail medical services such as medicine orders, diagnostics, live online consultations, and therapy, etc. Recent research shows, 59% of the total smartphone users have at least once used their smartphones to avail themselves of medical services and 12% of all the smartphone users have at least one healthcare application installed on their smartphone [10]. At the same time, we cannot ignore the concerns of obtaining healthcare services online. Such as ordering medicines from the illegal or unregistered pharmacy, outdated medicines, no active ingredients or harmful ingredients in the medicines, identifying unauthorized prescriptions. Data protection, strict regulation, verification of certified doctors, verification of registered pharmacies are at the core of security enhancement for online healthcare. Proper usage of Machine Learning and Deep learning can definitely help online healthcare for security enhancement [12]. Since the deep learning model heavily relies on data the selection and transformation of relevant data. The data mining process can be completed through deep learning approach using Convolutional Neural Network (CNN) Algorithm which can carry out the further development of this project. [15]

The objective of this paper is to make proper use of deep learning and algorithms to develop an application that aids in prescription processing and makes it easier for users to connect with online health care services. Also, make the proper use of smartphones and modern technology to reduce medical errors, reduce paper work, prescription verification, connect patients with healthcare givers, easy prescription management option, and maintain health records making all of it time reducing.

2. Literature Review

The purpose of this review was to view the many advanced tools and technologies that are used in the development of the application Medway. We also review the mechanism behind our solution to convert the handwritten prescriptions into digital prescriptions and how it can impact the entire pharmaceutical industry. This paper provides a synopsis of the current state of pharmacy practice and points out the areas that can be improved for both pharmacies and patients using modern technology. This paper focuses on the patient care service provided by the pharmacies and discusses the areas that can be improved in order make the connection between pharmacies and patients more efficient. In this paper we also discuss how pharmacies can use this technology for managing their inventory as well as providing logistical support in order to assure better service to their customers. This paper does not take a position regarding future changes but is intended to serve as a foundation for connecting the patients with their caregivers in the most safe and efficient way. The key technical and logistical standards required for both pharmacists and patients are summarized and referenced in this paper.

Calculating error rate and analyzing the module is very important since prescription processing needs to have minimum errors to ensure minimum medication errors. This paper describes the implementations of an efficient inventory management system through the Medway application. An application that pharmacies can use to track orders, monitor supply and demands of medications, and facilitates prescription verification and billing. This application is concerned with the management of medicine and medication inventory, not the inventory of hospital equipment and devices. The application records each medicine that is dispensed and also counts the medicine that are stored. All these data are used to track medicines shipments and deliveries. This paper focuses on the efficiency of having a centralized inventory management system that can figure out the trend in usage, and trend data on anticipated demand versus reality. In terms of internal process of the application development, this paper discusses and provides a technical analysis that follows the Waterfall model also known as linear sequential lifecycle model. The main reason to choose this model for the development process because it allows for departmentalization and control. It is very important to choose the right development model before starting a project because it helps the internal team move more efficiently through the multiple phases of the project. It is clear from the research reviewed that this paper is a descriptive technical analysis of the application Medway. This is significant because the healthcare sector can hugely benefit from having an automated healthcare management system to streamline the redundant and time consuming task to provide a better and efficient service to its patients. The Medway application was reviewed by 81 users and they were asked objective questions regarding their experience with the application. The collected data is reviewed and presented in this paper. It is important to conduct more research and testing to gain a better understanding of those who are skeptical about the quality of the medicines ordered online.

3. Methodology

The application is being developed using the waterfall methodology and it has been reviewed in the research experiment by the questionnaire. This study draws upon mostly primary data collected from pilot survey from those customers who are using Medway application and secondary sources including academic books, journals, and authorized websites.

3.1. Functional Decomposition

The objective of functional decomposition is to break down the system step by step by beginning with the main function of the system and continuing with the interim levels down to the levels of elementary functions. Our main function of this program is using deep learning to process handwritten prescriptions and convert them into digital prescriptions.

