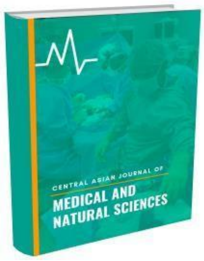

CENTRAL ASIAN JOURNAL OF
MEDICAL AND NATURAL SCIENCES
https://cajmns.centralasianstudies.org/index.php/CAJMNS
Volume: 06 Issue: 04 | October 2025 ISSN: 2660-4159

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Article

Advanced IoT-Based Smart Medicine Box Using Patients' Biometric Data

N. Selvam*[1], N. Mohammed Faizan[2], K. Mohamed Aarif[3], A. Mappillai Meeran[4], M. Mohamed Thariq[5], A. Mohamed Fahadhu[6]

1,5,6. Department of Computer Science and Engineering, Dhaanish Ahmed College of Engineering, Padappai, Chennai, Tamil Nadu, India
2,3,4. Department of Artificial Intelligence and Data Science, Dhaanish Ahmed College of Engineering, Padappai, Chennai, Tamil Nadu, India
* Correspondence: selvamn@dhaanishcollege.in

Abstract: There are also smart computer programs in the system that can determine when anything isn't right. When it encounters something unusual, it recommends the appropriate medicine based on established guidelines. This makes it easier for people to get health information quickly and can help them take better care of their health. The Smart Medical Box also features a mechanism to transmit messages using GSM (Global System for Mobile Communications) when someone is running low on medication. This implies that patients will know when they need more medicine and can acquire it before they run out. The Smart Medical Box is a comprehensive solution for monitoring your health and managing medications at home. It accomplishes this by utilising specialised sensors and intelligent applications. This approach empowers people to take charge of their health, enabling them to make informed choices about their well-being. The Smart Medicine Box utilises several biometric sensors, including fingerprint scanners and facial recognition, to identify each patient and ensure their medication is safe. It features a user-friendly interface for setting up medication schedules and receiving reminders about when to take your medicine, as well as the status of your medication box. This system utilises IoT connectivity to link to a central server or cloud-based platform, allowing you to monitor patient medication adherence in real-time. In general, the IoT-based smart medicine box is a valuable tool for enhancing patient care, promoting medication adherence, and improving overall health outcomes. Biometric verification and other sensors collect data that is used to track how the patient interacts with the medicine box. This provides healthcare providers with valuable insights into how patients behave and follow instructions.

Keywords: modern agriculture, embedded system, real-time operating system, real-time consumption of embedded systems computing, heart rate and temperature sensors, display interface

Citation: Selvam, N., Mohammed Faizan, N., Mohamed Aarif, K., Mappillai Meeran, A., Mohamed Thariq, M., & Mohamed Fahadhu, A. Advanced IoT-Based Smart Medicine Box Using Patients' Biometric Data. Central Asian Journal of Medical and Natural Science 2025, 6(4), 2271-2287.

Received: 30th Jul 2025
Revised: 11th Aug 2025
Accepted: 30th Aug 2025
Published: 29th Sep 2025

1. Introduction

Smart hydroponic systems and other new technologies are changing the way we farm today [26]. These systems employ a more advanced approach to farming by closely monitoring key factors such as light, temperature, water quality, and nutrients essential for plant growth. As part of our project, we developed a comprehensive smart hydroponic system equipped with numerous sensors and devices to ensure optimal growth conditions for plants [40]. Our system utilises Light Dependent Resistors (LDRs) to intelligently measure the amount of light in the room and activate additional lights as needed [32]. This ensures that plants receive sufficient light for photosynthesis to occur. Fans that work automatically maintain a stable temperature, preventing overheating and ensuring the best growth environment. The quality of the water is crucial for hydroponic farming, and our system ensures this with the use of pH monitors [22]. These sensors continuously monitor the water's pH level. If there is any imbalance, a pump is activated to correct it. This ensures that plants have the appropriate pH for absorbing nutrients and growing. NPK sensors also closely monitor nutrient levels. These sensors monitor key nutrients, including nitrogen, phosphorus, and potassium. If these levels drop below the optimal ranges, our system adjusts the delivery of nutrients to ensure that plants receive the right amounts of the right nutrients to grow well [36].

Along with these important tasks, our technology uses advanced machine-learning algorithms to find and treat plant illnesses [30]. The technology can detect indicators of sickness in plant leaves by analysing data from sensors and utilising advanced computer programs. This lets people act quickly and treat the plants. Not only do these technologies make hydroponic farming easier, but they also make it more environmentally friendly. Our solution provides farmers with precise control over environmental conditions and fertiliser management, enabling them to produce plants more effectively and sustainably [38]. This study explains how we designed, built, and used our smart hydroponic plant monitoring system. It shows how it could change the way farmers work today.

