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Enhancing Patient Care with the IoT-Enabled Smart Med Box: A New Era of Medication Adherence

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Abstract: The Smart Med Box is an innovative Internet of Things (IoT)-enabled device designed to enhance medication management and adherence among patients, particularly those with complex health needs. By combining automated dispensing with real-time monitoring, the Smart Med Box ensures timely and accurate medication intake. It integrates sensors and connectivity features to track dosage, send reminders to patients, and alert caregivers or healthcare providers in case of missed doses. This makes it ideal for elderly patients, individuals with chronic illnesses, and those requiring post-operative care or strict medication regimens. The device supports improved adherence, reducing the risk of complications from missed medications and enhancing overall patient outcomes. Additionally, the Smart Med Box leverages data analytics to provide insights into patient behaviour, enabling personalized care plans. Its user-friendly interface allows for easy setup and use, making it a vital tool in remote patient monitoring and home-based healthcare solutions. As an IoT-driven solution, in the field of digital health, the Smart Med Box represents a significant advancement, promoting safer, more efficient, and patient-centered care.

Keyword: *IoT, Smart Med Box, Patient Care and Medication Adherence.*

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I. INTRODUCTION

Maintaining continuous medication adherence is still a major healthcare concern in the fast-paced world of today. Poor health outcomes, particularly for people managing chronic diseases, can result from missed doses, incorrect intake, and delayed refills. Innovative solutions like the Smart Med Box—an intelligent, Internet of Things-enabled gadget intended to enhance medication management—have been made possible by the growth of the Internet of Things (IoT). In addition to reminding patients to take their medications as directed, this gadget tracks adherence habits and gives carers and medical professional's real-time reports. The Smart Med Box lowers the risk of medical mistakes, promotes proactive treatments, and improves patient participation by combining data analytics, remote monitoring, and an intuitive design. The potential of IoT-enabled drug management to transform patient care is examined in this presentation.

- *IoT Technology [3]:*

IoT (Internet of Things) technology refers to devices that connect to the internet and communicate with each other to share data. For the Smart Med Box, IoT allows it to sync with smartphones, send real-time notifications, track medication usage, and alert caregivers remotely. This ensures patients get reminders and their health is monitored, even when caregivers aren't physically present.

In short, IoT makes the Smart Med Box smarter by enabling connectivity and seamless monitoring from anywhere.[3 & 5]

- *Smart Med Box: [4]*

Presenting the Smart Med Box, your very own Internet of Things-enabled pharmaceutical helper. This cutting-edge gadget guarantees that you never miss a dosage and is made to benefit everyone, including the elderly, busy professionals, and those who are blind or hard of hearing. Managing your health has never been simpler thanks to customizable alarms,

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real-time carer updates, and easy smartphone connectivity. The Smart Med Box makes it easy, dependable, and accessible for everyone to take their medications as prescribed.

Fig 1 The Smart Med Box

II. LITERATURE REVIEW

➢ *Medication Adherence in Healthcare*

Medication non-adherence remains a persistent issue, especially in chronic disease management. According to the World Health Organization (WHO), only 50% of patients with chronic illnesses in developed countries adhere to treatment recommendations. Studies indicate that non-adherence contributes to approximately 125,000 deaths annually in the United States alone.

➢ *IoT in Healthcare*

The IoT has gained significant traction in healthcare over the last decade. Wearable devices, smart sensors, and connected platforms allow real-time data transmission, enabling health professionals to remotely monitor patients and personalize care. IoT technology has been used for remote patient monitoring, chronic disease management, and telemedicine. However, its application in medication adherence is still emerging.

➢ *Smart Medication Systems*

Several technological interventions have aimed to address non-adherence. Smart pill bottles, for instance, can track whether a patient has taken their medication. However, these solutions often fail to account for factors such as forgetfulness, confusion over medication schedules, or limited access to caregivers. The Smart Med Box aims to overcome these limitations by providing a comprehensive adherence solution.

A. Difference Between Traditional Smart Med Box vs IoT Enabled Smart Med Box: [5 &6]

The traditional Smart Med Box and the IoT-enabled Smart Med Box both aim to help patients manage their medication schedules more effectively, but they differ significantly in terms of functionality, connectivity, and overall capabilities. Below is a comparison of the two:

➢ *Connectivity and Real-Time Data Monitoring*

- *Traditional Smart Med Box:*

A traditional smart med box may offer basic reminders through alarms or visual indicators to help patients take their medications on time. However, it generally does not connect to external systems or devices, limiting its ability to provide real-time monitoring or feedback. Users must manually input data or track their adherence themselves, and healthcare providers do not have direct access to the medication data unless the patient reports it.

- *IoT-Enabled Smart Med Box:*

The IoT-enabled version connects to the internet and uses wireless communication (Wi-Fi, cellular, or Bluetooth) to track medication usage in real-time. It automatically sends data to a cloud-based platform or mobile application, enabling healthcare providers and caregivers to monitor medication adherence remotely. This real-time feedback allows for timely interventions, such as reminders to the patient or alerts to the caregiver if a dose is missed.

➢ *Automation and Reminders*

- *Traditional Smart Med Box:*

Traditional smart med boxes often come with basic reminder functions, such as beeping at a certain time or flashing lights to signal when medication needs to be taken. The reminders are typically preset and require manual intervention to reset or adjust.

- *IoT-Enabled Smart Med Box:*

An IoT-enabled Smart Med Box automates much of the medication management process. It can be pre-programmed via a mobile app to dispense the right medication at the correct time. Reminders can be customized and sent to the patient's smartphone, smart watch, or even voice-activated

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home assistants. Additionally, the system can adjust reminders based on the patient's adherence patterns, providing dynamic and adaptive scheduling.

➢ *Data Analytics and Reporting*

- *Traditional Smart Med Box:*

Traditional versions may have basic data storage capabilities, such as logging when the box was opened, but this data typically stays local to the device and must be manually retrieved (if at all). There is limited or no capacity for advanced data analytics.

- *IoT-Enabled Smart Med Box:*

In an IoT-enabled system, data is collected continuously and analyzed using cloud-based software. Healthcare providers can access detailed reports on the patient's medication habits, adherence trends, and potential risks of non-compliance. Some systems can also incorporate artificial intelligence (AI) to predict future adherence behaviors based on historical data.

➢ *Integration with Healthcare Systems*

- *Traditional Smart Med Box:*

These devices usually function independently and are not integrated into broader healthcare systems. Patients must manually share adherence information with healthcare professionals during visits, which may lead to delays in addressing non-adherence issues.

- *IoT-Enabled Smart Med Box:*

IoT devices are designed to integrate seamlessly with electronic health records (EHRs) and telemedicine platforms. This allows healthcare personnel to monitor patients remotely and intervene as needed, resulting in a more proactive approach to drug management. For instance, doctors can adjust medication regimens based on real-time data, and pharmacies can be alerted to renew prescriptions automatically.