We are dealing with an optical character recognition library that leverages deep learning and attention mechanisms to make predictions about what a particular character or word in an image is. We are using a set of computer vision problems that require us to convert images of a handwritten text image to machine readable text in a form our smartphones can process, store, and edit as a digital prescription file.

For years, people have tried solving optical character recognition problems with several conventional computer vision techniques like contour detection, image classification, filters etc. They performed well on a small scale and template based dataset but they are feasible on a large scale. To be able to deploy the application on a scale, we had to explore some new methods.

With the combination of deep learning and neural network it is now possible to localize the text in an image as well as understand what the text is. Methods that power the model:

- Attention Mechanism
- Transformer
- Convolutional Recurrent Neural Network

The model uses a Convolutional network to extract image features as encoded vectors followed by a recurrent network that uses encoded features to predict where each of the letters in the image text might be and what they are.

3.2. Functional Specification of the system

Admin: Admin has overall control of the system making it one of the most important part of the system. Admin is responsible for keeping the contents up-to date, backed up and fully functional. Also analyze the back-end process continuously to make sure everything is working properly. The admin has the rights to reject or approve any registrations.

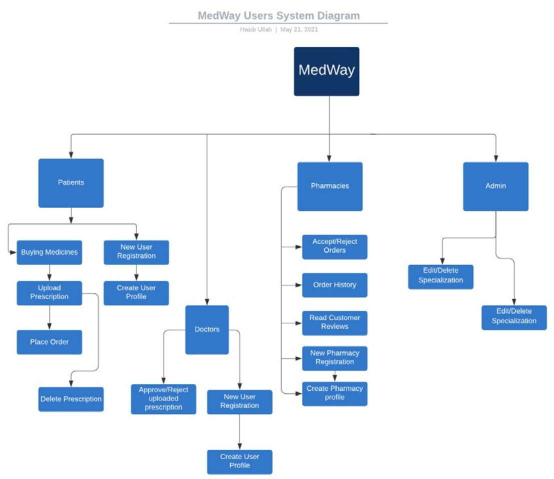

Figure 1. Functional specification diagram

Customer: Customer will go through a registration process and an identity proof process for the age confirmation. Users can authenticate with their mobile number. When they input their number and proceed, an OTP will be sent to their devices and the users will have to input the OTP on the app. If the input OTP matches with the sent OTP, the users shall be able to log into their profile. If the user is trying to login for the very first time they will be redirected to the "Profile Setup" page first otherwise they'll be redirected to their homepage. After successfully signing up the users shall be able to upload prescriptions, place orders, set medicine reminders, consult with the doctors etc.

Pharmacies: Pharmacies have the option to sign up and login. Each pharmacy will have to go through a registration and verification process before they can start taking orders. A pharmacy has to be a registered pharmacy by the Government otherwise the pharmacy will not be allowed into the platform and their registration application will be rejected. Once the pharmacy is verified, they can start taking orders for the prescriptions that were assigned to their portal and complete the order by sending the medicines to the ordered address.

Doctors: Doctors will also have to go through a registration and verification process. They will have to provide their educational details at the time of registration. After successfully registering to the platform, the doctors will be able to review the prescriptions, consult the patients etc.

3.3. Technical Specification of the System

Attention Mechanism: The concept of this mechanism is to pay greater attention to certain factors when processing the data.

