On The Design of a Novel Smart Medicine Box Towards Detecting the Medicine Expiry Date and Facilitating Medication Planning for Visually Challenged

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Abstract: - Population growth has led to the increase of different types of medication, burden on nurses and pharmacy clerks. Studies have shown that on an average a person takes about five different types of medication for any illness. This medication has led to several other medication errors as the patient is taking wrong medicine at the wrong time in a day. This is highly prevalent in people who are older in age and for the people, who are visual impaired or challenged. These people face difficulty in checking the expiry date of the medication because of smaller text size and fonts. It is well known that consumption of an expired product is fatal. To prevent this medication error, forgetting medicine intake and consumption of expired medication; the Smart Medicine Box idea is used. It is a boxlike structure with certain compartments. The compartment has LCD screen that displays the name of the medicine stored and the date of expiration for that medicine. In addition, the box contains speaker to announce the name of the medicine and date of expiration. To assist the visually impaired to take the correct medication vibration mechanism has been set up where the compartment containing the medicine to be taken at that time vibrates indicating to the user. Image processing technique is used to process and analyse the bar code of the medication for the expiration date and the name of the medication. Ultrasonic Sensors are used to detect the pending number of pills within the compartment; a microcontroller is used to control the process. In this research effort, after a critical overview of the state-of-the-art developments in this important field we outline in detail the proposed architecture for such an efficient smart medicine box, defining its components and its preliminary UML related diagrams

Keywords: Image Processing, LCD Screen, Reminder, Expiry date in medicine, Alert, visually challenged, smart medicine box, UML diagrams

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1. Introduction

Population growth has led to the increase of different types of medication, burden on nurses and pharmacy clerks. Studies have shown that on average a person takes about five different types of medication for any illness, this has led to several medication errors where the patient takes the wrong medicine at the wrong time of the day. This is highly prevalent in people who are older image and in people, who are visually impaired, they are unable to check the expiration date of the medication due to its small text size and fonts, it is well known that consumption of an expired product is fatal.

The existing system focuses on providing solutions which did not entirely benefit the patient. In existing system, there was either a solution to help blind people take their medication but not remind to take their medication on time or vice-versa. It did not announce the date of expiration for the medication if it had performed the above functionalities. The existing system does not remind the visually disabled person to take their medication on time if assistance is provided. It does not aid in taking medication if there is reminder to take medication. It does not announce the date of expiration to the patient if both the above features

are present. These are the limitations of the existing system.

The medical industry is exhausting its human resources such as nurses and pharmacy clerks to the peak. A major cause of health deterioration in aging and the visually impaired is due to the consumption of wrong medicine, forgetting to consume medication and consumption of expired medication. To prevent this medication error, the forgetting of medicine and consumption of expired medication; the smart medicine box idea is used.

Smart medicine box is a method of overcoming these issues and also reducing the stress on nurses. Smart medicine box makes use of various components such as LCD screens, vibrations, buzzers. Image processing technique is used to analyse and process the name and expiration date of the medication. Ultrasonic Sensors are used to detect the number of pills still left within the compartment; a microcontroller is used to control the process. A RTC Clock module and a vibration motor are used to vibrate the compartment on time.

1.1 A Critical Literature review of state-of-the-art smart medicine box systems proposed

Text string detection from natural scenes by structure-based partition and grouping is performed in two steps image partition technique to find the text character candidates based on local gradient features and colour uniformity of character components using two algorithms text string detection adjacent character grouping method and text line grouping method [1].

Design of a safe and smart medicine box calculates the weight of each pill setting the schedule of medical intake, alarming the user of the number of remaining pills, generating alarms whenever the patient does not take the required number of pills or doesn't take them at all [2].

Product barcode and expiry detection for the visually impaired using a smart phone provides a solution for a visually impaired person or a blind person to check the expiration date independently. It focuses mainly on helping the blind user to locate the barcode and the expiration date on a product package [3].

Design and implementation of an automated reminder medicine box for old people and hospital where the main objective is to remind old people or patients in the hospital to take their medicine on time. It also informs whether the medication should be taken before or after a meal [4].

Intelligent medicine box for medication management using IOT alerts the patient to take their medication on time. It is connected to the internet to give timely update about the medicine through an android application. A SMS alerts are given when there are irregularities in vital signs are noted [5].

Image based label detection with voice output for visually challenged people using classifiers provides a computer vision algorithm enabling a blind person to locate and read a barcode. It includes numeral string pre-processing, string segmentations, features extractions and numeral recognition [6].