An embedded system is a controller programmed and controlled by a real-time operating system (RTOS) that has a specific task to perform within a larger mechanical or electrical system [24]. This is typically done while the embedded system is utilising computational resources in real-time. It is built into a complete gadget, which typically includes both hardware and mechanical components. Embedded systems control numerous everyday items. Ninety-eight per cent of all microprocessors are made to be parts of embedded systems [41]. Some features that distinguish embedded computers from general-purpose computers include their low power consumption, compact size, wide operating ranges, and low cost per unit. This comes at the cost of low processing power, which makes them much harder to program and use [31]. However, by integrating intelligence into the hardware, utilising current sensors and a network of embedded units, one can optimise resource management at both the unit and network levels, and introduce new functions that extend beyond current capabilities. For instance, you can make smart systems that control power. The embedded system consists of hardware components based on microcontrollers [39]. These parts include sensors for collecting biometric data (such as heart rate and temperature), a GSM module for wireless connection, and a display interface for user interaction.

Embedded systems are widely used in various applications across multiple sectors, including military, commercial, medical, automotive, industrial, and consumer industries [28]. Telecommunications systems utilise numerous embedded systems, including telephone switches for the network and cell phones for the end-user. The software component of the embedded system is composed of firmware written in a low-level programming language [21]. This firmware controls hardware peripherals, processes sensor data, and runs logic for medication reminders and warnings [35]. Dedicated routers and network bridges are used in computer networking to send data. There are several types of consumer electronics, such as MP3 players, cell phones, video game consoles, digital cameras, GPS receivers, and printers. Embedded systems in household appliances, such as microwaves, washing machines, and dishwashers, make them more flexible, efficient, and useful.

Advanced HVAC systems utilise networked thermostats to more effectively and accurately control the temperature, which can fluctuate throughout the day and the seasons. Home automation utilises both wired and wireless networks to control various devices, including lights, climate control, security, audio-visual systems, and surveillance

[27]. These devices have built-in sensors and controls, similar to those found in traffic lights, industrial controllers, and more complex systems, such as hybrid automobiles, MRI scanners, and avionics [37]. Embedded systems can be small, such as digital watches and MP3 players, or large, like installations that remain in one place. The complexity can be simple, with just one microcontroller, or high, involving multiple microcontrollers. An embedded system typically comprises an embedded processor [33]. Embedded systems are used in various digital devices, including microwaves, VCRs, and automobiles. Some embedded systems come with an operating system. Others are quite specific; thus, the entire logic is encapsulated in one program. Some gadgets have these systems built in for a specialised purpose other than general-purpose computing.

Motor control, cruise control, body safety, engine safety, robotics on an assembly line, car multimedia, car entertainment, e-commerce access, mobile devices, and more are all examples of embedded systems in cars [29]. Telecommunications embedded systems encompass a range of technologies, including networking, mobile computing, and wireless communications, among others. Smart cards have embedded systems for banking, mobile phones, and security applications [34]. This study highlights the significance of embedded systems in advancing healthcare technologies. It demonstrates how they can solve complex problems and enhance patient care with innovative ideas [23]. The embedded system enables real-time monitoring of medicine levels, biometric data, and box status by seamlessly integrating hardware and software components [25]. This makes it easier to intervene quickly and helps patients stick to their drug schedules.

Literature Survey

In the main procedure, research into health demands differs from the various requests that IoT makes [7]. Healthcare professionals often show a great deal of interest in IoT methods, as they can save money, are easy to understand, and help patients feel more confident about their care. This research helps us visualise how the Internet of Things (IoT) can be utilised in complex healthcare processes [3]. One of the most important IoT apps that connects the Internet to mobile sensors, people, doctors, networks, and other connected equipment is the "Mobile Healthcare Management System (HMS)." The IoT-based smart HMS didn't work, but it did enable doctors to monitor their patients in remote regions at all times. The Internet of Things utilises various technologies, including the Wireless Sensor Network (WSN), which employs CoAP, 6LoWPAN, REST, and other protocols to communicate with one another [13]. These technologies include radio frequency data, smart mobile devices, and wireless sensor networks.