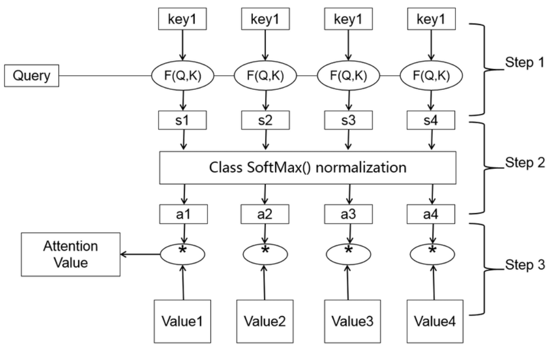

Figure 2. Attention Mechanism Calculation Process

This layer has trainable weights that help us capture the relationships between different elements of sequences. It works by using query, key, matrices, passing the input embedding through a series of operations and getting an encoded representation of our original input sequence. There are variants to the attention mechanism. Depending on the availability of the handwritten prescription image, the attention mechanism can be either hard or soft attention. We can achieve soft attention by laying each patch smoothly over the sequence of the image to make it differentiable.

Transformer: In this model, we are using multi headed attention which means several query, key and value matrices are being used and being trained independently. Then we concatenate them and extract a usable matrix for our following network by using an additional set of weights. Time dependencies are also an important element to our model. In transformers, there is something called positional embedding that encodes the time at which an element in a sequence appears. We add these positional embedding to our input for the network to learn time dependencies.

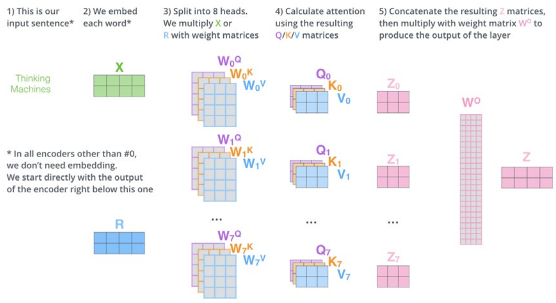

Figure 3. Multi headed self-attention [14]

Convolutional Recurrent Neural Network: Finally we use CRNN for extracting features and pass these features to the recurrent layers by-directional LSTMs. Then a transcription layer takes the frames generated by LSTM and decodes the frames using a probabilistic approach. Each frame is decoded into a character and these characters are fed into a final transcription layer that gives us the final predicted sequence.

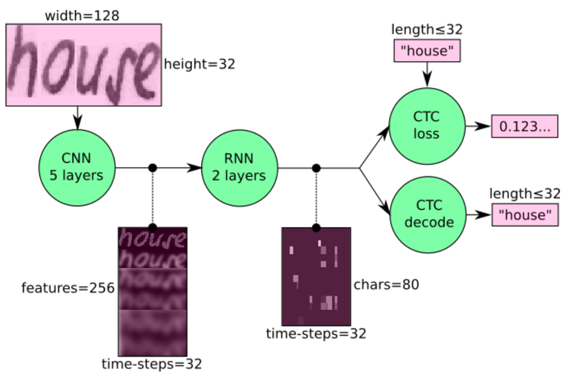

Figure 4. Network Architecture [14]

This architecture consists of 3 parts:
Convolutional layers: These layers extracts a feature sequence from the input image

Function	Propose
Upload Prescription	Upload prescription to user's database so that they can manage the prescription from one place.
Digital Prescription	Save a digital version of their uploaded hand-written prescription.
Medicine Reminders	Remind users to take medicines on time
Place orders	Place orders for the prescribed medicines
Medicine Auto-refill	Instead of placing repeated orders, users can get the necessary medicines periodically.

Recurrent Layers: These layers predict a label distribution for each frame. **Transcription Layer:** This layer translates the per-frame predictions into the final label sequence.

Evaluate the model: Finally we can use all the processed data to in the further development of our smartphone app to provide the following solutions.

- Create a digital prescription format that utilizes the processed data from the model.
- Extract the medicine names and dosages to send patients scheduled reminders for taking the medicines on time.

3.4. Application Development

Medway app is being developed using the waterfall model. One of the main features of the App is using deep learning for handwritten prescription digitalization. We are initially using IAM dataset to process the prescriptions but at the same time we are also training our custom dataset. Once the prescription is uploaded, we process the uploaded prescription through the network and extract the data. Then we compare the data with the IAM dataset to get the output. But the data is also used to create our custom dataset. Custom dataset is training a CRNN based architecture with CTC loss. A CNN is used to extract the visual features which are passed to a RNN and CTC loss is applied at the end with a decoder to get the output.