Health alert and medicine remainder using internet of things ensures that old people take their medication on time; it also continuously monitors the health condition like blood pressure, ECG through the sensors [7].

The design of a smart medicine box that has been proposed can be used by patients as well as nurses or caregivers in order to monitor and ensure that the correct dosage of each medicine is being taken at the right time. It provides visual and audio notifications to alert the user when a certain medicine is to be taken or refilled. Furthermore, a mobile application is designed to send SMS messages and email notifications to the patient and the caregiver [8].

A smart pill box with remind and consumption functions ensures that the patients consume the right medication at the appropriate time. This is done with a smart pill box equipped with a camera and is based on a medicine bag concept; a bar code is printed on the medicine bag which interacts with the pill box to perform the functions [9]. Similar recent attempts have been recently presented [10,11].

The summary of the existing systems is given in Table 1a.

Table 1a: Comparison of the proposed system with the existing systems

Refe-rence	Inference	Limitation	Proposed methodology
[1]	Colour based partition performs better than the gradient based	It takes more time to detect text strings on each colour layer.	It does not take much time in detecting the expiry date.

	partition.		
[2]	This system reminds the patient to take the medicine. The safety feature that will alarm the patient in case of not taking and/or bad dosage taking for medication.	Only the alarm is used to remind the patient to take the medicine.	The name of the medicine is also given as a voice output.
[3]	This system uses a smartphone for the Product barcode and expiry date detection.	Usage of smartphone for the visually impaired people may be difficult.	The name of the medicine and the number of pills left out which are given as voice output will be very helpful for the visually impaired people.
[4]	The device plays a sound in the speaker to share the information of medicine quantity and blinks the LED of the specific compartment where medicine is kept for that time.	This system cannot be used for visually impaired people.	This system can be used for visually impaired people and old age people.
[5]	The proposed model has an intelligent medicine box that gives alerts to patients for their medication at right time. It is connected to internet to make timely updates about medicine to patient's Smartphone through notices in android application.	It is only used to alert the patients to take the medicine.	The name of the medicine is also given as a voice output.
[6]	It helps the user or caregiver by specifying the required pill quantity, the exact time to take the pill each day, and the need to refill some pills.	The computer vision output based on the various classifiers will provide feedback of whether the product is expired or not.	A scanner is attached to the Smart medicine box that scans the bar code of the medication for the expiration date and the name of the medication.
[7]	Medicine remainder and also health monitoring for elderly persons at home using a simple electronic application. it is a convenient way to use by people of any age and people busy with their work will not forget to take medicine.	The system would be better if it accommodates the need of disabled/visually impaired people such as giving voice output as the name of the medicine and the number of pills remaining in the medicine box.	The name of the medicine and the number of pills left out which are given as voice output will be very helpful for the visually impaired people.
[8]	The purpose of this device is to remind the old people or patient to take medicine on time with appropriate dose.	The system would be better if it accommodates the need of disabled/visually impaired people such as giving voice output as the name of the medicine and the number of pills remaining	The name of the medicine and the number of pills left out which are given as voice output will be very helpful for the visually impaired

		in the medicine box.	people.
[9]	This paper proposes a smart pill box equipped with a camera and based on the medicine bag concept. The matrix bar code printed on the medicine bag is used to interact with the pill box in order to perform pill remind and confirm functions.	The system would be better if it accommodates the need of disabled/visually impaired people such as giving voice output as the name of the medicine and the number of pills remaining in the medicine box.	The name of the medicine and the number of pills left out which are given as voice output will be very helpful for the visually impaired people.

The recent advancements in smart medicine box systems for visually challenged individuals focus on integrating image processing techniques to detect expiry dates effectively. These systems leverage various technologies to enhance medication management and safety.

Intelligent Drug Box Systems

Zhou Feng's intelligent drug box system incorporates a detection device that monitors drug conditions and alerts users about medication status through wireless communication [20]. This system enhances user awareness and medication adherence.

Expiry Date Detection Techniques

Terenna's research introduces a micro-controller-based system that utilizes transformable labels to indicate expiration dates, providing a visual cue when the product is no longer safe [21]. This approach can be integrated into smart medicine boxes to assist visually impaired users.

Assistive Technologies for the Visually Impaired

Mukhiddinov et al. propose smart glasses that utilize deep learning for object recognition and audio feedback, which can be adapted to help users locate and read expiration dates on medicine packaging [22].