➢ *Patient-Caregiver Interaction*

- *Traditional Smart Med Box:*

The interaction between patients and caregivers is limited. Caregivers may need to visit the patient physically or rely on the patient's self-reporting of medication adherence, which can lead to gaps in information and delayed interventions.

- *IoT-Enabled Smart Med Box:*

In an IoT-enabled system, caregivers can receive instant notifications if the patient misses a dose or if the device encounters an issue. Caregivers can also remotely monitor adherence through a web or mobile dashboard, providing continuous support without needing to be physically present. This real-time interaction strengthens the support system around the patient and ensures prompt assistance when needed.

➢ *Security and Privacy*

- *Traditional Smart Med Box:*

Traditional devices pose little risk of data breaches as they usually don't connect to external networks. However, this also means they offer fewer protections for data sharing, as patients must manually communicate their adherence details to healthcare providers.

- *IoT-Enabled Smart Med Box:*

IoT-enabled devices are subject to stringent security and privacy concerns due to their network connectivity and data transmission. "These devices must adhere to regulations like the Health Insurance Portability and Accountability Act (HIPAA) to ensure patient data is encrypted, stored securely, and only accessible to authorized personnel".

Proper authentication mechanisms, such as multi-factor authentication, are often incorporated to protect sensitive health data.

➢ *Adaptability and Scalability*

- *Traditional Smart Med Box:*

Traditional med boxes are often limited in their ability to scale or adapt to changes in the patient's medication regimen. Adjustments may require manual reprogramming or reconfiguration, which can be cumbersome for both patients and caregivers.

- *IoT-Enabled Smart Med Box:*

These systems are highly adaptable and can be scaled to fit the needs of different patient populations. For instance, dosage adjustments can be made remotely through the companion app, and the system can be integrated with other IoT devices, such as wearable health monitors, to provide a holistic approach to patient care.

Table 1 Summary of Key Differences[8]

Feature	Traditional Smart Med Box	IoT-Enabled Smart Med Box
Connectivity	No network connectivity	Internet-connected, real-time data transmission
Reminders	Basic alarms, visual indicators	Automated, customizable reminders via apps, devices, etc.
Data Collection and Reporting	Limited, local data collection	Real-time data analytics and cloud-based reporting
Integration	No integration with healthcare systems	Integrated with EHRs, telemedicine, and pharmacy systems

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Caregiver Interaction	Manual reporting, in-person interaction required	Real-time alerts and monitoring for caregivers
Security	Minimal data security concerns	Requires encryption, compliance with healthcare regulations
Scalability	Limited adaptability	Highly scalable and customizable

➢ *Parts of IoT Enabled Smart Med Box:* [1, 2, 5, 7, 15 &17]

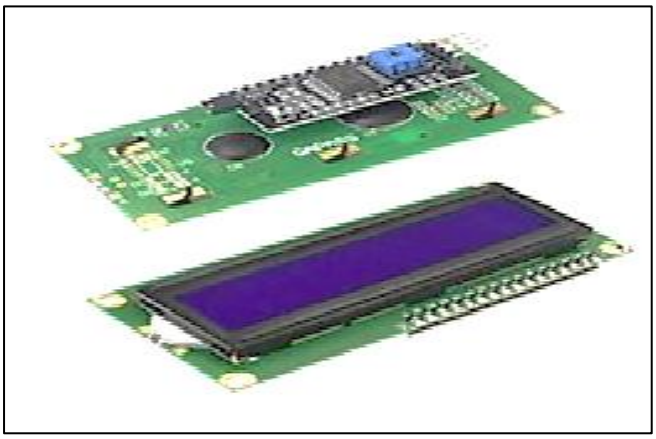

Fig 2 12 C LCD Interface Display

Fig 3 Breadboard Power Supply

Fig 4 Micro Servo Motor

B. Medication Dispensing Unit [9, 10 & 11]

This is the central component responsible for storing and dispensing medications at predefined times. It typically consists of:

➢ *Compartments/Slots:*

The medication dispensing unit includes multiple compartments to store different types of medications. Each compartment can be preloaded with the appropriate pills, capsules, or tablets required for a patient's treatment regimen. The number of compartments may vary depending on the design and the patient's medication complexity.

➢ *Automated Dispensing Mechanism:*

A motorized mechanism automatically dispenses the correct dosage at the scheduled time. The system is preprogramed via a mobile app or healthcare provider, ensuring that the correct type and amount of medication is dispensed.

➢ *Sensors:*

Embedded sensors detect whether the correct medication has been dispensed, if the compartment is empty, and if the box has been opened or closed by the patient. These sensors ensure accurate tracking of medication intake.

C. Communication and Connectivity Module [12]

The IoT-enabled Smart Med Box must communicate with external devices and networks to transmit data and receive updates. Key components include:

➢ *Wi-Fi/Cellular/Bluetooth Module:*

The box comes equipped with wireless communication technology (Wi-Fi, cellular, or Bluetooth) to connect to the internet or local devices. This module allows the med box to transmit adherence data to cloud servers or healthcare systems, enabling real-time monitoring. It can also connect to smartphones, tablets, or wearable for notifications and interaction.

➢ *SIM Card Slot (Optional):*

Some Smart Med Boxes may include a SIM card slot for cellular connectivity, allowing it to work in areas without Wi-Fi. This feature is useful for patients living in remote locations or those who frequently travel.

➢ *Cloud-Based Data Storage and Processing* [13 & 14]

This component is part of the IoT infrastructure and operates on the cloud, not directly inside the physical Smart Med Box. However, it is a crucial element of the system:

➢ *Cloud Servers:*

All medication adherence data, including dosage times, patient interaction, and missed doses, is uploaded to a secure cloud platform. This data is stored and can be accessed by

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healthcare professionals, caregivers, or the patient themselves via mobile apps or web portals.

➢ *Data Analytics:*

Advanced analytics tools running on the cloud help analyze medication adherence patterns. These tools can identify non-compliance trends, predict adherence issues, and trigger personalized interventions when needed. The data is also used to generate reports for healthcare providers.

D. Mobile Application (User Interface) [14]

The mobile app is the interface through which patients interact with the Smart Med Box. It provides several functions:

➢ *Medication Reminders:*

Patients receive notifications through the app when it's time to take their medication. These reminders can be customized based on the user's schedule and preferences (e.g., push notifications, SMS alerts, or alarms).

➢ *Adherence Tracking:*

The app displays detailed reports of the patient's adherence, showing how many doses were taken, missed, or delayed. This information is visually represented to help users keep track of their progress.