Table 1. Functionalities of Medway

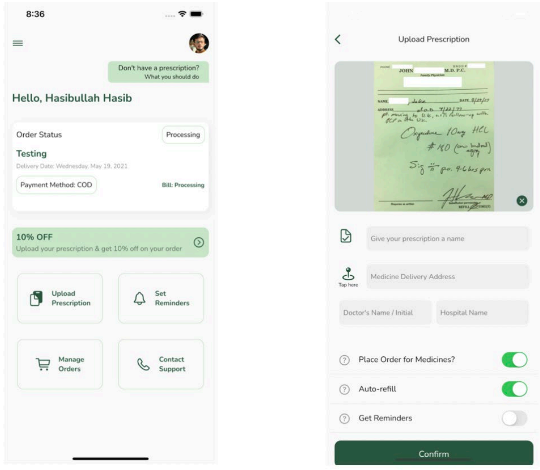

Figure 4. Screenshot of upload prescription functionality

Fig - 6 shows the screenshots of the Medway's Upload Prescription process. On the left is the Home page, from there they can navigate to the Upload prescription page and they can select a prescription to upload it.

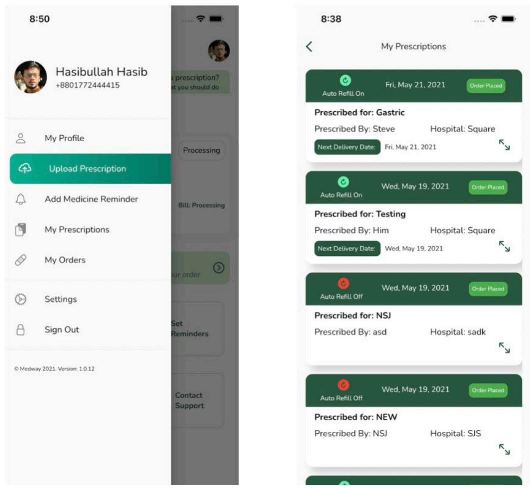

Figure 5. Screenshot of digital prescriptions

In Fig-7, the screenshots include a digital prescription function. From the left panel there's a "My prescriptions" option. Tapping on that will navigate the users to the list of their digital version of the prescriptions they have uploaded.

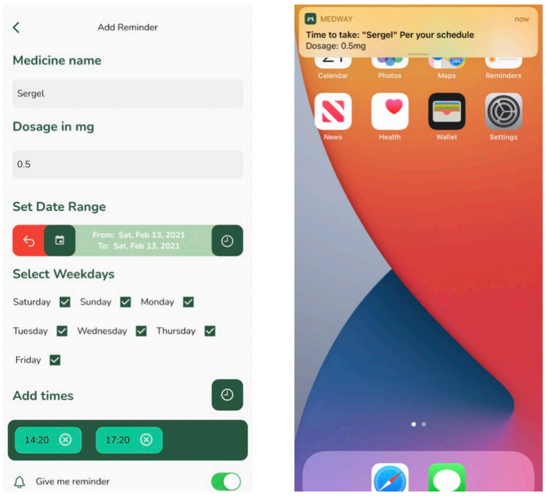

Figure 6. Screenshot of medicine reminders

Fig-6 demonstrates how Medicine reminders work in the Medway app. Users can manually set reminders for their medicines (Left) and get notified when it's time to take the medicine (Right). For those who forget to take their medicine doses on time, this feature acts as a reminder to ensure they never miss a dose. Skipping doses lowers the efficacy of the medication and delays the treatment. Hence, this feature is extremely helpful for people who take medicine on a regular basis. Users can enable this feature while uploading their prescription as well (Fig-4: Right).

