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EFFECTIVE MEDICINE MANAGEMENT FOR VISUALLY IMPAIRED PEOPLE: POCKETMED

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Abstract. *Managing medication can be a challenging task, especially for individuals with physical disabilities, the elderly, or those who are visually impaired. Identifying medications and reading package inserts can be difficult for visually impaired patients, which can pose a safety risk. A solution is required to help manage medication effectively and safely. To address these challenges, a system for drug management has been proposed. This system includes a web application for pharmacists to enter prescription information and generate a QR code, and a mobile application for visually impaired individuals to access the medication information stored in the QR code applied on the medicine. The PocketMed app provides vital information such as the name of the medicine, the dosage, the schedule for taking the medication, the expiry date, and the duration for which the medication should be consumed. The app also sends timely notifications to visually impaired patients to remind them about their medication intake. The proposed system has been tested with 30 participants, and they found it to be useful for taking medication on time and independently. PocketMed has user-friendly interface, potent functionality, and ease-of-use making medication management safer and simpler for visually impaired and elderly people.*

Keywords: Assistive aid, Medicine management, Mobile application, Mobile health applications, Visually impaired, Technology tools

1. **Introduction.** There are 2.2 billion people worldwide who are visually impaired as per the World Health Organization [1]. Vision impairment impacts personally and economically the quality of life of an individual. Several of the UN's international conventions, the protocol on the rights of people with disabilities, recognize the significance of human freedom and control for disabled individuals, along with the opportunity to make their own choices [2]. Several kinds of research are being done for aiding visually impaired people in navigation and for obstacle detection [3-5]. Other than safe navigation, there are numerous other challenges faced by visually impaired people. It is a common finding that elderly individuals and persons with impairments need to take medication regularly to be healthy and strong. Failure to take the proper medication at the appropriate time may lead to health complications, around 30% of visually impaired persons consumed an overdose of medicine, resulting in adverse effects on their health [6]. Visually impaired people are vulnerable to drug errors and have less awareness about drug management, which leads to greater risk of improper treatment. Thus, there is a need of proper pharmaceutical care services [7].

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The primary goal of this work is to create a new smart medication management app that will assist visually impaired and elderly people to consume the correct medicine and notify them about medicine intake based on the prescriptions. The user can interact with this system through voice to know the details of medicine. Another major goal of this initiative is to let visually impaired individuals independently consume medicine, thus helping them to become more self-sufficient. The proposed solution will safeguard blind people from taking too much medication or taking incomplete doses.

Current mobile applications and solutions for medication management for visually impaired persons developed by various researchers are reviewed and presented further. There are cumulative numbers of smartphone applications available to assist individuals with efficient medicine management [8]. Patients with chronic illnesses have shown gains in health outcomes and care procedures when self-management assistance is delivered digitally, including understanding and monitoring therapy. However, the majority of presently available applications simply serve as intake reminders, implying that they are based on a behavioral adherence approach [9].

"Medication Dispensing Device" is proposed by [10] to help individuals with Geriatrics, taking their medications on time. It is critical to develop a smart medicine box that allows nurses or patients to select the quantity and timing of medication [11]; thus, the authors proposed the box having seven sections and enable users or nurses to enter information about various medications. It uses sound and light to remind people of taking their medications.

The utilization of medication patterns for Saudi Arabia people using braille labels is described by [12]. This study highlighted the need for braille labelling information for medicine descriptions for visually impaired people. A system for the identification of medication aid by blind people is proposed by [13]. This system used machine learning algorithms for the detection of objects and gave an accurate description of the tablet information. A system to detect and identify medicine using smart glass is proposed by [14]. This device can read the name and detailed information of the treatment, and it provides the audio of such information via a speaker to the user. A voice-based mobile application for knowing medicine information by blind people is proposed by [15]. It uses image processing techniques to know medicine name which is time consuming approach.

A method for the recognition of medicines for blind people is proposed by [16]. The method included 3D printed boards with braille as well as moon labels. A system including a pair of wearable electronic glasses, a reusable waist-mounted medication pill identification device, a mobile device app, and a virtualized administration platform is proposed by [17]. The process framework that focuses on the requirements of particular users has been used by many researchers in the healthcare and medicinal services fields to design and develop the systems [18]. A system for analysis of usage patterns of medications, pharmacy services for visually impaired people and the status of medication counseling for the visually impaired people conducted by the community pharmacists was proposed by [19]. A system for monitoring the medicine intake activity of old age people, by applying RFID tags consisting of information about medicine bottles and a vision-based technique to identifying users' faces was developed by [20]. Labelling of medicine using 3DP technology for visually impaired people was proposed by [21], but it is an expensive approach.