➢ *Remote Control:*

Patients or caregivers can adjust medication schedules, refill reminders, and dosage instructions through the app. This remote functionality reduces the need for manual intervention at the device itself.

➢ *Integration with Wearable:*

The mobile app can also connect with wearable health devices (e.g., smart watches or fitness bands) to provide additional feedback, such as reminders through vibrations or haptic feedback.

E. Web Portal for Healthcare Providers [15]

Healthcare providers need a dedicated interface to monitor their patients remotely. This component often consists of:

➢ *Dashboard View:*

A web-based dashboard allows healthcare professionals to view adherence data from multiple patients in real time. The dashboard provides summaries, alerts, and detailed medication histories.

➢ *Alerts and Notifications:*

If a patient misses a dose or exhibits a pattern of non-adherence, healthcare providers are notified. This allows them to intervene quickly, either by adjusting medication regimens or by contacting the patient.

➢ *Patient Management Tools:*

The web portal enables providers to set up medication plans, adjust dosages remotely, and manage multiple patients simultaneously. It also facilitates communication between doctors, pharmacists, and caregivers.

F. Sensor Array for Monitoring [15]

The Smart Med Box relies on a variety of sensors to monitor patient interactions and ensure correct medication intake. Key sensors include:

➢ *Weight Sensors:*

These sensors measure the weight of medication before and after each dosage. They can confirm whether the patient has taken the correct dose or if the medication remains in the compartment.

➢ *Optical Sensors:*

These detect when the medication tray or drawer is opened and closed, ensuring that the medication is accessed at the right time. Optical sensors can also verify whether the correct compartment is accessed.

➢ *Pill Counting Sensors (Optional):*

Some advanced Smart Med Boxes use pill-counting sensors that measure the exact number of pills dispensed, providing an additional layer of adherence tracking.

G. Battery and Power Management System [15]

Power supply and efficient energy management are critical for the continuous operation of the IoT-enabled Smart Med Box:

➢ *Rechargeable Battery:*

The device is powered by a rechargeable lithium-ion battery, which ensures that the Smart Med Box can function during power outages. The battery life can vary depending on the features and frequency of use, but the device typically alerts users when it's time to recharge.

➢ *Power Adapter:*

In addition to battery operation, the Smart Med Box is equipped with a power adapter for constant use while connected to an electrical outlet.

➢ *Battery Status Monitoring:*

The Smart Med Box's app or display unit often includes a battery status indicator to notify the user when the battery is low and needs charging.

H. Audio-Visual Feedback

To enhance user interaction and alert patients, the Smart Med Box is equipped with audio and visual feedback mechanisms:

- *LED Indicators:*

The device includes LED lights to signal different statuses (e.g., medication due, box opened, missed dose). Color-coded LEDs provide simple, intuitive visual alerts to the user.

- *Speakers for Audio Reminders:*

Audio reminders, such as beeps or voice prompts, are built into the device to alert patients when it's time to take their medication. Some advanced systems may offer customizable voices or tones.

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I. Security System

Ensuring the security of patient data and protecting the integrity of the system is vital for IoT devices. The Smart Med Box includes various security features:

- *Encryption:*

All data transmitted between the Smart Med Box and the cloud is encrypted using secure protocols such as TLS (Transport Layer Security) to protect patient privacy.

- *Access Control:*

Patients, caregivers, and healthcare professionals can only access the system through authenticated logins. Multi-factor authentication (MFA) may be used to ensure that only authorized users can modify medication schedules or view adherence data.

- *Tamper Detection (Optional):*

Some models feature tamper-detection mechanisms that alert healthcare providers or caregivers if the device is being manipulated improperly, ensuring the integrity of medication storage.

J. Display Unit (Optional)

Some Smart Med Boxes are equipped with a small screen or display unit that provides real-time information to the patient:

➢ *LCD/LED Display:*

The display shows the time, next scheduled dose, medication instructions, or any other important information. It helps patients by providing at-a-glance details about their medication regimen.

➢ *Touchscreen Interface (Optional):*

Advanced models may have touchscreen displays where users can manually interact with the device, adjust settings, or view their adherence history.

Table 2 Summary of IoT-Enabled Smart Med Box Components[16]

Component	Function
Medication Dispensing Unit	Automates storage and dispensing of medications based on a predefined schedule.
Communication Module	Wireless communication facilitates real-time data transfer and remote control.
Cloud-Based Data System	Stores, processes, and analyses adherence data, accessible by healthcare providers.
Mobile Application	Provides reminders, tracks adherence, and allows users to adjust medication schedules remotely.
Web Portal	Offers healthcare providers tools to monitor and manage patient adherence.
Sensor Array	Monitors medication use through weight, optical, and pill-counting sensors.
Battery and Power System	Ensures uninterrupted operation with rechargeable batteries and power management.
Audio-Visual Feedback	Provides audio and visual alerts for medication reminders and status notifications.
Security System	Protects data through encryption, access control, and tamper detection.
Display Unit	Offers real-time information on medication schedules and adherence (optional touchscreen).

