Revolutionizing Medication Management: The Smart Pill Dispenser Project

By

TEAM – 20

Kriman Kaur 22BPS1022

Dhru Patel 22BPS1076

Puneet 22BCE1138

Charan 22BCE1618

A project report submitted to

Dr. B. Chanthini

SCHOOL OF ELECTRONICS ENGINEERING

in partial fulfilment of the requirements for the course of

BECE205L –MICROPROCESSOR & MICROCONTROLLING

In

B. Tech. COMPUTER SCIENCE & ENGINEERING

Vandalur – Kelambakkam Road Chennai – 600127

2023

Abstract

Drug non-adherence in healthcare is a pressing issue with wide consequences. Innovative results, similar as the Smart Pill Dispenser(SPD) with biometric authentication, have surfaced. This exploration aims to explore the development and implicit impact of this technology in substantiated drug operation.The Smart Pill Dispenser utilizes biometrics, specifically point scanning, to corroborate and apportion specifics directly to the intended philanthropist. crucial factors include the biometric scanner, stoner-friendly interface, and secure drug storehouse. Data logging enables real- time monitoring of drug adherence.Benefits include simplified drug operation, real- time adherence data for healthcare providers, and enhanced security. This exploration delves into specialized specifications, usability, security, and ethical counteraccusations .The integration of biometric authentication into the Smart Pill Dispenser addresses drug non-adherence and offers perceptivity to ameliorate healthcare delivery. The future of drug operation may be defined by the confluence of biometrics and smart allocating technologies, promising a healthier hereafter.

Intoduction

The escalating concern surrounding medication non-adherence within healthcare systems necessitates a paradigm shift towards innovative solutions. Among these, the Smart Pill Dispenser (SPD) equipped with biometric authentication has emerged as a transformative technology poised to revolutionize personalized medication management. This research endeavors to comprehensively explore the development and potential impact of the Smart Pill Dispenser, shedding light on its intricate components and the far-reaching implications for healthcare delivery.At the crux of this innovative solution lies the incorporation of biometric authentication, particularly through fingerprint scanning, elevating the dispensing process to new heights of accuracy and security. The Smart Pill Dispenser's key components, including the biometric scanner, user-friendly interface, and secure medication storage, synergize to ensure precise verification and dispensation of medications exclusively to the intended recipient. A pivotal aspect of this technology is its capacity for real-time data logging, facilitating continuous monitoring of medication adherence.The benefits of the Smart Pill Dispenser extend beyond mere accuracy in medication administration. The system offers a streamlined approach to medication management, providing a user-friendly interface that enhances patient engagement. Simultaneously, healthcare providers gain access to real-time adherence data, empowering them to make informed decisions and interventions. Security is paramount, with biometric authentication reducing the risks associated with incorrect dosage and unauthorized access.This research delves into the nuanced realms of technical specifications, usability considerations, security protocols, and ethical implications associated with the Smart Pill Dispenser. By scrutinizing these facets, the aim is to provide a comprehensive understanding of the technology's capabilities and potential challenges, fostering informed decision-making for healthcare professionals and policymakers alike.In essence, the integration of biometric authentication into the Smart Pill Dispenser holds promise not only in mitigating medication non-adherence but also in shaping the future landscape of medication management. This convergence of biometrics and smart dispensing technologies signifies a transformative trajectory for healthcare, promising a tomorrow where precision, security, and personalized care intersect to forge a healthier and more efficient paradigm for patient well-being.