Smartphone Applications

Peng et al. developed a smartphone solution that guides visually impaired users to locate barcodes and expiration dates, utilizing existing decoding algorithms [3]. This method emphasizes accessibility and independence.

Smart Medicine Planner

Al-Haider et al. present a Smart Medicine Planner that combines dispensing and alerting systems, utilizing voice interaction to assist users in managing their medication [12]. This holistic approach ensures timely reminders and medication organization.

While these systems show promise, challenges remain in ensuring reliability and user-friendliness, particularly in low-light conditions or with low-resolution images. Further research is needed to enhance the robustness of these technologies for practical use. Based on some of the most cited papers in the literature with respect to systems utilizing these technologies we present the following table 1b, about their limitations.

Table 1b: Limitations of the most cited research works integrating the needed technologies for developing a proposal for the design of a state-of-the-art smart medicine box for the visually challenged.

Research Papers	Limitations towards developing a fully functional novel smart medicine box for the visually challenged
[12]	The paper does not propose a system architecture for detecting expiry dates using image processing techniques; it focuses on voice interaction and medication dispensing for visually impaired users.
[13]	The paper focuses on medicine box recognition using image processing techniques but does not propose a system architecture for detecting expiry dates specifically for visually challenged individuals.

Research Papers	Limitations towards developing a fully functional novel smart medicine box for the visually challenged
[14]	The paper does not propose a system for detecting expiry dates using image processing techniques; it focuses on a Braille-based pillbox with audio reminders for medication management.
[15]	The proposed system extracts and classifies pill labels and expiry dates using image processing techniques, enabling visually challenged individuals to identify medicines accurately and independently.
[16]	The paper does not propose a system architecture for detecting expiry dates in medicine using image processing techniques for visually challenged individuals.
[17]	The paper focuses on developing a smart medicine box for the elderly, emphasizing alarm reminders and automatic dispensing, but does not address expiry date detection for the visually challenged.
[18]	The paper proposes a smart pill box that utilizes IoT to remind users about medicine intake and manage expiry dates but does not specifically address image processing for visually challenged individuals.
[19]	The paper focuses on NFC and RFID for medicine expiry detection, not on image processing techniques for visually challenged individuals in a smart medicine box system architecture.

2. The Overview of the Proposed System Architecture

This section explains in detail about the architecture of the proposed system and its components involving the block diagram approach. Moreover, the relevant proposed design and functionality is illustrated through utilizing the needed UML diagrams. The architecture diagram using the block diagram approach is shown in Fig 1.

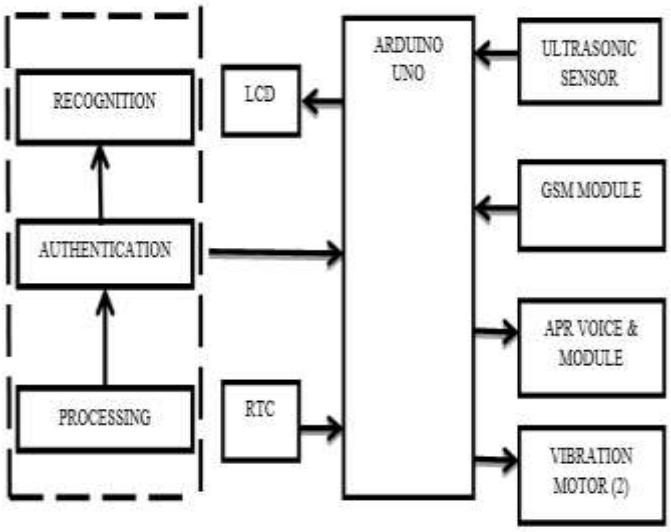

Fig 1. Proposed Smart Medicine Box thehitecture diagram

Image processing techniques are used to recognise, authenticate and process the barcode of the medication to detect the name and expiry date of the medication. The original barcode of the medicine and the binary image of that barcode after being analysed through Image Processing techniques is shown in Fig 2. More details about all components will be provided in the next section

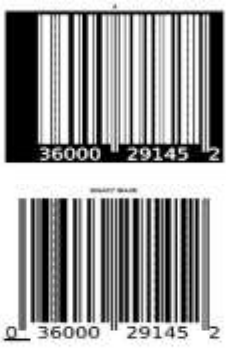

Fig 2. Original Barcode and Binary Image of the medicine

The LCD and Speaker are used to display and announce the name of the medicine and, also, the expiry date of the medication stored in the compartment as shown in Fig 3.