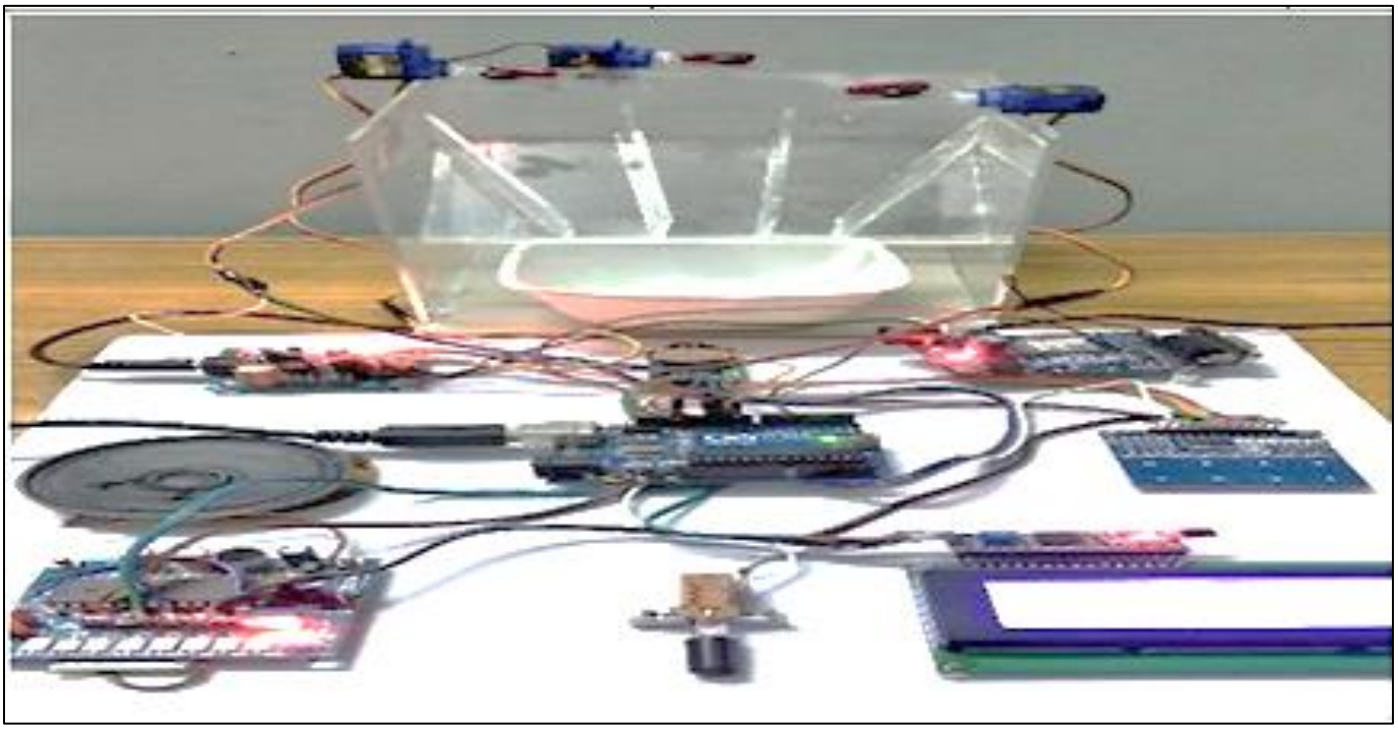

Fig 5 Proposed Model

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➢ *IoT Enabled Smart Med Box for Some Category Patients: 16, 17 & 18*

- Blind Patient
- Deaf Patient or Hearing Loss Patient
- Deaf Blind Patient
- Women's with different Disabilities
- Old Patients

➢ *Blindness in India:*

According to data from the National Programme for Control of Blindness (NPCB) and the World Health Organization (WHO):

India's blind population is estimated to be around 12 million people, accounting for approximately 20% of the world's blind population.

The prevalence of blindness in India is around 1.1% of the total population, with major causes being cataracts, glaucoma, and corneal blindness.

➢ *Deafness in India:*

Based on data from the World Health Organization (WHO) and studies by the All India Institute of Speech and Hearing (AIISH):

An estimated 63 million people in India suffer from significant hearing loss (including both partial and complete deafness).

The prevalence of severe hearing impairment is around 6.3% of the total population.

➢ *Approximate Ratio:*

Given these estimates, we can calculate the approximate ratio of blind patients to deaf patients in India:

- Blind Population: 12 million
- Deaf Population: 63 million

The approximate ratio of blind to deaf patients in India is: 12 million: 63 million or approximately 1: 5 (1 blind patient for every 5 deaf patients).

➢ *Elderly Population (Old Patients) in India:*

According to data from the Census of India and various demographic studies:

The elderly population (aged 60 years and above) in India was estimated to be around 138 million as of 2021, representing about 10.1% of the total population.

This number is projected to increase significantly due to the aging population trend in India.

➢ *Deaf-Blind Population in India:*

Deaf-blindness is a rare condition involving both significant hearing and vision loss. The exact prevalence of deaf-blindness is difficult to determine due to varying definitions and underreporting. However:

According to estimates by Sense International India, an organization working for people with deaf-blindness, the number of deaf-blind individuals in India is estimated to be 400,000 to 500,000 people.

This number includes individuals with both congenital and acquired deaf-blindness.

➢ *Approximate Ratio:*

Using these estimates, we can calculate the approximate ratio of,

Old patients (people aged 60 and above) to deaf-blind patients in India:

Old Patients: 138 million

Deaf-Blind Patients: 0.4 to 0.5 million (400,000 to 500,000)

The approximate ratio of old patients to deaf-blind patients in India is: 138 million: 0.5 million or approximately 276: 1 (for every 276 elderly people, there is 1 deaf-blind person).

III. WOMEN WITH DIFFERENT DISABILITIES

A Smart Med Box can be a critical tool for ensuring medication adherence for women dealing with various health conditions, especially those that require regular and precise medication management. Here are several categories of conditions where women might benefit from using a Smart Med Box for effective medication adherence:

➢ *Chronic Conditions*

For chronic illnesses that require long-term treatment, consistent medication adherence is crucial. Women with the following chronic conditions can greatly benefit from a Smart Med Box:

- *Diabetes:*

Women with Type 1 or Type 2 diabetes often need to manage multiple medications, including insulin, oral hypoglycaemic, and related treatments. A Smart Med Box can help ensure timely medication intake and even integrate with blood glucose monitoring devices.

- *Hypertension (High Blood Pressure):*

Women with hypertension may need multiple antihypertensive medications daily. A Smart Med Box ensures timely reminders to avoid complications such as stroke, heart attack, or kidney damage.

- *Asthma:*

Women with asthma often require regular use of inhalers, corticosteroids, or other medications. A Smart Med Box can help track adherence and remind the user to take preventive medications.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec1601

- *Heart Disease:*

Women with heart conditions like coronary artery disease, heart failure, or arrhythmias often require daily medication. The Smart Med Box can help manage complex drug regimens and ensure correct dosing to prevent heart attacks, strokes, or worsening of heart conditions.

➢ *Hormonal and Reproductive Health*

Women's reproductive health often requires strict adherence to medication schedules, especially in these cases:

- *Hormone Replacement Therapy (HRT):*

Post-menopausal women or those undergoing treatment for conditions like polycystic ovary syndrome (PCOS) or endometriosis may require hormone medications. A Smart Med Box can assist in taking HRT medications at the right time.

- *Contraceptive Pills:*

Women using birth control pills must take them daily at the same time to ensure effectiveness. A Smart Med Box can provide reminders and prevent missed doses that could lead to unintended pregnancy.

- *Fertility Treatments (IVF):*

Women undergoing fertility treatments often need to take medications like gonadotropins, progesterone, or other hormone-related drugs on a precise schedule. A Smart Med Box can help manage these time-sensitive regimens.

- *Postpartum Depression or Perinatal Care:*

New mothers experiencing postpartum depression may be prescribed antidepressants or other medications. A Smart Med Box can remind patients to take their medication amidst the challenges of new motherhood.

➢ *Mental Health Disorders*

Mental health conditions often require strict adherence to medication for effective management. For women dealing with these disorders, a Smart Med Box can provide essential support.

- *Depression:*

Women with major depressive disorder or persistent depressive disorder (dysthymia) often need daily antidepressants. A Smart Med Box can remind them to take their medication and provide data on adherence for healthcare providers.