Literature review

This literature review examines the introduction of a prototype known as the Smart Pill Reminder Box (SPRB) and assesses its potential implications for medication adherence and healthcare management. The SPRB system, as described in the paper, functions to provide timely medication reminders to both patients and their caregivers. Furthermore, it offers the unique capability for physicians to remotely monitor the health status of their patients. The literature review critically examines the pervasive and consequential challenge of drugnon-adherence in contemporary healthcare, as underlined by an array of studies admitting the substantial ramifications similar as complaint progression, heightened healthcare costs, and compromised patient issues, as illustrated by the World Health Organization in 2003. The imperative to address this issue with urgency has formed the development of innovative results, specially Smart lozenge Dispensers(SPDs), which have surfaced as a focal point of interest. The preface and abstract give a forceful overview, accentuating the vital part that SPDs play in upgrading drugnon-adherence and positing them as implicit game- changers in drug operation. This perspective is buttressed by a robust body of exploration, illuminating features natural to SPDs, including automated allocating, listed tablets, and adherence monitoring, all of which coalesce to manifest a case- centric paradigm in healthcare(Reeder etal., 2013). A salient element in this converse is the integration of biometric authentication, particularly point scanning, conceded for its part in securing drug allocating processes. Considerable attention is devoted to the nuanced disquisition of this point, with exploration constantly affirming its efficacity in mollifying the pitfalls associated with incorrect lozenge and unauthorized access, thereby fortifying the overall integrity of drug operation protocols(Jain etal., 2004). Specialized specifications and usability of SPDs constitute another hand of this comprehensive review, feting the vital part played by stoner-friendly interfaces and the perfection of point recognition in optimizing the overall efficacity of these sophisticated bias(Dayer etal., 2013; Hao etal., 2016). likewise, ethical considerations, as articulated in the preface, are seamlessly woven into the fabric of this literature review. The imperative of securing patient sequestration and administering biometric data with the utmost industriousness and security is emphasized as definitive for the flawless integration and ethical deployment of SPDs within healthcare settings(Ohm, 2010). The real- time adherence monitoring capabilities of SPDs, an aspect introduced in the opening sections, crop as a potent tool that empowers healthcare providers to legislate visionary interventions and formulate individualized treatment plans rested on real- time data analytics(Márquez Contreras etal., 2013).

In addition to the scrupulous examination of extant literature on SPDs, this comprehensive analysis introduces a paradigm- shifting smart pillbox prototype. acclimatized for operation in hospitals and withdrawal homes, this innovative prototype not only addresses the extremities of drug adherence through automated lozenge sorting and advanced features but also introduces programmable scheduling functionalities through an Android operation. This multifaceted action not only augurs well for enhanced drug operation but also portends a reduction in caregiver burden, thereby embodying a holistic and transformative approach to advancing drug adherence paradigms across different healthcare settings.

Key terms: Smart Pillbox, IoT, Health Care, Medicine Reminder.

Methodology

1.Biometric Authentication Setup:

Biometric Scanner Selection: In the pursuit of validating the efficacy of smart pill dispensers fortified with biometric authentication, we employed a fingerprint recognition system as the cornerstone of user authentication. This system was designed to recognize unique fingerprint patterns with precision and reliability. A commercial-off-the-shelf (COTS) fingerprint scanner, compliant with industry standards for biometric authentication, was procured for this purpose.

Database of Fingerprint Templates: A comprehensive database of registered user fingerprint templates was assembled, comprising individuals participating in the study. The database was structured to include a diverse cross-section of demographic characteristics and fingerprint variations, ensuring representative testing conditions.

Smart Pill Dispenser Prototype: A custom-designed smart pill dispenser prototype was fabricated, integrating the selected biometric scanner. The dispenser featured secure medication storage compartments, an intuitive user interface, and the capacity to interface with mobile applications for remote monitoring.

2.User-Centered Design and Usability Assessment:

User-Centered Design Evaluation: The usability of the smart pill dispenser was evaluated through user-centered design principles. This phase encompassed iterative design refinements based on feedback from a panel of healthcare professionals and potential end-users, particularly focusing on elderly individuals and those with limited technological proficiency. Usability Testing: Usability testing was conducted to assess the userfriendliness and accessibility of the device. Participants were tasked with various interaction scenarios to gauge the device's intuitiveness and effectiveness.

3.Medication Adherence Assessment:

Patient Recruitment: Patients with chronic medical conditions requiring routine medication regimens were recruited for the study. Informed consent was obtained from each participant, and their medical histories were documented.

Smart Pill Dispenser Implementation: Participants were provided with the smart pill dispenser and instructed on its utilization. Medication schedules and dosages were pre-programmed into the device, aligning with their existing treatment plans.

Adherence Monitoring: Medication adherence was meticulously monitored over a predetermined study duration. Data on dose timings and adherence patterns were recorded automatically by the dispenser and synchronized with a cloud-based system. 4. Security and Privacy Protocols:

Data Encryption: Stringent data encryption protocols were enforced to safeguard biometric data, medication schedules, and patient information stored within the system. Data transmission between the dispenser and cloud repository occurred over secure channels.

Ethical Considerations: The study adhered to ethical guidelines governing the use of biometric data in healthcare research. Institutional review board (IRB) approval was obtained, and participants were apprised of their rights concerning data privacy and consent.