People's lives are easier since technology is advancing at a rapid pace. About 20,000 people die every month because they don't pay enough attention to their bodies [10]. People often overlook their health due to a busy schedule. Science and technology work together to make everything possible and make life easier for people. The importance of suggesting this approach is to prevent diseases and reduce the number of hospital visits, especially during the current pandemic [18]. The suggested health monitoring gadget will measure patients' health data, such as blood pressure, temperature, heart rate (pulse rate), and an EMG electrode to detect emotions [4]. The most essential health indicators that indicate a patient's overall well-being are their body temperature and pulse rate. The LCD and a mobile app display the data collected by the sensors. An IoT web server is used to compare these numbers to the normal values. If the data collected is higher than normal, steps can be taken to stop it from happening again [15]. This suggested healthcare monitoring system ensures that doctors receive timely medical assistance and that patients' health data are kept up to date, thereby reducing the likelihood of illness [20].

Several recent meta-analyses suggest that telemedicine-supported care pathways are not only effective but also cost-saving. The benefits appear to be significant, including a 30–35% reduction in mortality and a 15–20% drop in hospitalisations [5]. Patients with implanted cardiac devices can also benefit from integrated remote clinical management, as all contemporary devices are capable of transmitting technical and diagnostic data [16]. Telemedicine may aid heart failure patients just within a collaborative and cohesive multi-disciplinary and multi-professional 'chronic care model'. Additionally, the future growth of remote telemonitoring programs in Italy will require the primary use of certified medical devices, validated organisational solutions, and innovative care methods adopted by the government and the public [11]. There will also need to be significant growth in clinical care competence to handle the complexity of chronicity remotely.

Many people have specific health concerns these days and need to take medication regularly [9]. A poll found that over 65% of people forget to take their medicines on time. To prevent people from not taking their medicine, a system has been proposed that utilises an IoT platform, sensors, and a medical box. An IMB model that connects wirelessly (via a WiFi module) makes it easier for doctors and patients to talk to each other. The model that has been created features a smart medical system that reminds individuals to take their medication on time. The sensors also let the doctor check on the patient from a distance [1]. The sensors will continuously monitor the patient's health. The doctor changes the number of pills to be taken if there is any change. The server will still have information on missed doses if the patient forgets to take their pills even after being reminded [17]. The doctor can update the drug information on the IOT server remotely, and patients can receive quick updates regarding their medications [14]. They say that this scheme is the finest way to encourage people to take their prescriptions on time and monitor their health regularly.

There is significant business potential for in-home healthcare services that utilise the Internet of Things (IoT), but there is currently no all-in-one platform. This study proposes and implements an intelligent home-based platform called the iHome Health-IoT [12]. The platform includes an open-platform-based intelligent medicine box (iMedBox) that can connect to and switch between different devices and services, an intelligent pharmaceutical packaging (iMedPack) that can communicate using passive radio-frequency identification (RFID) and functional materials, and a flexible and wearable bio-medical sensor device (Bio-Patch) that uses the latest inkjet printing technology and system-on-chip [6]. The suggested platform brings together IoT devices (such as smart medical packages and wearable sensors) and in-home healthcare services (like telemedicine) in a way that benefits both users and providers, making them more efficient [19]. Field tests have shown that the iHome Health-IoT platform works as planned. People believe that the advancement in IoT healthcare represents a significant step forward for the health of older individuals [8]. Older adults and people with long-term illnesses need to take their pills on schedule every day. Because caretakers have a lot to do every day, they may forget when and how to administer patients' medications [3]. Additionally, healthcare workers who have a large number of patients may feel overwhelmed when they need to filter through the drug list to find the right medication for the right patient at the right time.

2. Materials and Methods

Taking medications as prescribed is an important part of managing a patient's health, especially for people with long-term illnesses or complicated medication schedules [43]. But there are many reasons why people don't take their medications as prescribed, such as forgetting, not knowing how much to take and when, having physical restrictions, and not having someone watch over them. Not following the rules can lead to worse health, more healthcare costs, and a lower quality of life [55]. Additionally, the traditional method of managing medications typically employs manual tools, such as pill organisers and written timetables, which are prone to errors and require patient or caregiver involvement. In a clinical context, healthcare practitioners often struggle to monitor whether patients are taking their medications and responding to missed doses, which can compromise the effectiveness of treatment [48]. As the population ages and chronic diseases become increasingly prevalent, it is more crucial than ever to have a medication management system that functions effectively and is reliable [45]. Not having automated solutions makes it more challenging to ensure that medications are safe and that people take them as prescribed [53]. This puts patients and healthcare systems at greater risk. According to traditional healthcare conventions, people should visit their doctor regularly for check-ups, diagnostic tests, and to discuss any health concerns they may have. These appointments are important for determining what's wrong and how to treat it, but they don't occur immediately or regularly, unlike real-time monitoring [50]. This makes it more difficult to identify and address new health issues promptly. At the same time, caregivers or family members play a crucial role in monitoring the health of their loved ones when they are at home.