- *Anxiety Disorders:*

Women with anxiety disorders, such as generalized anxiety disorder (GAD) or panic disorder, may need regular medication, including SSRIs or benzodiazepines. A Smart Med Box can ensure regular dosing to avoid anxiety spikes or withdrawal symptoms.

- *Bipolar Disorder:*

Women with bipolar disorder may be prescribed mood stabilizers, antipsychotics, or antidepressants. Managing these medications, often with complex dosages, requires strict adherence, which a Smart Med Box can help facilitate.

- *Schizophrenia:*

Women with schizophrenia who need antipsychotic medications to manage symptoms like hallucinations or delusions must adhere to a strict medication regimen. The Smart Med Box can ensure they take medications as prescribed.

➢ *Autoimmune Disorders*

Women are disproportionately affected by many autoimmune disorders, and managing these conditions often involves multiple medications:

- *Rheumatoid Arthritis:*

Women with rheumatoid arthritis often need disease-modifying antirheumatic drugs (DMARDs) and biologics. Adherence to these medications is critical for controlling symptoms and preventing joint damage.

- *Lupus (Systemic Lupus Erythematous - SLE):*

Women with lupus typically require a combination of medications, including corticosteroids, immunosuppressant's, and antimalarial. A Smart Med Box can help ensure that the patient follows the correct dosing schedule to manage flares and reduce long-term complications.

- *Multiple Sclerosis (MS):*

Women with MS may need medications to reduce the frequency of relapses or slow disease progression. Timely medication intake, such as disease-modifying therapies, is critical and can be supported with a Smart Med Box.

➢ *Cancer Treatment*

Cancer treatment often involves multiple medications, including chemotherapy, hormone therapy, and supportive care drugs. For women undergoing cancer treatment, a Smart Med Box can be essential,

- *Breast Cancer:*

Women with breast cancer undergoing chemotherapy, hormone therapy (e.g., tamoxifen), or immunotherapy require precise medication schedules. The Smart Med Box can ensure these are followed to optimize treatment outcomes.

- *Ovarian or Cervical Cancer:*

Women with ovarian or cervical cancer undergoing chemotherapy or targeted therapies need strict adherence to medication schedules. A Smart Med Box can help manage these regimens and monitor side effects.

- *Post-Cancer Maintenance Therapy:*

Women in remission from cancers may need ongoing medications, such as hormone therapy, to prevent recurrence. Consistent adherence is vital, and the Smart Med Box can provide reminders.

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➢ *Neurological Disorders*

Certain neurological disorders can make it difficult for women to manage their medication schedules, making a Smart Med Box particularly useful:

- *Parkinson's Disease:*

Women with Parkinson's need consistent medication to manage symptoms like tremors and stiffness. A Smart Med Box ensures they receive the correct dosage of medications like levodopa at the right times.

- *Alzheimer's Disease and Dementia:*

Women with dementia or Alzheimer's often struggle to remember when to take their medications. A Smart Med Box can automate the process, reducing the burden on caregivers and improving patient outcomes.

- *Epilepsy:*

Women with epilepsy need strict adherence to anti-seizure medications to prevent seizures. A Smart Med Box can help ensure consistent medication intake.

➢ *Infectious Diseases*

Certain infectious diseases require long-term treatment, where adherence to medication is crucial:

- *HIV/AIDS:*

Women with HIV/AIDS require daily antiretroviral therapy (ART) to manage the virus. Missing doses can lead to drug resistance or viral load increases, making a Smart Med Box essential to ensure adherence.

- *Tuberculosis (TB):*

Women undergoing treatment for TB often need to take antibiotics for 6-9 months. A Smart Med Box can help prevent missed doses, reducing the risk of drug resistance.

- *Post-Surgical Recovery*

After major surgery, women may need to follow strict medication schedules to prevent infection, manage pain, or reduce complications:

- *Post-Surgical Medications:*

Pain relievers, anticoagulants, and antibiotics are often prescribed after surgery. A Smart Med Box can help patients adhere to these medication schedules, particularly if they are complex or involve multiple drugs.

➢ *Substance Use Disorder Recovery*

Women in recovery from substance use disorders may need medications to manage withdrawal symptoms or prevent relapse:

- *Opioid Use Disorder (OUD):*

Women undergoing treatment for opioid use disorder may require medications like methadone or buprenorphine. A Smart Med Box can help ensure these medications are taken as prescribed to reduce cravings and prevent relapse.

- *Alcohol Use Disorder (AUD):*

Medications like naltrexone or acamprosate, used in the treatment of alcohol use disorder, need to be taken regularly to prevent relapse. A Smart Med Box can support adherence to these medications.

➢ *Postmenopausal Osteoporosis*

Women with osteoporosis, particularly postmenopausal women, may need long-term medications to prevent bone fractures:

- *Bisphosphonates:*

Medications like alendronate are often prescribed to prevent bone loss. A Smart Med Box can ensure these are taken at the correct intervals, as some require weekly or monthly dosing.

- *Calcium and Vitamin D Supplements:*

To manage osteoporosis, women often need daily calcium and vitamin D supplements. A Smart Med Box can ensure consistent intake, reducing the risk of fractures.

➢ *IoT Enabled Smart Med Box Working:* [19,20,21,22 & 23]

The IoT-Enabled Smart Med Box is designed to improve medication adherence by leveraging Internet of Things (IoT) technology. It combines various sensors, connectivity features, and automation to ensure patients take their medications correctly and on time. Here's a detailed explanation of how it works.

➢ *Components of IoT-Enabled Smart Med Box:*

- *Smart Compartments:*

The med box contains multiple compartments, each designated for specific medications.

These compartments can be programmed to open automatically at specific times based on the patient's medication schedule.

Each compartment may have an electronic lock that only opens when it's time to take the medication.

- *Sensors:*

✓ *Weight Sensors:*

Measure the amount of medication inside each compartment and detect when pills are removed. This helps track if the patient has taken the right dose.

✓ *Proximity/Cap Sensors:*

Detect whether the compartment has been opened or closed. If the box is opened but no pills are taken, the system can send an alert.

✓ *Optical Sensors:*

Can be used to detect if pills are present in the compartments or to ensure the correct medication is being dispensed.

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- *Connectivity (IoT Integration):*

The box is connected to the internet using Wi-Fi or Bluetooth, enabling real-time communication with other devices (smartphones, tablets, etc.) and cloud-based servers.

Mobile App Integration: The patient or caregiver can manage medication schedules via an app.