Fig 3. Display the name and expiry date of the medicine

Medication is reminded to the patient to take medicine on time. As shown in Fig 4. Using a real time clock (RTC) the patient is reminded to take their medications on time. A vibration module is used to alert the patient on which compartment the medication to be taken is.

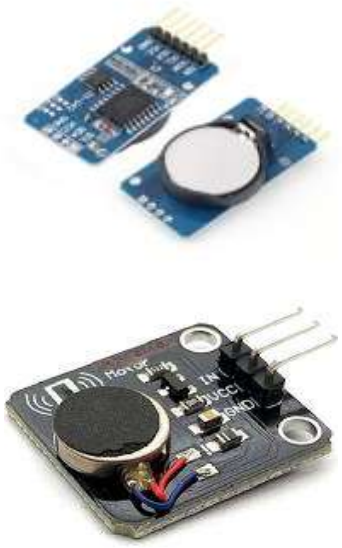

Fig 4. RTC Clock Module and Vibration Sensor

As shown in Fig. 5 using ultrasonic sensors the caretaker is given an alert notification when there is a significant decrease in the number of medicines/pills still left in the container.

Fig 5. Alert notification

As shown in Fig 6 the GSM module is used to notify the patient's caretaker regarding the status of the pill. That is, if the number of pills goes down beyond a threshold the GSM module is used to send an SMS notification to the caretaker.

Fig 6. Notification to patient's caretaker

Smart medicine box is a boxlike structure with various compartments. These compartments have their own LCD screen that display the name of the medicine stored and the date of expiration for that medicine, the box also contains speakers that announce the name of the medicine and date of expiration.

To assist the visually impaired or challenged to take the correct medication a vibration mechanism has been set up where the compartment containing the medicine to be taken at that time vibrates indicating to the user. A scanner is attached to the Smart medicine box that scans the bar code of the medication for the expiration date and the name of the medication.

3. A Preliminary Illustration of the Detailed Design of The Proposed Smart Medicine Box System

To design the proposed Smart Medicine Box, we can create several UML diagrams to represent different aspects of the system. Here are the key UML diagrams for this project:

3.1. Use Case Diagram

This diagram shows the interactions between the user and the system, highlighting the main functionalities.

```
A[User] -->|Interacts with| B[Smart Medicine Box]
B --> C[Display Medicine Info]
B --> D[Announce Medicine Info]
B --> E[Vibrate Compartment]
B --> F[Process Barcode]
B --> G[Detect Pill Count]
```

3.2. Class Diagram

This diagram represents the structure of the system by showing its classes, attributes, methods, and relationships.

```
classDiagram
    class SmartMedicineBox {
        +LCDScreen lcdScreen
        +Speaker speaker
        +VibrationMechanism vibrationMechanism
        +ImageProcessor imageProcessor
        +UltrasonicSensor[] sensors
        +Microcontroller microcontroller
        +void displayMedicineInfo()
        +void announceMedicineInfo()
        +void vibrateCompartment()
        +void processBarcode()
        +void detectPillCount()
    }

    class LCDScreen {
        +String medicineName
        +Date expirationDate
        +void displayInfo()
    }

    class Speaker {
        +void announceInfo(String info)
    }

    class VibrationMechanism {
        +void vibrate()
    }

    class ImageProcessor {
        +void processBarcode(String barcode)
    }

    class UltrasonicSensor {
        +int pillCount
        +void detectPillCount()
    }

    class Microcontroller {
        +void controlProcess()
    }

    SmartMedicineBox --> LCDScreen
```

SmartMedicineBox --> Speaker
SmartMedicineBox --> VibrationMechanism
SmartMedicineBox --> ImageProcessor
SmartMedicineBox --> UltrasonicSensor
SmartMedicineBox --> Microcontroller

3.3. Sequence Diagram

This diagram shows how objects interact in a particular scenario of the system.

sequenceDiagram
participant User
participant SmartMedicineBox
participant LCDScreen
participant Speaker
participant VibrationMechanism
participant ImageProcessor
participant UltrasonicSensor
participant Microcontroller

User ->> SmartMedicineBox: Request Medicine Info
SmartMedicineBox ->> ImageProcessor: Process Barcode
ImageProcessor ->> SmartMedicineBox: Return Medicine Info
SmartMedicineBox ->> LCDScreen: Display Medicine Info
SmartMedicineBox ->> Speaker: Announce Medicine Info
SmartMedicineBox ->> UltrasonicSensor: Detect Pill Count
UltrasonicSensor ->> SmartMedicineBox: Return Pill Count
SmartMedicineBox ->> VibrationMechanism: Vibrate Compartment

3.4. Activity Diagram

This diagram represents the workflow of the system.