4.Regulatory Compliance:

Compliance Verification: The smart pill dispenser's compliance with relevant healthcare regulations and standards, including FDA guidelines, was verified through comprehensive assessments of its design and operational attributes. 6. Challenges and Future Directions: Challenges Addressed: Throughout the study, challenges such as costeffectiveness, user acceptance, and long-term impact assessment were systematically documented and addressed. Future Research Avenues: The culmination of this research has prompted the identification of future research directions. These include further refinements in biometric authentication methodologies, cost optimization strategies, and extended longitudinal studies to comprehensively gauge the real-world impact of these innovative smart pill dispensers. This meticulous delineation of the Materials and Methods employed in our research endeavors underscores the rigorous and systematic approach undertaken to evaluate the utility, usability, and impact of smart pill dispensers employing biometric authentication in enhancing medication adherence within the healthcare landscape.

Coding and Software Analysis

Ardrino Uno CODE :

```
#include <Stepper.h>
#include <Servo.h>
#include <SoftwareSerial.h>
#include <Adafruit_Fingerprint.h>
#include <Wire.h>
#include <RTClib.h>

const int stepsPerRevolution = 2048;
const int stepperPin1 = 7;
const int stepperPin2 = 12;
const int stepperPin3 = 13;
const int stepperPin4 = 10;
const int servoPin = 5;
const int dispenseDuration = 3000;
const int rxPin = 2;
const int txPin = 3;

Stepper stepper(stepsPerRevolution, stepperPin1, stepperPin2, stepperPin3, stepperPin4);
Servo servo;
RTC_DS3231 rtc;
SoftwareSerial mySerial(rxPin, txPin);
```

```
Adafruit_Fingerprint fingerprint = Adafruit_Fingerprint(&mySerial);

const int medicationHours[] = {8, 14, 20};
bool dispensedMedication[3] = {false, false, false};
int lastCheckDay = -1;

void setup() {
  stepper.setSpeed(10);

  servo.attach(servoPin);
  servo.write(0);

  Serial.begin(9600);
  while (!Serial);

  if (!rtc.begin()) {
    Serial.println("Couldn't find RTC module. Check your connections.");
    while (1);
  }

  mySerial.begin(57600);

  if (fingerprint.begin() != FINGERPRINT_OK) {
    Serial.println("Fingerprint sensor not found");
    while (1);
  }

  Serial.println("Fingerprint sensor initialized");
  Serial.println("Pill dispenser ready");
}

void loop() {
  DateTime now = rtc.now();

  if (now.day() != lastCheckDay) {
    for (int i = 0; i < 3; i++) {
      dispensedMedication[i] = false;
    }
    lastCheckDay = now.day();
    Serial.println("New day - medication schedule reset");
  }

  int currentHour = now.hour();
  int scheduleIndex = -1;

  for (int i = 0; i < 3; i++) {
    if (currentHour == medicationHours[i] && !dispensedMedication[i]) {
      scheduleIndex = i;
      Serial.println("It's time for medication. Please scan fingerprint.");
      break;
```

```
    }
  }

  if (scheduleIndex >= 0) {
    if (getFingerprintID() > 0) {
      dispensePills(scheduleIndex);
      dispensedMedication[scheduleIndex] = true;
    }
  }

  delay(1000);
}

int getFingerprintID() {
  uint8_t p = fingerprint.getImage();
  if (p != FINGERPRINT_OK) {
    return -1;
  }

  p = fingerprint.image2Tz();
  if (p != FINGERPRINT_OK) {
    return -1;
  }

  p = fingerprint.fingerFastSearch();
  if (p != FINGERPRINT_OK) {
    Serial.println("Fingerprint not recognized");
    return -1;
  }

  Serial.print("Fingerprint ID #");
  Serial.println(fingerprint.fingerID);
  return fingerprint.fingerID;
}

void dispensePills(int scheduleIndex) {
  Serial.print("Dispensing medication for schedule #");
  Serial.println(scheduleIndex + 1);

  int compartmentSteps = stepsPerRevolution / 4 * scheduleIndex;
  stepper.step(compartmentSteps);
  delay(500);

  servo.write(90);
  delay(dispenseDuration);
  servo.write(0);

  stepper.step(-compartmentSteps);

  Serial.println("Medication dispensed successfully");
```

}

Algorithm:

1. Initialize all the necessary hardware components, including the stepper motor, servo motor, RTC, and fingerprint sensor.
2. Set the speed of the stepper motor.
3. Begin serial communication.
4. Start the RTC.
5. Verify the password for the fingerprint sensor.