The Advanced IoT-Based Smart Medicine Box addresses these issues by utilising biometric data to provide a comprehensive and secure approach to managing medications [52]. This system utilises the Internet of Things (IoT) to create a smart medicine box that automates key aspects of dispensing, tracking, and monitoring medications. This makes it easier for patients to adhere to their treatment plans and reduces the likelihood of errors [42]. The suggested method uses biometric sensors, such as fingerprint scanners or facial recognition, to ensure that only authorised people can access the medicine box. This function not only keeps unauthorised people out, but it also allows patients to control their medications in a way tailored to their unique biometric data [46]. The medicine box can connect to a central server or cloud platform through the Internet of Things (IoT). This allows healthcare providers to monitor the box remotely and sync data in real-time [49].

This manual surveillance involves carefully managing prescription schedules, closely monitoring vital signs such as blood pressure and temperature, and being vigilant for any subtle changes in health indicators [51]. However, this type of surveillance, which relies on people, is always prone to mistakes and oversights, which can lead to missed opportunities for timely interventions or incorrect readings of subtle health indicators. Although a lot of effort goes into these monitoring efforts, people still struggle to take care of their health [47]. The complexities of monitoring techniques, combined with the lack of instant access to comprehensive health data, present substantial obstacles to maintaining excellent health trajectories [44]. Caregivers also struggle to keep up with their loved ones' health when they cannot be with them constantly. This can lead to gaps in monitoring and delays in getting the medical help they need [54].

3. Results

The goal of the IoT-Based Smart Medicine Box project is to develop a comprehensive medication management system that utilises biometric data, heart rate, and temperature monitoring to ensure patients take their medication safely and on time. Biometric authentication must be built into the system so that only authorised users can access the medicine box. This may involve using technologies such as fingerprint scanning or facial recognition [86]. The biometric system must be both fast and dependable, providing patients with secure access while remaining easy to use. Being able to detect when the medicine box is empty or has a low level of medicine is crucial. The box needs to be able to connect to the internet or cloud platforms so that it can be monitored and data can be stored from afar [95]. This connection enables healthcare workers to view patient information and monitor patient adherence to their medications. This could include weight sensors, infrared sensors, or other equipment that monitors the pharmaceutical stock level. When stock levels fall below a specific level, the system should send out alerts.

The project requires an alert system that can send text messages to specific numbers when certain events occur [98]. This means informing a caregiver or healthcare provider if the medicine box is empty, if a dose is missed, or if the patient's heart rate or temperature fluctuates unusually. The SMS system needs to be able to work over a GSM network and be dependable. Health data must be stored and transmitted securely, with stringent access controls in place to ensure adherence to healthcare regulations, such as HIPAA or GDPR. To prevent others from intercepting or modifying the information, every communication between the smart medicine box and external systems must be encrypted. People with different levels of technical know-how, including those with visual impairments, should be able to use the system [89]. The goal of the hardware design for the Advanced IoT-Based Smart Medicine Box is to make a system that is safe, dependable, and effective for managing medications. Biometric sensors, such as fingerprint scanners or facial recognition cameras, play a crucial role in helping to identify patients safely. Automated dispensing mechanisms deliver the right medicine at the right times.

The design also includes visual and audio signals, such as LEDs and buzzers, to notify you when it's time to take your medicine and when system alarms occur [91]. A steady power source with a backup battery is incorporated to ensure the system remains operational [94]. These new systems utilise cutting-edge technologies, such as the Internet of Things (IoT) and Artificial Intelligence (AI), to offer seamless, real-time monitoring, proactive interventions, and improved health outcomes for both patients and caregivers. This comprehensive hardware design serves as the foundation for the smart medication box, enabling easy connection to IoT and other systems.

The software implementation part of the Advanced IoT-Based Smart Medicine Box project encompasses a comprehensive development process that aims to make the system user-friendly and secure, while ensuring it functions effectively [97]. In this stage, firmware, communication protocols, companion apps, and security measures are all made. First of all, firmware development is very important since it controls the primary functions of the medicine box, such as biometric authentication, dispensing medicines, and communicating with other devices. The firmware is carefully designed to provide precise control over these tasks, ensuring that the drug management process remains reliable and accurate. Second, communication protocols are carefully chosen and implemented to ensure that data can flow smoothly between the medicine box and the cloud platform [85]. Protocols such as MQTT, HTTP, or WebSocket are used to ensure dependable and efficient communication. This ensures that prescription schedules, adherence statistics, and alerts are all up to date in real-time.