Stand-alone talking devices, mobile apps, and memory aids are some of the current technologies and techniques in use. The stand-alone talking devices, such as AccessaMed [22] and Talking RX [23], are used to record the pharmacist's instructions as voice instructions, such as the number of pills to be taken, the proper time to take them, and whether to take them before or after meals. When blind individuals wish to take the medication, these voice instructions are played over to them. Understanding the doctor's or pharmacist's accent is a challenge.

Smartphones today assist individuals with impairments, allowing visually impaired people to use mobile phones with the help of Voice-Over, a screen reader. A mobile application which would help blind and their helper community for interacting and assisting the blind people is proposed by [24]. A method used to assist blind individuals in reminding their medicine intake by means of smart pill box is proposed by [25]. The tool iRemember [26] helps blind people to organize their medicine-taking schedule and provides reminders for medicine intake, it also helps them to know when last they had taken the medicine, but it is an expensive tool. There are a variety of mobile apps available that assist visually impaired people with navigation, object detection, reading, etc. as per [27], but there is no mobile app mentioned which is specifically designed for medicine management. Visually impaired people will be benefitted by development of mobile application for administration and medicine intake as per [28].

According to the reviews and research, blind and visually impaired people face challenges when it comes to medication management. The motivation of this research work is to enable independent medicine management for visually impaired and elderly people and to provide a solution for medicine management which will be easy to use and ensure safety of their health by providing correct medicine information and timely reminders for intake of medicine. Consuming the correct medication dose, especially for liquid medicine dose, recognizing medicine or distinguishing them on basis of various forms and sizes, reading and understanding package inserts with medical data or dosage requirements, recognizing expiry, and correct prescription consumption is only a few of the challenges. Thus, to overcome the challenges faced by visually impaired people, a medicine management system with mobile based application is proposed here. The major contribution of the system is

1) To provide a facility for the pharmacist to generate a dynamic QR code of the medical prescription;
2) To apply the generated QR code on the medicine strip or bottle;
3) To develop an Android application to read medicine information via QR code scanning such as medicine name, dosage, and expiry date of medicine;
4) To set notifications in the mobile application for the consumption of medicine at a given time as mentioned in the prescription for visually impaired people;
5) To implement auto SMS service using GSM APIs for indication of alarms to visually impaired and old aged people.

The further sections of the paper are divided as follows. Section 2 describes the proposed system. The results of system implementation are written in Section 3. Section 4 describes the evaluations done followed by Section 5 which provides the conclusion and future scope of the proposed system.

2. **Proposed System.**

In this work, the focus is on how a mobile application can support elderly and visually impaired people in managing their medication or more specifically, which technologies and functionalities should be provided to facilitate medication management for the particular user group. Hence, a corresponding concept is introduced and implemented in the mobile application PocketMed. Figure 1 shows the architecture of the proposed system. The pharmacist or the medical practitioner accesses the webpage to generate the QR code for the medicine prescribed to the patient by the doctor. The generated QR code is stuck to the medicine strip which is then scanned by the end user and the information related to medicine and the alarm for taking the medicine is saved in the local database after the first time scanning the information. As per the prescribed timing, the notification is generated for the visually impaired person to take the medicine. Then the visually impaired person can scan the QR code stuck on the medicine to know the name, dosage, and other details of the medicine. The system comprises two modules: one to generate the QR code and the second for scanning the QR code.