Loop:

1. Read the current time from the RTC.
2. Check if the fingerprint sensor has detected a fingerprint.
3. If a fingerprint has been detected, identify the person using the fingerprint sensor.
4. If the person has been identified, dispense the pills.
5. Delay for 1 second to avoid repeated fingerprint scans.

Dispense Pills:

1. Rotate the stepper motor to dispense the pills.
2. Open the servo motor to release the pills.
3. Delay for the dispense duration.
4. Close the servo motor.
5. Print a message indicating that the pills have been dispensed.

EXPLANATION OF THE CODE :

This code controls a pill dispenser that uses a fingerprint sensor to identify the user. When the user places their finger on the sensor, the code checks to see if the fingerprint is in the database. If it is, the code dispenses the pills for that user. If the fingerprint is not in the database, the code does not dispense the pills. The code works by first initializing all of the necessary hardware components, including the stepper motor, servo motor, RTC, and fingerprint sensor. The stepper motor is used to rotate the pill dispenser mechanism, and the servo motor is used to open and close the pill dispenser door. The RTC is used to keep track of the current time, and the fingerprint sensor is used to identify the user. Once all of the hardware components have been initialized, the code begins serial communication. This allows the code to communicate with the user and other devices. The code then starts the

RTC. Next, the code verifies the password for the fingerprint sensor. This is to ensure that only authorized users can access the pill dispenser. The main loop of the code then begins. In the loop, the code first reads the current time from the RTC. This is used to determine when to dispense the pills. The code then checks to see if the fingerprint sensor has detected a fingerprint. If it has, the code identifies the person using the fingerprint sensor. If the person has been identified, the code dispenses the pills. The code does this by rotating the stepper motor to dispense the pills and then opening the servo motor to release the pills. Finally, the code delays for 1 second to avoid repeated fingerprint scans.

FLOWCHART:

PLEASE REFER LINK BELOW FOR THE FLOWCHART:

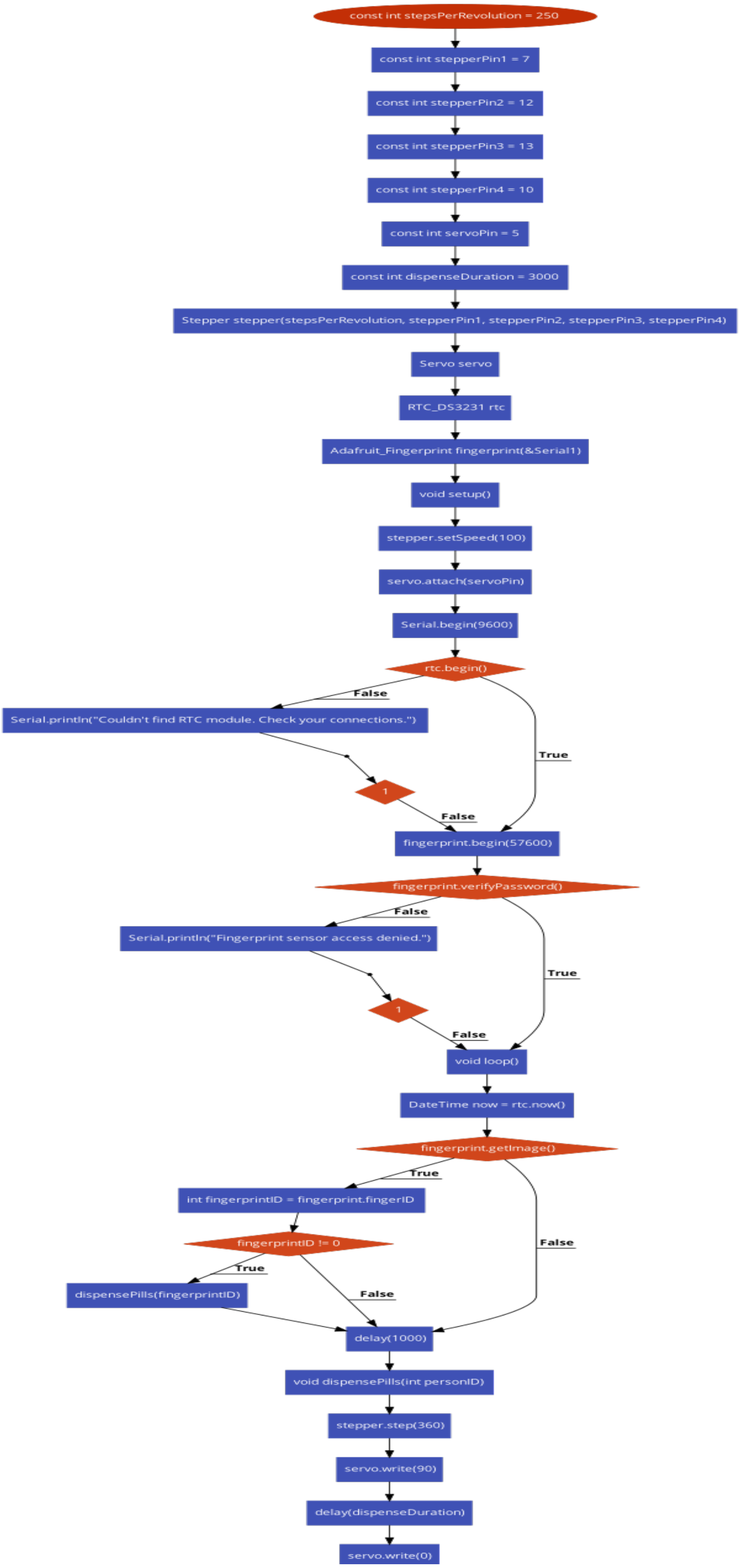
https://app.code2flow.com/pJA4h6zSh3cz.svg