➢ *This App can be Used to:*

- Set reminders.
- Receive alerts when medications are missed.
- Monitor adherence through a visual dashboard.
- Receive updates on medication stock levels.
- Notification and Reminder System:
- Audible Alarms: When it's time to take a medication, the box can sound an alarm to notify the patient.
- Visual Indicators: LED lights can indicate which compartment to open or blink when medication is due.
- Push Notifications/Alerts: Notifications are sent to the patient's or caregiver's phone if a medication is missed or not taken correctly.
- Cloud-Based Data Storage and Analytics:
- The med box sends data (e.g., when and which medication was taken) to a cloud server.
- Doctors and caregivers can access this data to monitor the patient's adherence and adjust treatment plans if needed.
- Data analytics can be used to track patterns in medication adherence and provide insights into a patient's behaviour.
- Automatic Refills and Stock Monitoring:
- The med box monitors medication levels through weight or optical sensors.
- It can notify the patient or pharmacy when medication is running low, enabling automatic refill requests through the integrated app.
- Emergency and Remote Support:
- If a patient consistently misses doses, the system can trigger alerts to family members or caregivers.
- The med box may include an emergency button that patients can press to contact caregivers or healthcare professionals if they are experiencing side effects or have questions about their medications.

IV. WORKING PROCESS OF IOT-ENABLED SMART MED BOX: [24 & 25]

➢ *Initial Setup and Prescription Entry:*

The patient's medication schedule is programmed into the Smart Med Box via a mobile app or web portal. This includes information like,

- Names of medications.
- Dosage amounts.
- Frequency and timing of doses.
- Each compartment of the med box is filled with the corresponding medications.

➢ *Medication Dispensing:*

At the scheduled time, the Smart Med Box activates the appropriate compartment, which either unlocks or opens automatically.

A reminder (via alarm, notification, or light) alerts the patient that it's time to take their medication.

The patient removes the medication from the compartment, and sensors detect whether the medication was taken (based on weight change or pill detection).

➢ *Monitoring and Alerts:*

If the medication is not taken within a set time (e.g., 30 minutes after the reminder), the med box sends a notification to the patient's phone and/or caregivers.

Caregivers or healthcare providers can log in to a monitoring platform to check the patient's adherence and be alerted of any missed doses.

➢ *Real-Time Feedback and Data Analytics:*

The Smart Med Box continuously collects data on medication adherence, which is transmitted to the cloud in real-time.

Caregivers and healthcare providers can access this data to adjust prescriptions, identify trends (e.g., frequent missed doses), and improve overall care.

➢ *Refill Reminders and Integration with Pharmacies:*

When the med box detects low stock levels in any compartment, it can automatically notify the patient and, if configured, send a refill request to the pharmacy.

Some advanced systems may integrate directly with local pharmacies to manage prescription refills seamlessly.

➢ *End-to-End Medication Management:*

Through the IoT-enabled features, the Smart Med Box helps manage the entire medication process, from dispensing the right medication to tracking intake, sending alerts, and handling refills. The result is a seamless, reliable system for medication adherence.

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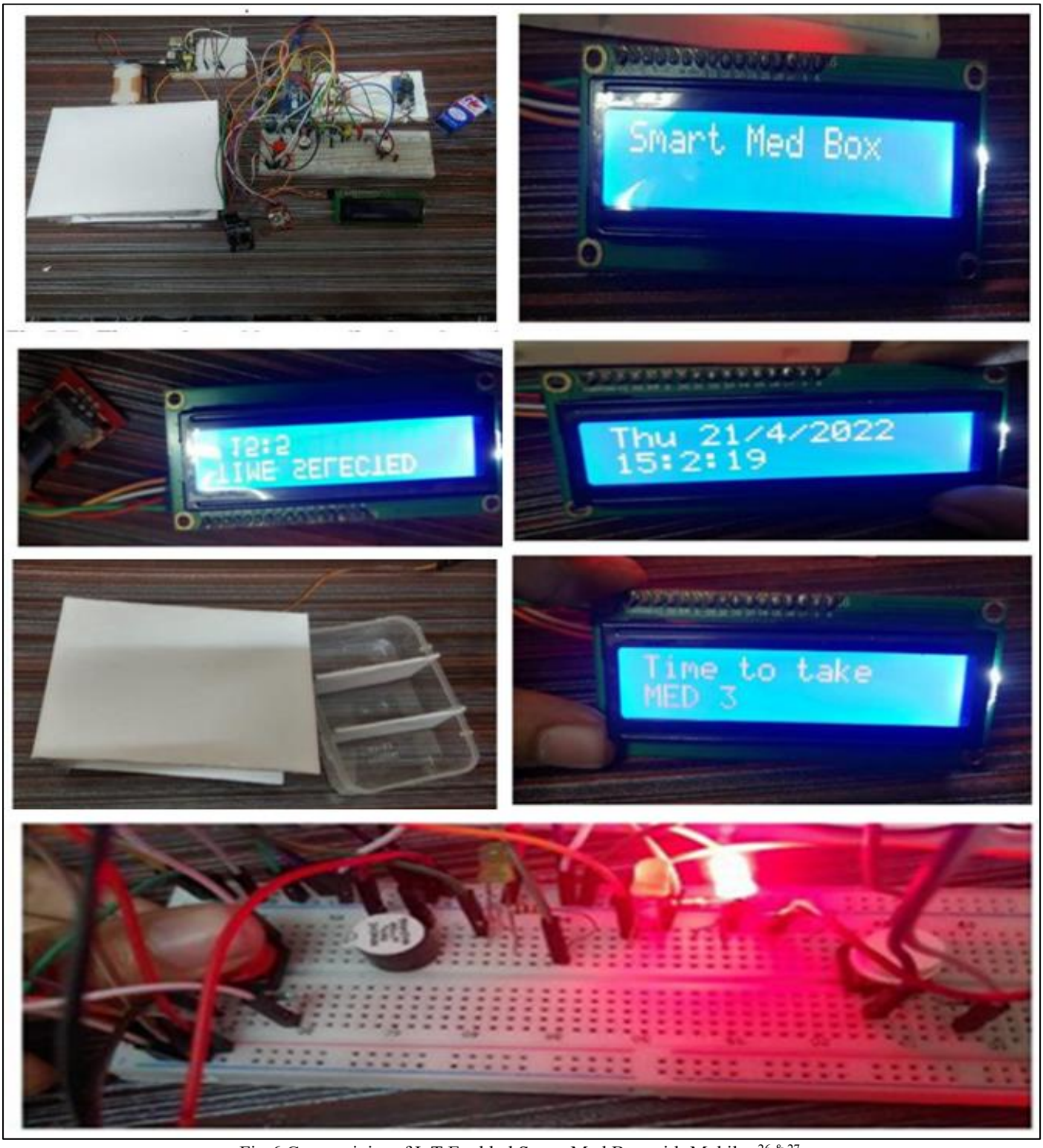

Fig 6 Connectivity of IoT Enabled Smart Med Box with Mobile: [26 & 27]

The IoT-Enabled Smart Med Box connects to a mobile device (smartphone or tablet) to provide real-time tracking, notifications, and control over medication schedules. This connectivity ensures seamless communication between the Smart Med Box and the patient or caregiver's mobile device, enhancing medication adherence and management. Here's a breakdown of how the connectivity between the IoT-enabled Smart Med Box and a mobile device works:

➢ *Wireless Connectivity Options* [26]

The IoT-enabled Smart Med Box typically uses one or more of the following wireless technologies to establish a connection with mobile devices:

- *Wi-Fi Connectivity:*

The Smart Med Box connects to the home Wi-Fi network, allowing it to communicate with the mobile app over the internet.