A[Start] --> B[Scan Barcode]
B --> C[Process Barcode]
C --> D[Display Medicine Info]
D --> E[Announce Medicine Info]
E --> F[Detect Pill Count]
F --> G[Vibrate Compartment]
G --> H[End]

3.5. Component Diagram

This diagram shows the organization and dependencies among the components of the system.

A[Smart Medicine Box] --> B[LCD Screen]
A --> C[Speaker]
A --> D[Vibration Mechanism]
A --> E[Image Processor]
A --> F[Ultrasonic Sensors]
A --> G[Microcontroller]

4. On the Design of the Critical Components of the Proposed Smart Medicine Box System

In the previous sections we have analysed the architecture and the major components of the proposed smart medicine box system. Out of these components the critical ones for the correct functionality of the system are two. Namely, the barcode detection and recognition system as well as the ultrasound sensors-based system for counting pills in the box.

4.1 The barcode detection and recognition subsystem design

To design a system for detecting and reading the barcode of a medicine, even within an environment with limited light, we create several detailed UML diagrams. These diagrams will cover again different aspects of the system, including use cases, class structure, sequence of operations, and component interactions.

4.1.1. Use Case Diagram

This diagram shows the interactions between the user and the system, highlighting the main functionalities.

A[User] -->|Interacts with| B[Barcode Detection System]
B --> C[Scan Barcode]
B --> D[Process Image]
B --> E[Read Barcode]
B --> F[Display Information]

4.1.2. Class Diagram

This diagram represents the structure of the system by showing its classes, attributes, methods, and relationships.

classDiagram
class BarcodeDetectionSystem {
+Camera camera
+ImageProcessor imageProcessor
+LightSensor lightSensor
+Display display
+void scanBarcode()
+void processImage()

```
    +void readBarcode()
    +void displayInfo()
}

class Camera {
    +void captureImage()
}

class ImageProcessor {
    +void enhanceImage()
    +void decodeBarcode()
}

class LightSensor {
    +int lightLevel
    +void detectLight()
}

class Display {
    +void showInfo(String info)
}

BarcodeDetectionSystem --> Camera
BarcodeDetectionSystem --> ImageProcessor
BarcodeDetectionSystem --> LightSensor
BarcodeDetectionSystem --> Display
```

4.1.3. Sequence Diagram

This diagram shows how objects interact in a particular scenario of the system.

```
sequenceDiagram
    participant User
    participant BarcodeDetectionSystem
    participant Camera
    participant ImageProcessor
    participant LightSensor
    participant Display

    User ->> BarcodeDetectionSystem: Start Scan
    BarcodeDetectionSystem ->> LightSensor: Detect Light Level
    LightSensor ->> BarcodeDetectionSystem: Return Light Level
    BarcodeDetectionSystem ->> Camera: Capture Image
    Camera ->> BarcodeDetectionSystem: Return Image
    BarcodeDetectionSystem ->> ImageProcessor: Enhance Image
    ImageProcessor ->> BarcodeDetectionSystem: Return Enhanced Image
    BarcodeDetectionSystem ->> ImageProcessor: Decode Barcode
    ImageProcessor ->> BarcodeDetectionSystem: Return Barcode Data
    BarcodeDetectionSystem ->> Display: Show Info
```

4.1.4. Activity Diagram

This diagram represents the workflow of the system.

```
A[Start] --> B[Detect Light Level]
B --> C[Capture Image]
C --> D[Enhance Image]
D --> E[Decode Barcode]
E --> F[Display Information]
F --> G[End]
```

4.1.5. Component Diagram

This diagram shows the organization and dependencies among the components of the system.

```
graph TD
    A[Barcode Detection System] --> B[Camera]
    A --> C[Image Processor]
    A --> D[Light Sensor]
    A --> E[Display]
```

4.2 Detailed Description of Components

- **Camera**: Captures images of the barcode. It may include features to adjust exposure based on light levels detected by the light sensor.
- **Image Processor**: Enhances the captured image to improve barcode readability. This may involve noise reduction, contrast adjustment, and other image processing techniques.
- **Light Sensor**: Detects the ambient light level inside the box. If the light level is low, the system can adjust the camera settings or use additional lighting to ensure a clear image.
- **Display**: Shows the decoded information from the barcode, such as the medicine name and expiration date.