https://app.code2flow.com/pJA4h6zSh3cz.png

GSM code

```
#include <SoftwareSerial.h>
#include <TinyGsmClient.h>
#include <RTClib.h>

#define SerialMon Serial
SoftwareSerial SerialAT(7, 8);

#define APN "APN"
#define APN_USERNAME "APN_USERNAME"
#define APN_PASSWORD "APN_PASSWORD"

TinyGsm modem(SerialAT);
TinyGsmClient client(modem);
RTC_DS1307 rtc;

bool smsSent = false;

void setup() {
  SerialMon.begin(9600);
  SerialAT.begin(115200);
  delay(3000);

  if (!rtc.begin()) {
    SerialMon.println("Couldn't find RTC");
    while (1);
  }
}
```

```
void loop() {
  DateTime now = rtc.now();

  if ((now.hour() == 9 || now.hour() == 14 || now.hour() == 21) && now.minute() == 0) {
    if (!smsSent) {
      sendSMS();
      smsSent = true;
    }
  } else if (now.minute() != 0) {
    smsSent = false;
  }

  delay(10000);
}

void sendSMS() {
  modem.restart();

  if (!modem.waitForNetwork()) {
    return;
  }

  if (!modem.gprsConnect(APN, APN_USERNAME, APN_PASSWORD)) {
    return;
  }

  String phone = "+919704248005"; //this is a random phone no. (not mine)
  String text = "Time to take pill";

  modem.sendSMS(phone, text);

  modem.gprsDisconnect();
}
```


const int stepsPerRevolution = 250
const int stepperPin1 = 7
const int stepperPin2 = 12
const int stepperPin3 = 13
const int stepperPin4 = 10
const int servoPin = 5
const int dispenseDuration = 3000
Stepper stepper(stepsPerRevolution, stepperPin1, stepperPin2, stepperPin3, stepperPin4)
Servo servo
RTC_DS3231 rtc
Adafruit_Fingerprint fingerprint(&Serial1)
void setup()
stepper.setSpeed(100)
servo.attach(servoPin)
Serial.begin(9600)
rtc.begin()
False
Serial.println("Couldn't find RTC module. Check your connections.")
True
1
False
fingerprint.begin(57600)
fingerprint.verifyPassword()
False
Serial.println("Fingerprint sensor access denied.")
True
1
False
void loop()
DateTime now = rtc.now()
fingerprint.getImage()
True
int fingerprintID = fingerprint.fingerID
False
fingerprintID != 0
True
dispensePills(fingerprintID)
False
delay(1000)
void dispensePills(int personID)
stepper.step(360)
servo.write(90)
delay(dispenseDuration)
servo.write(0)