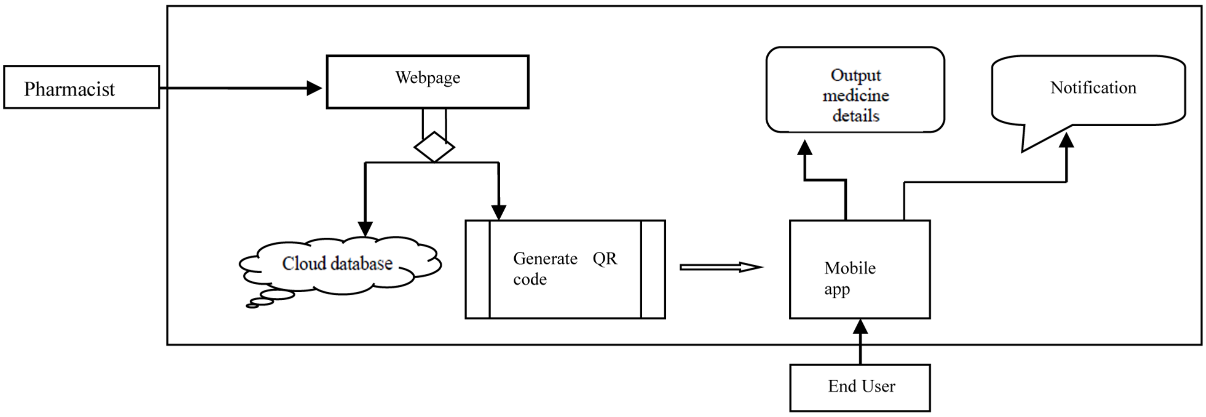

Figure 1. Proposed system

1) **Generate QR code:** Denso Wave, a Japanese organization, created the QR (Quick Response) code, a two-dimensional barcode [29]. Information is encoded vertically and horizontally, allowing it to store several times more data than a conventional bar code. Because of their capacity to encode Kanji characters by default, these codes have quickly acquired global appeal and have been adopted by many systems, particularly in Japan. The medicine information mentioned in the prescription given by the doctor is filed by the medical practitioner into QR code generation module. The information consists of the name, dosage, expiry date of the medicine, the time and number of days for which medicine has to be consumed, and the start and end date of the medicine. Using this information, the module generates a QR code image.

   Depending on the QR code shares and encoding level, 8-bit code words will be split into multiple error detection blocks. 'spire. Barcode. BitMatrix' is used to generate a QR code for text data. The description below explains how to generate a QR code and store it using the Google API.

$$\int P[\ ]\sum_{k=0}^{n}\frac{\Delta y}{\Delta x}\left[(k).byte\right] \tag{1}$$

   In Equation (1), k is the length of input text, Δy is the current byte array converted from widespread text, Δx is the total number of pixels in a QR image, and $P[\ ]$ is the final built pixel array. To generate QR code images based on the given text, *com.google.zing.BinaryBitmap* and *com.google.zing.EncodeHintType* open-source libraries are used. The generated matrix required input as a QR generation method, and it creates the final QR code as shown in Figure 3. Moreover, the entire process indicates the strategic framework of QR generation with various functionalities. Initially BitMatrix class manages the format in given dimensions with included text; thus, *MatrixToImageWriter.writeToPath* method generates the QR matrix, and *QRCodeWriter* is the inbuilt class that writes the final QR images.

2) **Scan QR code:** In the data extraction phase, QR code scanning has to be performed using a smartphone in our application. Hence, to perform this task, the PocketMed Application has to be launched, and then after clicking on the Scan QR button camera will activate automatically. After the camera activation, set up the QR code with the camera and keep our smartphone steady until the application generates the beep event, extracting all of the contents stored in the code. The QR code scanning operation is done using Equation (2).

$$data[r][c]=\sum_{n=0}^{w}\sum_{m=0}^{h}pixel[n][m] \tag{2}$$

According to Equation (2), n indicates the rows of the image and m indicates the columns of the image, and the specific pixel values have been denoted by $pixel[n][m]$. The entire data is stored in a single matrix and is converted into string64baseEncoder for text. The text data contains all the information in the prescription of medicines like medicine consumption time, the dosage of medicine, start date, and end date.

3) **Generate events:** According to extracted information from the QR code after scanning, it dynamically set up the alarms on specific dates for medicine intake. Based on extracted data, it determines to set up the mobile or buzzer alarms; thus, the SMS service for indication of alarms is also integrated into the app which is also helpful for old age people who are not blind. When the medicine QR code has been scanned, the validity of the medicine and duration of the medicine are indicated.