Additionally, companion apps are being developed for both mobile devices and the web, providing consumers with an easy way to manage their prescription schedules, receive reminders, and communicate with their healthcare providers. These apps are designed to be easy to use, intuitive, and compatible with a variety of devices and platforms, making them accessible to a broad range of people. Additionally, strict security mechanisms are built into the software design to protect patient data and prevent unauthorised individuals from accessing it [92]. To protect sensitive information's privacy, integrity, and availability, encryption methods, secure data transmission protocols, and strong authentication methods are used. This builds trust and confidence in the system's security. Overall, the software implementation phase of the project is carried out with great care to provide a robust, dependable, and user-friendly solution that prioritises patient safety, security, and convenience, while addressing the challenges of medication management.

Data Processing and Analytics are crucial components of the Advanced IoT-based Smart Medicine Box. They are what make it possible to measure how well people are following their prescriptions, provide healthcare providers with useful information, and enable remote monitoring [90]. The first step is to gather data from various sources, including biometric sensors, prescription dispensing logs, and user interactions with the system. This raw data is sent securely to a central cloud platform, where it is stored, processed, and analysed. Data cleansing and validation are the initial steps in processing data. This ensures that the collected information is accurate and error-free. This step is crucial for maintaining data security, particularly when it comes to sensitive biometric data and medical records [99]. After being verified, the data is organised such that healthcare practitioners can easily analyse and query it.

The analytics part involves applying various methods to extract useful information from the data. For example, time-series analysis can identify patterns in how well patients adhere to their medication schedule. This can help determine whether patients are consistently skipping doses or taking them at odd times. You can use this information to set up automatic alerts or notifications to remind patients or notify healthcare practitioners about potential compliance issues. Predictive modelling is another key part of data analytics [88]. The technology can forecast potential dangers or non-compliance in the future by analysing past data on adherence to medications and interactions with biometric data [96]. This capacity to forecast events allows healthcare professionals to intervene before they occur and provide additional support or adjust treatment strategies as needed. Data processing and analytics enable us to observe things from a distance.

Healthcare providers can securely access patient data remotely, allowing them to monitor patients' adherence to their medications. This feature enables quick responses to missed doses, keeping patients and healthcare providers in touch with each other [93]. The system employs robust encryption methods and secure connection protocols to safeguard patient privacy and data integrity. This is necessary to keep private biometric information safe and to comply with healthcare regulations such as HIPAA in the US and GDPR in Europe. In short, the advanced IoT-based smart medicine box's Data Processing and Analytics features enable it to track how well people are taking their medicine, identify trends, predict hazards, and provide healthcare remotely [87]. This part is crucial for enhancing patient outcomes, reducing medication errors, and improving communication between patients and healthcare workers.

4. Discussion

Sound is a mechanical wave that propagates through a medium, which can be a solid, liquid, or gas [81]. The speed at which sound waves move across a medium depends on the type of medium they are moving through. When sound waves with high frequencies hit a boundary, they bounce back and produce unique echo patterns [62]. Longitudinal waves, also known as shear waves, are the most common method used for ultrasonic testing. The longitudinal wave is a type of compression wave in which the particles move in the same direction as the wave itself. A shear wave is a type of wave motion in which the particles move in a direction that is perpendicular to the wave's path of propagation [70]. Ultrasonic detection sends high-frequency sound waves into a test object to learn more about it without changing or harming it in any way, see Figure 1.

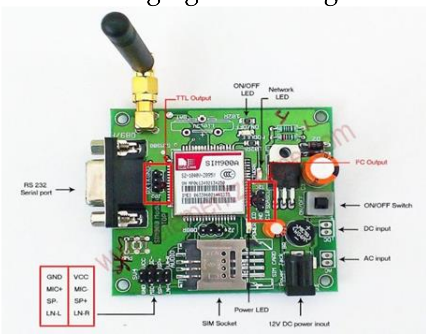

Figure 1. GSM Network.