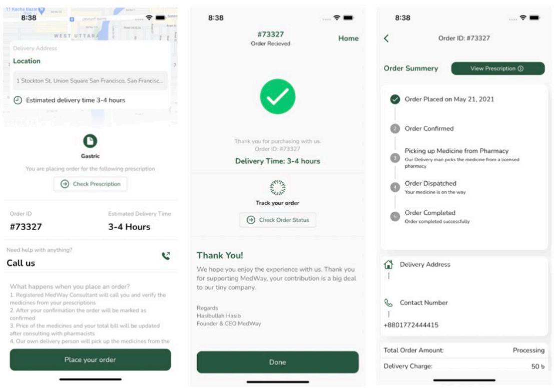

Figure 7. Screenshot of order placing functionality

Fig-7 indicates the "Order Placing" functionality of the app. While uploading the prescription (Fig-6 Right) users have the option to place an order. If the "Place order" is enabled, the user will be navigated to the "Place your order" page (Left). Here they will have an option to change their delivery address and place the order. Tapping on the "Place your order" will place the order for the user and navigate to the "Order Confirmed" page (Middle). Users have the option to see their order history and track their orders (Right).

5. Data presentation and analysis

The mobile app has been reviewed in the research experiment by the questionnaire. Then the app has been suggested to the users for uploading their prescription and placing orders. The participants in this experiment were asked objective questions and 81 participants took part in this experiment.

Table 2. List of questions to ask participants for general information

Questions
G1 - Age
G2 - Preferred platform for ordering medicine online
G3 - Frequency of buying medicine
G4 - Average cost spent on buying medicine

Table 3. List of questions to ask participants about their attitude towards the use of mobile applications as a tool in primary care treatment.

Questions	
Q1	Using healthcare applications would provide positive primary care treatment results.
Q2	Using healthcare applications could provide precise information for healthcare treatment as same as the professional advice from doctors or pharmacists.
Q3	Using healthcare applications could help make better self-healthcare.
Q4	Using healthcare applications would not cause serious consequences to the health of users
Q5	Using healthcare applications would help users in reducing the healthcare costs when illness occurs.
Q6	Using healthcare applications would facilitate users in primary treatment.

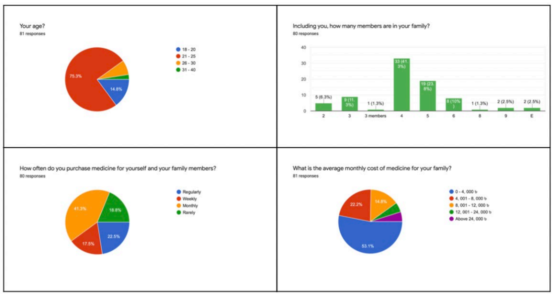

Figure 8. Indicates the response to the questions asked for their General Information

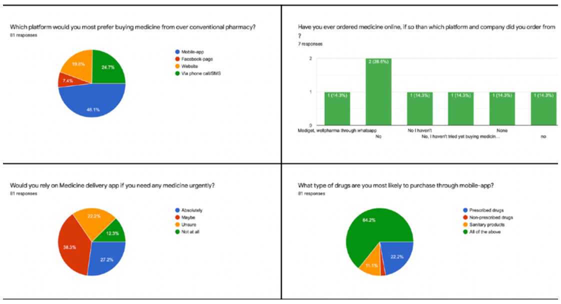

Figure 9.1. Indicates the response to their attitude towards the use of mobile application as tool in primary care treatment