3. **Results and Discussion.** Extensive experimental analysis has been done by deploying the systems on the Android platform. Initial QR code generation implementation has been done in Java open-source environment, and the rest of the functionality has been done in Android. Figure 2 depicts the QR code generation while filling the prescription or supportive information; once the functionality has been done, it generates QR codes containing information about the respective medicine. Figure 3 demonstrates a QR code generated after feeding the entire information by a pharmacist. He then pastes the generated QR code on a medicine box or medicine strip. This QR code helps for the extraction of medicine information when users scan this code.

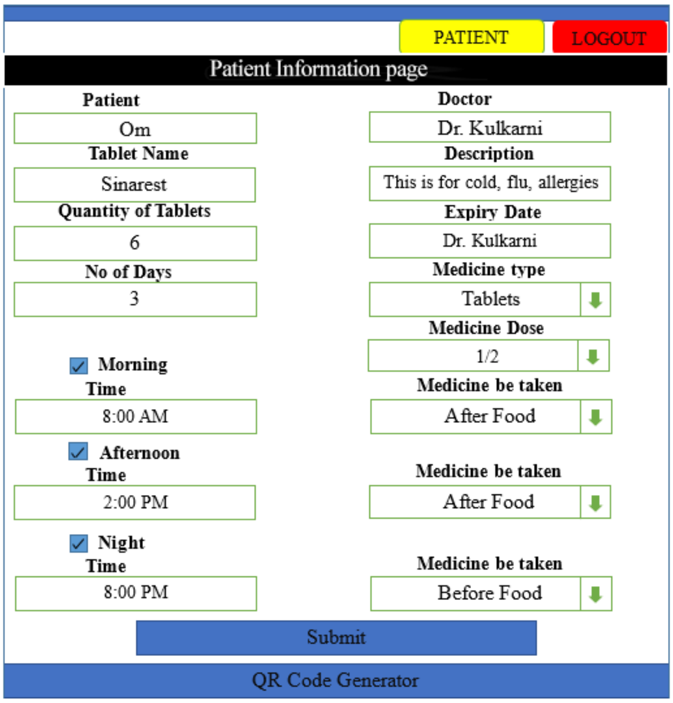

FIGURE 2. QR code generation web app

FIGURE 3. Sample QR code generation with respective input data

Figure 4 illustrates the main menu screen of the application form which has two functions. The SCAN QR code functions for scanning the specific medical strips code, while updating the details of medicine in the local database. When the user clicks on the take medicine button, the details of the medicine are known to the blind user. Figure 5 illustrates the mobile app screen while scanning the QR code of medicine. Figure 6 describes extracted data from a QR code after scanning by our mobile application, and the scanned

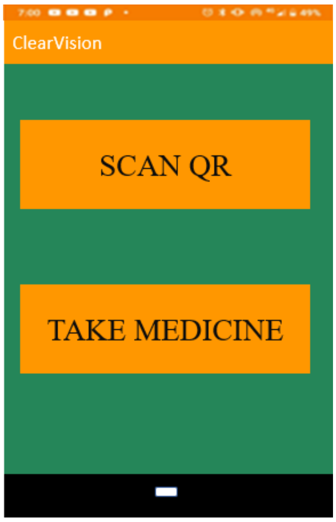

FIGURE 4. Menu screen

FIGURE 5. QR code scanning

FIGURE 6. Screen after QR code scanning

information is stored in the local database. Based on the above information, the mobile app generates an alarm when a specific time event has occurred.

According to experimental analysis, the research contains few imperfections. First and foremost, PocketMed App is available for the Android platform only. Android is the most prevalent smartphone operating system worldwide (75%), although it does not support IOS, which has to be created. For future enhancement, it is still necessary to offer more effective features in the application by combining appropriate IoT methods with machine learning algorithms.

4. **Evaluation.** In the extensive experimental analysis, the proposed product is evaluated with 30 people, out of which 10 are blind and 20 are old age people with low vision. The users were explained how to use the PocketMed app and were given the medicine strips with QR code applied on it.

The users found it very easy to use the app knowing the medicine information. Figure 7 shows an image of user scanning the QR code on medicine strip.