Ultrasonic distance sensors are useful in various fields, including robotics and automation, as well as in vehicles and medical devices. They work by sending out ultrasonic sound waves and measuring the time it takes for the waves to bounce back from an object. This allows them to determine the distance based on the speed of sound. As mentioned in earlier parts of this SMS lesson, modems are controlled by AT commands on computers [75]. A shared set of standard AT commands works with both GSM modems and dial-up modems. A GSM modem works the same way as a dial-up modem. GSM modems may utilise a broader range of AT commands than standard AT commands. The GSM standards say what these extra AT instructions are.

Ultrasonic distance sensors can measure distances with great accuracy, sometimes to within millimetres, depending on the model and use. Because they are so accurate, they are ideal for jobs that require precise distance measurement. These sensors can detect objects at various distances, typically ranging from a few millimetres to a few meters [66]. The sensor's design and intended application determine the exact range, making them suitable for measuring objects over both short and long distances. These sensors are designed to operate in harsh conditions, including those with dust, moisture, or temperature fluctuations. They are strong enough to be used in factories, outside, and in other tough situations. A GSM modem can only handle roughly six to ten SMS messages per minute, which is relatively low, see Figure 2.

Figure 2. GSM Modem Application.

Access control devices can now send and receive text messages to and from servers and security personnel. The head office server maintains a full record of transactions immediately, and the device can send an alarm to the security personnel's mobile phones immediately if a problem occurs. Biometric authentication is the primary method used to regulate access in this project [74]. This is typically accomplished using fingerprint scanners or facial recognition technologies. This method ensures that only registered users can open the medicine box, making it very safe and reducing the risk of unauthorised access. Biometric data is a reliable means of proving one's identity, making it ideal for managing medications for each individual. The access control device ensures that only authorised individuals, such as the patient and their assigned caregivers, can access the medication. This level of control helps ensure the medicine remains safe and prevents unauthorised use. It also lowers the chance of making mistakes with medications, especially in homes with more than one person living there or in clinical settings. The ability to log access attempts is another important function of the access control device [82]. The system keeps track of every time someone attempts to access the medicine box, whether they succeed or not. It does this by recording the time and the person's identification (if authentication is successful). This tracking feature enables healthcare providers to monitor how well patients are adhering to their treatment plans and detect any unusual or unauthorised access attempts.

Central servers can employ SMS messaging to confirm transactions on the EDC machine's POS terminals. The best aspect of this is that the central server can be located anywhere in the world. You now need local servers in every city, and they should have more than one phone line [61]. You save a significant amount of money on infrastructure costs and transaction fees. Most transaction terminals have card readers that can read credit, debit, and prepaid cards. These scanners can work with magnetic stripe cards, chip-based cards (EMV), and contactless payments (NFC), providing customers with a choice of payment methods. These terminals typically feature user-friendly interfaces, and many of them include touch screens or physical keypads. Customers can submit important information, such as a personal identification number (PIN), approve payments, and verify transaction details using this interface [80]. These terminals are designed to handle transactions efficiently and accurately. They often come with software that helps businesses track transactions, generate reports, and analyse data to inform their decisions. For business accounting and reconciliation, it's crucial to maintain accurate transaction records and generate reports.

Supply chain management (SCM) is a crucial aspect of running a business. It encompasses planning, coordinating, and managing all the steps necessary to deliver goods and services from suppliers to customers. It encompasses all the steps, from acquiring raw materials to delivering final products to clients [69]. To ensure that products are delivered on time, cut costs, and improve efficiency, supply chain management must be executed effectively. Today, SCM requires a significant amount of IT infrastructure, including leased lines, networking devices, data centres, and workstations. However, it still experiences significant downtime and incurs substantial costs. With GSM M2M technology, you can do all of this for a lot less money. You need a central server in your head office that can use GSM. This way, you can get transaction data from all your branch officers, warehouses, and business partners right away, with no downtime and at a reasonable cost [56]. Sourcing refers to the process of identifying and selecting sources for raw materials, components, or finished products. Procurement is all about acquiring these materials at the optimal price, quality, and terms. To ensure you always have the necessary items, it is essential to maintain strong connections with suppliers, possess effective negotiation skills, and have a thorough understanding of the market [83]. The act of managing inventory involves keeping track of where items are stored, how they are transported, and their availability throughout the supply chain. Effective inventory management ensures that there is sufficient product to meet demand while minimising excess stock. Just-in-Time (JIT) inventory management and safety stock levels are two methods used to strike the optimal balance between supply and demand.