4.3 The ultrasound sensors-based system for counting pills in the box.

Here are the detailed UML diagrams for the design of an ultrasound sensors-based system for counting pills in a medicine box:

4.3.1. Use Case Diagram

This diagram shows the interactions between the user and the system, highlighting the main functionalities.

```
A[User] -->|Interacts with| B[Ultrasound Pill Counting System]
B --> C[Count Pills]
B --> D[Display Pill Count]
B --> E[Alert Low Stock]
```

4.3.2. Class Diagram

This diagram represents the structure of the system by showing its classes, attributes, methods, and relationships.

```
classDiagram
class UltrasoundPillCountingSystem {
+UltrasoundSensor[] sensors
+Display display
+Microcontroller microcontroller
+void countPills()
+void displayPillCount()
+void alertLowStock()
}

class UltrasoundSensor {
+int pillCount
+void detectPills()
}

class Display {
+void showPillCount(int count)
+void showAlert(String message)
}

class Microcontroller {
+void controlProcess()
+void processSensorData()
}

UltrasoundPillCountingSystem --> UltrasoundSensor
UltrasoundPillCountingSystem --> Display
UltrasoundPillCountingSystem --> Microcontroller
```

4.3.3. Sequence Diagram

This diagram shows how objects interact in a particular scenario of the system.

```
sequenceDiagram
participant User
participant UltrasoundPillCountingSystem
participant UltrasoundSensor
participant Microcontroller
participant Display

User ->> UltrasoundPillCountingSystem: Start Counting
UltrasoundPillCountingSystem ->> UltrasoundSensor: Detect Pills
UltrasoundSensor ->> UltrasoundPillCountingSystem: Return Pill Count
UltrasoundPillCountingSystem ->> Microcontroller: Process Sensor Data
Microcontroller ->> UltrasoundPillCountingSystem: Return Processed Data
UltrasoundPillCountingSystem ->> Display: Show Pill Count
UltrasoundPillCountingSystem ->> Display: Show Alert (if low stock)
```

4.3.4. Activity Diagram

This diagram represents the workflow of the system.

```
A[Start] --> B[Detect Pills]
B --> C[Process Sensor Data]
C --> D[Display Pill Count]
D --> E[Check Stock Level]
E --> F[Alert Low Stock]
F --> G[End]
```

4.3.5. Component Diagram

This diagram shows the organization and dependencies among the components of the system.

```
A[Ultrasound Pill Counting System] --> B[Ultrasound Sensor]
A --> C[Microcontroller]
A --> D[Display]
```

4.4.Detailed Description of Components

- **Ultrasound Sensor**: Detects the number of pills in each compartment by emitting sound waves and measuring the time it takes for the echoes to return. This data is used to calculate the pill count.
- **Microcontroller**: Controls the overall process, including initiating the pill detection, processing the sensor data, and managing the display and alert functions.
- **Display**: Shows the current pill count and alerts the user if the stock is low. It provides a user-friendly interface for interacting with the system.

5. Conclusion and Future Work

The herein research develops in detail the design of a novel smart medicine box system architecture proposal identifying all functionalities and components after presenting the state-of-the-art systems and in comparison, with them. Although this research project is in IoTs first steps implementation, the potential is high for a high-level efficient system. The main function of the Smart Medicine Box is to announce the name and date of expiration of the medication being taken by the visually challenged and old aged patients. The vibration sensor installed inside the Smart Medicine Box helps in guiding the patient to take the correct medication; it also ensures that the patient takes their medication on time. GSM is used to send notifications to the patient's caretaker to notify them regarding the status of the pill. Although the implementation of the proposed system is in the final stage of a prototype, the detailed evaluations will follow hopefully very soon. In any case the scope of the present research effort is to present in detail the design of such a novel medicine box system, in terms of architecture, components analysis and the UML relevant diagrams.

The future scope of this project, apart from the extensive evaluation of its performance, could include more critical functionalities. More precisely, it could ensure that, with the use of motion sensor technology to open the compartment containing the medication with a simple "wave" motion of the patient's hand. This could ensure that the visually impaired patient need not struggle with opening the medication box manually. The Smart Medicine Box can also contain Reed switches on the latches of each compartment, this can be used to send notification to the caretaker upon opening of the medication box. This assists the caretaker to know if the patient took their medication on time or not.

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