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This enables remote access to data and control from anywhere, as long as the mobile device has internet access (via Wi-Fi or cellular data).

Through Wi-Fi, the Smart Med Box can send real-time updates, notifications, and reminders to the mobile app.

- *Bluetooth Connectivity:*

Bluetooth is used for short-range, direct communication between the Smart Med Box and the mobile device.

This connection is typically used when both devices are within close proximity (within a few meters). Bluetooth Low Energy (BLE) may also be used to conserve power and maintain efficient communication between the devices.

- *Cellular Connectivity (Optional):*

Some advanced Smart Med Boxes may include a cellular modem, allowing them to communicate with mobile devices and the cloud without relying on home Wi-Fi.

This option is particularly useful in rural areas or places where Wi-Fi is unreliable.

➢ *Mobile App Integration* [26]

The Smart Med Box is controlled and monitored through a companion mobile application that is installed on the user's smartphone or tablet. The app acts as the interface for the user to interact with the Smart Med Box. Key features of the mobile app include:

- *User Interface (UI):*

The app provides a simple, user-friendly dashboard where users can view their medication schedules, doses, and reminders.

Visual elements (calendars, pill icons, timers) help users understand when to take their medications and which compartment contains the next dose.

- *Medication Management:*

The app allows users to input or update their medication schedule, including the type of medication, dosage, and timing.

It can also store prescription details provided by healthcare providers or pharmacists.

- *Reminders and Alerts:*

The app sends push notifications or text alerts to remind the patient when it's time to take their medication.

If a dose is missed, the app sends additional alerts, and it can escalate notifications to caregivers or family members.

- *Real-Time Monitoring:*

The app provides real-time updates from the Smart Med Box, displaying information such as:

✓ When the medication was taken (time, date).
✓ Any missed doses.
✓ Current stock of medications in each compartment.
✓ Caregivers or healthcare providers can access this data remotely to monitor the patient's adherence.

- *Sync with Calendar:*

The app can sync medication reminders with the user's smartphone calendar, ensuring they receive alerts even when they are busy or away from the app.

➢ *Remote Control and Updates* [26 & 27]

- *Remote Scheduling and Adjustments:*

The mobile app allows patients, caregivers, or healthcare providers to remotely update the medication schedule on the Smart Med Box. This feature is particularly useful for elderly patients who may need assistance managing complex medication regimens.

For instance, if a doctor adjusts a patient's medication dosage or timing, the changes can be made remotely through the app, and the Smart Med Box will automatically adjust the dispensing schedule.

- *Real-Time Feedback and Alerts:*

The mobile app provides real-time feedback on the patient's adherence:

✓ Alerts when medication is taken.
✓ Notifications if the medication is skipped or taken late.
✓ Warnings if the stock is running low.

These alerts can be configured to send messages to both the patient and their caregivers, ensuring timely interventions in case of missed doses.

- *Emergency Notifications:*

In case of prolonged non-adherence or emergency situations, the mobile app can trigger emergency alerts to caregivers or healthcare professionals.

The app may also include an SOS button, which patients can use to send an emergency alert directly to their caregivers.

➢ *Cloud Connectivity and Data Syncing* [26]

- *Cloud-Based Storage:*

All data collected by the Smart Med Box (e.g., medication adherence, stock levels) is uploaded to a cloud server via the mobile app or directly through Wi-Fi/cellular.

The mobile app can sync with the cloud in real-time, allowing caregivers or healthcare professionals to access the data from any device with internet access.

- *Data Analytics:*

The app provides detailed insights into medication adherence over time, with charts and reports.

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Healthcare professionals can use these analytics to adjust treatment plans based on the patient's adherence patterns.

➢ *Automatic Refill Reminders*

The Smart Med Box can track the stock levels of medications in its compartments using sensors. When the stock runs low, the mobile app sends a low-stock alert to the patient and/or caregiver.

Some systems may integrate with local pharmacies through the app, enabling automatic refill requests or prescriptions to be sent directly from the app to the pharmacy.

➢ *Integration with Other IoT Devices* [26]

The mobile app may integrate with other IoT-enabled health devices, such as:

- Smart watches (to provide medication reminders on the wrist).
- Blood pressure monitors and glucose meters (to track vital signs and adjust medication schedules accordingly).
- Voice Assistants (such as Alexa or Google Assistant) to provide verbal reminders.

➢ *Security and Privacy Features* [26]

- *Secure Data Transmission:*

The connection between the Smart Med Box, the mobile app, and the cloud is encrypted to ensure patient data is protected.
Multi-factor authentication (MFA) may be required to access sensitive data or make changes to medication schedules.

- *Privacy Settings:*

The app allows users to control who has access to their medication data, ensuring that only authorized caregivers or healthcare providers can monitor adherence or make schedule adjustments.