Mobility and quick installation are two related concepts that aim to make things more flexible, convenient, and efficient across a wide range of fields, particularly in technology, industrial systems, and consumer electronics. GSM technology lets you move about. Unlike regular phone lines, GSM terminal modems can be quickly set up and used in other locations [65]. You can also move about with GSM terminals and communicate with the server using your phone. You can purchase GSM hardware, such as modems, terminals, and mobile phones, insert SIM cards, and configure the software. Then you're ready to use GSM. Devices and systems are made to be light and easy to move or carry. This is prevalent in consumer devices, such as laptops, tablets, and cell phones, as well as in industrial equipment, including portable generators and mobile workstations. To make them more useful, many mobile gadgets and systems have more than one purpose [76]. Smartphones, for example, are portable devices that combine communication, computing, entertainment, and other features.

A vibrating motor is a type of electric motor commonly used in devices to produce vibration. These motors are compact and efficient, enabling them to be used in a wide range of applications [79]. Here are some key points to consider about vibration motors. Most of the time, vibration motors are small and cylindrical, with a weight that is off-centre attached to the motor shaft. The motor vibrates when it turns because the weight is not evenly distributed. Vibration motors convert electrical energy into mechanical motion, resulting in vibrations [67]. This is typically achieved by adding an imbalanced mass to the motor's shaft, causing it to move back and forth as it spins. You can adjust the amount of vibration by altering the motor speed, mass, or its position. These are the types of vibration motors most often used in small electronic devices, mobile phones, and wearable devices. When the motor is turned on, an eccentric weight on a shaft makes vibrations. Changing the speed of the motor can change the frequency and strength of the vibration [84]. These larger vibration motors are used in factories for tasks such as sorting, handling materials, or compacting. They are built to last and can make strong vibrations for big jobs.

Many cell phones have vibration motors in them. They provide haptic feedback for calls, notifications, and touch interactions. Some game controllers include vibration motors to provide players with force feedback, making the game more engaging. They are ubiquitous in today's world, offering users a range of features that extend beyond mere communication [71]. Mobile devices encompass a wide range of products, including smartphones, tablets, smartwatches, and portable game consoles. Many mobile devices feature sensors such as accelerometers, gyroscopes, and ambient light sensors, enabling them to perform tasks like rotating the screen, detecting motion, and adjusting brightness automatically.

Vibration motors are typically built into smartwatches and fitness trackers to send alerts and notifications. Smartwatches, fitness bands, and other wearable devices can track various health variables essential for managing medications. These measurements could be things like heart rate, activity levels, sleep patterns, and other useful information. Healthcare practitioners can gain a deeper understanding of a patient's health by connecting these wearable devices to the smart medicine box system. This information can help them make informed decisions about when to administer medications and how much to adjust them. One of the primary purposes of wearable devices in this project is to remind people to take their medication [57]. There are three ways to remind you: vibrations, sounds, and visual alerts on the device's screen. This feature is particularly helpful for individuals who are frequently on the go or who may not always have access to their smart medicine box when it's time to take their medication. This kind of identification makes things safer and easier.

Vibration motors are used in industrial machines to move materials or warn operators. Utilising the project's technologies and concepts in a wider industrial or healthcare setting. The goal of these apps is to make managing medication and patient care more efficient, safe, and productive. Managing medications is crucial in hospitals, nursing homes, and assisted living facilities [64]. With its innovative features, the smart medicine box can make this process easier. Healthcare workers can ensure that only authorised individuals can access pharmaceuticals by implementing biometric authentication. This lowers the possibility of mistakes and unauthorised access [77]. The smart medicine box integrates with electronic health records to facilitate seamless information sharing among various systems. This connection ensures that drug information is accurately documented in the patient's medical record, facilitating better collaboration among healthcare practitioners. It also reduces the need to enter data manually, which lowers the likelihood of errors.

Adding a buzzer makes the smart medication box easier for individuals with visual impairments or those who struggle with using complex technologies. You can expand the smart medicine box to meet the evolving demands of the healthcare institution, making it easy to add more space as the number of patients increases. The technology can be applied in diverse industrial settings, as it can be configured in various ways and integrated with existing systems. Using sound as a communication medium in a basic yet efficient way helps close any gaps in accessibility, ensuring that more patients can benefit from the system [60]. The buzzer is a crucial and versatile component of the advanced IoT-based smart medicine box. It provides clear audio alerts and feedback to ensure that people take their medicine and that the system is safe. Its presence makes managing medications more reliable and easier to utilise.