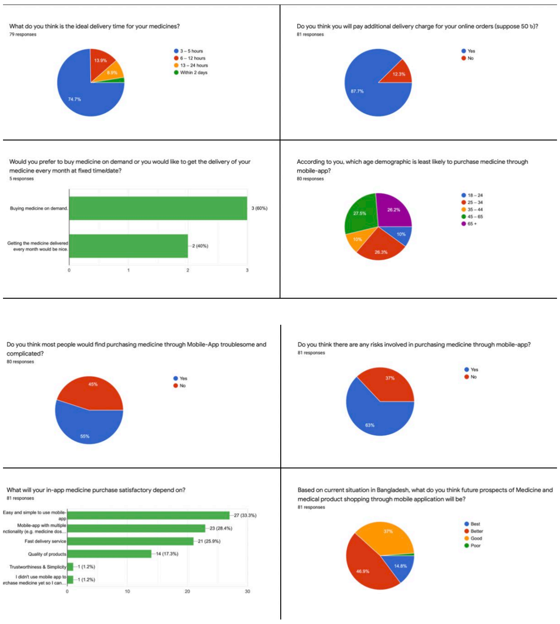

Figure 9.2. Indicates the response to their attitude towards the use of mobile application as tool in primary care treatment

The experimental result in Figure 8 and 9 indicates the response to the questions asked for their general information and their attitude towards the use of the mobile application. The majority of the participants were between 21 to 25 years old. In regards to members in their family, the majority of people of 4 family members which is 41.3% of the participants. Again 41.3% of the entire participants have said to buy medicines on a monthly basis and 53.1% of the entire participants spent around 4,000 (BDT) on medicines while 14.8% of the participants spend ranging from 12,001-24,000 (BDT) on medicines.

6. Discussion

Our deep learning model uses two equations to calculate the error rates in the processing of handwritten prescriptions. 1. Character error rate and 2. Word error rate.

Character error rate: CER calculation relies on the concept of Levenshtein distance. It's for measuring the difference between two sequences of a string. It is string metric theory. It is basically a number that tells how different two strings are. The higher the number, the more different two strings are. With the following formula (1) we count the minimum number of character level operation to transform the reference text to OCR text.

The sum of Character substitutions (Sc) insertions (Ic) and deletions (Dc) are divided by total number of characters returns the character error rate. "Eq (1)"

$$CER = \frac{S_c + I_c + D_c}{N_c} \quad (1)\ [18]$$

The output of this equation represents the percentage of characters in the reference input that was incorrectly predicted in our model's output.

Word error rate: In the use case of transcription of paragraph and sentences with multiple words, then word error rate is more suitable. The formula for word error rate is almost similar to the formula of character error rate, but WER operates on word level. It represents the number of word insertions, substitutions or deletion required to transform one sentence to another. The sum of word substitutions (Sw) insertions (Iw) and deletions (Dw) are divided by total number of words returns the word error rate. "Eq (2)"

$$WER = \frac{S_w + I_w + D_w}{N_w} \quad (2)\ [18]$$

WER and CER are well-correlated. But generally absolute WER value is expected to be higher that the CER value. For Example,

Reference Text: "machine learning is fun"
Our model Output: "machinee leerning iz fun"

Here, from the equation we get that the CER is

16.67% while WER is 75%. WER is 75% because 3 out of 4 words are wrongly transcribed by the model.

7. Conclusion

The application is based on deep learning that implements transformer architecture that uses multi headed self-attention layers at both visual and text stages. This allows the model to learn character recognition and decodes language-related dependencies of the character sequences. Also current findings suggest that while training our own custom model, it is important to follow the data structuring of IAM Dataset. Training a custom model requires varieties of data. We could have reduced the Word Error Rate (WER) and Character Error Rate (CER) significantly if we could roll out our application to wider audience.

Pharmacies interact with multiple patients every day and data regarding each of these interactions are usually not stored. After reviewing the data collected from users of Medway, it is clear that pharmacies can streamline their daily tasks in order to make the entire workflow more efficient by simply integrating our inventory management system. We discussed how our Inventory Management and logistical support for pharmacies will allow them to manage stores at multiple locations easily. Data regarding each of these interactions between pharmacy and their patients are stored within the pharmacy inventory system. Pharmacies can analyze these data and make data driven decisions to boost their pharmacies growth.

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