Fig 7 Smart Med Box's Connectivity with Mobile Devices

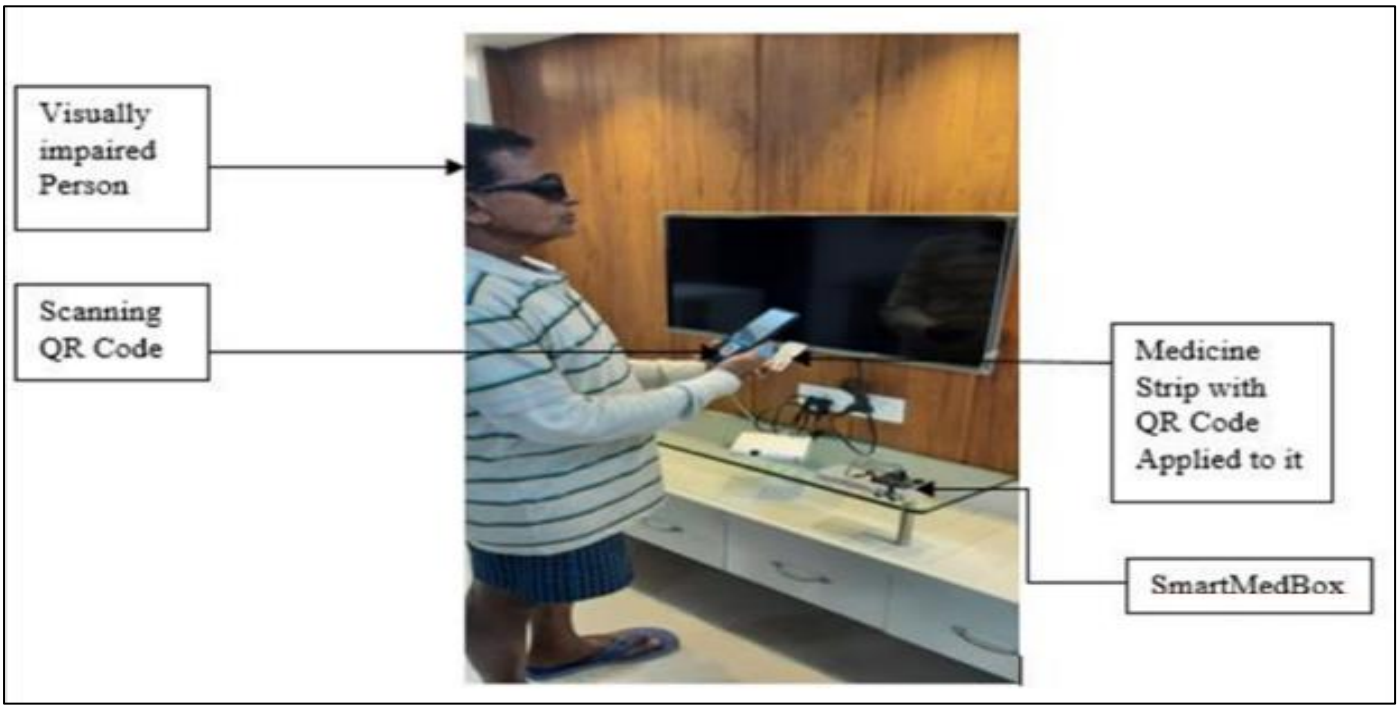

Fig 8 IoT-Enabled Smart Med Box Setting

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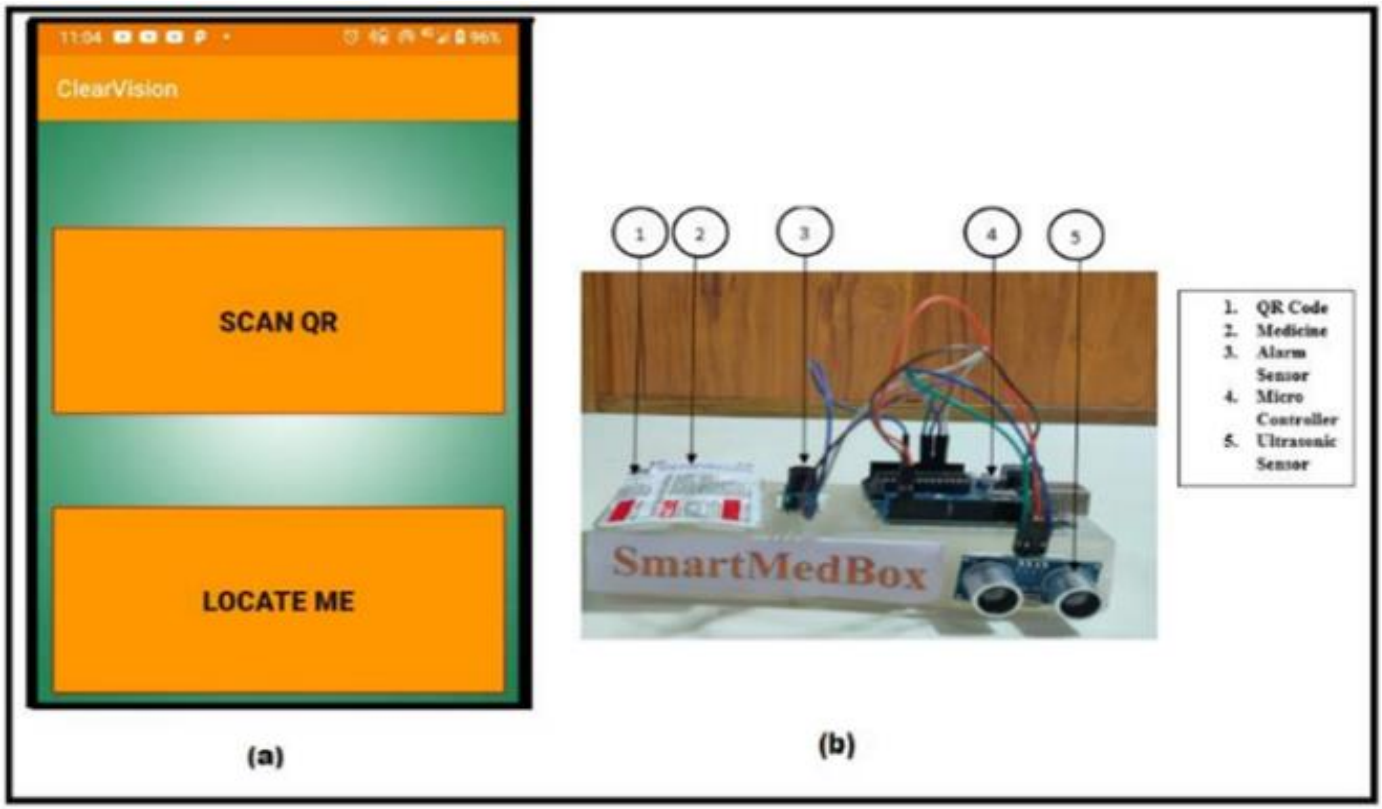

Fig 9 The IoT-Enabled Smart Med Box

V. CONCLUSION AND DISCUSSION

The IoT-Enabled Smart Med Box represents a significant advancement in healthcare technology, particularly in improving medication adherence for patients with chronic conditions, the elderly, and individuals who require assistance in managing complex medication regimens. By leveraging IoT technology, this smart device provides seamless connectivity with mobile applications, enabling real-time monitoring, remote control, and automatic alerts for both patients and caregivers. Its combination of smart compartments, sensors, and cloud integration ensures that medications are taken on time, in the correct dosage, and with minimal risk of error.

The Smart Med Box's connectivity with mobile devices enhances patient engagement and promotes better health outcomes through user-friendly interfaces, convenient medication scheduling, and proactive notifications. It also offers significant benefits for caregivers and healthcare providers by offering remote monitoring and data-driven insights into a patient's adherence to prescribed therapies. With additional features such as automatic refill requests and integration with other health devices, the IoT-Enabled Smart Med Box has the potential to transform medication management and elevate the standard of patient care. In conclusion, the IoT-Enabled Smart Med Box represents a critical step forward in healthcare innovation, empowering patients, caregivers, and healthcare providers to improve medication adherence and, ultimately, patient health and well-being.

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