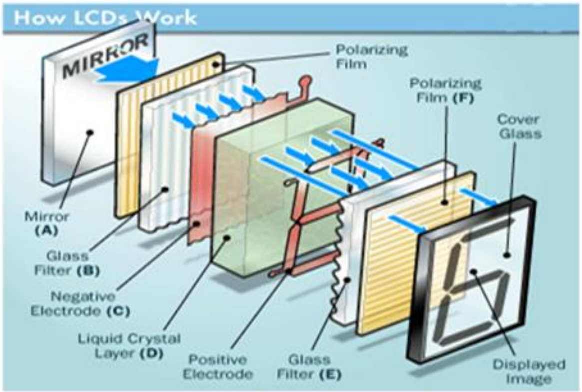

Figure 3. LCD Layer.

When there is no current, the light passes through the front of the LCD. It will be reflected by the mirror and bounced back. As the electrode is connected to a battery, the current from it will cause the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle to untwist [68]. Depending on the type of LCD (like Twisted Nematic), viewing angles can be limited, causing colour distortion when viewed from the sides [58]. LCDs may have slower response times compared to other technologies, such as OLED, which can lead to motion blur in fast-moving images. Since LCDs rely on a backlight, they cannot achieve true blacks like OLED displays, which can turn off individual pixels, see Figure 3.

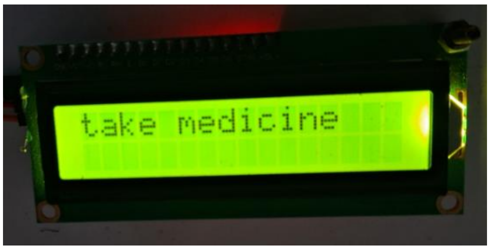

Figure 4. Sample output.

The Smart Medicine Box project demonstrates that hardware and software can work effectively together, enabling the complete management of medications and health monitoring [78]. The system, created using the Arduino IDE platform, accurately monitors and displays both temperature and heart rate when a finger is placed on the corresponding sensors. This real-time biometric data collection enables consumers to easily check their health status directly from the smart medicine box interface [72]. Sensors in the smart medicine box monitor the patient's blood pressure and pulse rate. Readings are taken at regular intervals and displayed on a mobile app or web interface that is straightforward for both patients and healthcare practitioners to use, see Figure 4. The data is examined to identify any significant deviations from normal levels that may indicate underlying health issues. If the heart rate or blood pressure exceeds certain levels, an alert is sent to the patient's doctor or caregiver, allowing them to take prompt action. One of the most important features of the smart medicine box is that it can track when pills are available.

Additionally, the system's smart monitoring features extend beyond simply displaying statistics. If the temperature or heart rate data indicate an unusual condition, the system automatically initiates a series of preconfigured operations. First, it sends an alert message to a pre-programmed number, notifying caregivers or healthcare providers about the observed problem. The Smart Medicine Box project demonstrates a strong and user-friendly approach to managing medications and monitoring health [63]. The system utilises the Arduino IDE and combines several hardware components to provide useful information about biometric data and medication status. This leads to better patient outcomes and better healthcare delivery.

The system's intelligence is evident in its proactive alerting systems, which extend beyond simply collecting basic data. When the biometric data indicates potential issues, such as an erratic heart rate or high temperature, the system automatically initiates a series of steps to ensure that help is available promptly [73]. The technology sends SMS warnings to the right caregivers or healthcare providers immediately, which helps them respond quickly and receive the appropriate medical care. This could lower health risks and improve patient outcomes. The smart medicine box also constantly monitors the levels of medications in each of its compartments. If a container is empty, it means that the medication has to be refilled [59]. In that situation, the system emits a buzzing sound and displays a message on the LCD screen instructing the user to refill the box.

5. Conclusion

The conclusion of the Advanced IoT-Based Smart Medicine Box project demonstrates how integrating IoT technology with biometric data can significantly enhance patient care and medication administration. This project addresses significant issues with adhering to medication prescriptions. It offers an automated and secure system that makes it easier for patients to follow their prescriptions and lowers the risks of missing doses or drug errors. Patients can be assured that their medication is securely stored and accessible only to authorised individuals through biometric authentication. This not only makes things safer, but it also makes the medication management experience more personal, which makes patients feel more responsible and likely to follow the rules. The automated dispensing feature and the buzzer's auditory reminders make it easier for patients to remember to take their medicine. This allows them to focus on other aspects of their health without worrying about forgetting to take their medication. The smart medication box's IoT connection enables healthcare providers to easily send and receive data, as well as monitor conditions in real-time. This capacity to monitor patients from a distance provides healthcare personnel with useful information about how patients behave and adhere to their treatment plans, which enables them to intervene quickly and create more personalised treatment regimens.

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