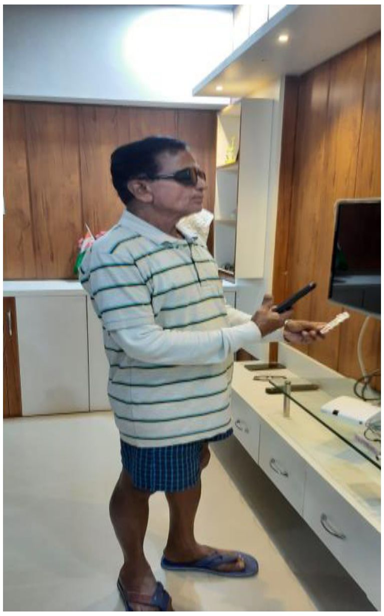

Figure 7. User scanning the QR code applied on medicine strip

Based on the above evaluation, it is concluded the initial objective to assist visually impaired people in consuming medicines is successfully achieved with the given development. Table 1 demonstrates the efficiency of the proposed model with some existing devices. The detection of QR codes is very high with the extraction of metadata. It also provides faster execution with very low power consumption and the portability is also applicable on various Android versions.

Table 1. Comparative analysis of the proposed system with other assistive devices

Assistive devices	Detection accuracy	Time/Cost	Power utilization	Portability
Navigation system for VIP [30]	Low	Medium	Low	Yes
Blind guidance system [31]	Medium	Fast	Low	Yes
Electronic mobility cane for vision rehabilitation [32]	High	Fast	Low	Yes
Watch You're Step: [33]	Medium	Fast	Low	Yes
Proposed	High	Fast	Very Low	Yes

Moreover, in another experiment, device produces excellent performance throughout the execution. The system could not give any results when only conversion fails text from input from the user. In such a case, application is not able to understand the actual input from the user and generates null input, and does not return anything. From Figure 7, it is evident that a visually impaired individual is able to successfully scan the QR code affixed to the medicine strip. Figure 8 depicts four major functionalities which are evaluated in experiment analysis and measure the QoS parameters of the application. Almost no failure is achieved for QR code generation with QR scanning. Sometimes voice-to-text and text-to-voice conversion produces errors due to inaccurate user ascent. Based on the analysis, the system provides better results than some existing modules which are developed by preceding authors.

5. **Conclusions.** Nowadays smartphones are used to perform the majority of our everyday tasks via mobile applications. People with visual impairments need help access these applications through portable devices such as smartphones and tablets. Several mobile

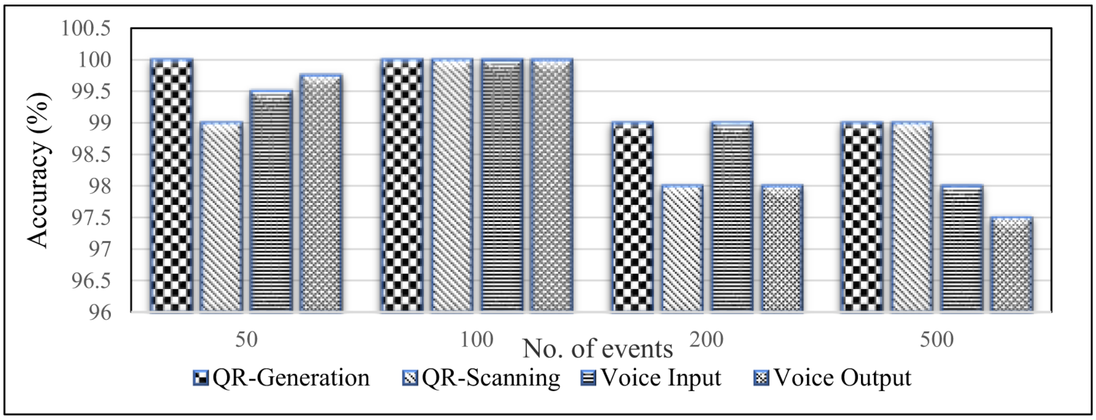

Figure 8. Accuracy of the proposed system with different numbers of experiments

applications for visually impaired people have been developed by previous researchers which are obtainable from the play store. However still, users cannot easily communicate with the system due to insufficient user-friendly functionality. To eliminate such problems, our application works by collaborating with Google services. This system would be used by people with a variety of impairments, including vision, color blindness, hearing, agility, cognitive difficulties, and more.

This research focuses on smartphone usability for blind users for effective medical management. Initially, once the QR code has been scanned, it reads the prescription information from the QR image and automatically schedules the alarm for each activity according to the dates. In the future, the system can be enhanced to generate QR code stickers in the Braille language which would require braille embossers and heavy papers to generate QR code stickers.

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