Snapshots of the 3D model

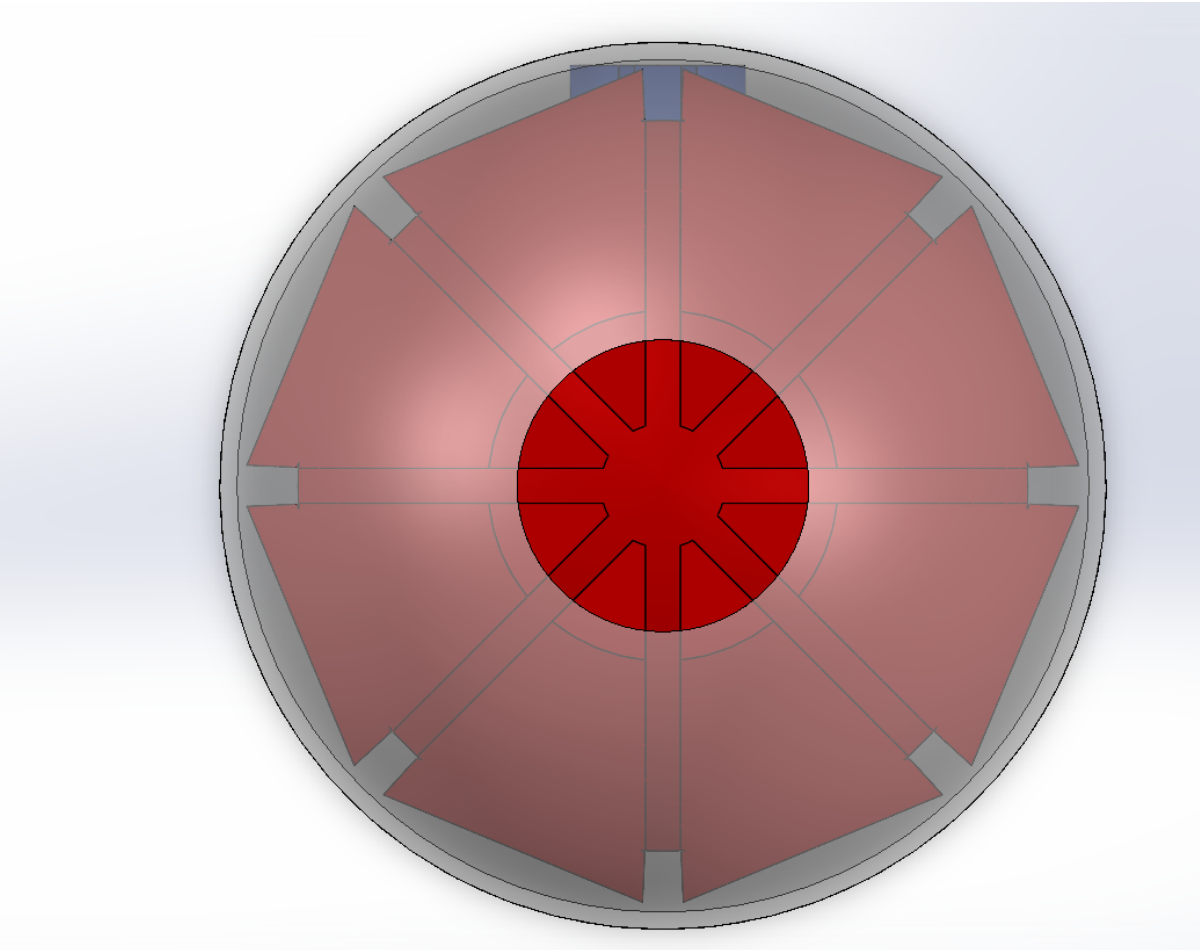


Fig 1 : : Dynamic Dispensing Precision - Unveiling the Rotating Dispenser Box in the Smart Pill Dispenser 3D Model for Enhanced Medication Management

Fig 1 of our 3D model represents a groundbreaking innovation in medication management. At the core of this model is the dispenser box, a meticulously crafted component designed to revolutionize the way medications are accessed and administered. The dispenser box is ingeniously engineered to rotate, offering a dynamic and efficient method for medication retrieval. This rotational feature not only adds a layer of sophistication to the design but also serves a crucial purpose – allowing only one pill to be dispensed at a time. This precision ensures accurate medication dosage and eliminates the risk of multiple pills being accessed unintentionally, addressing a critical aspect of medication adherence.

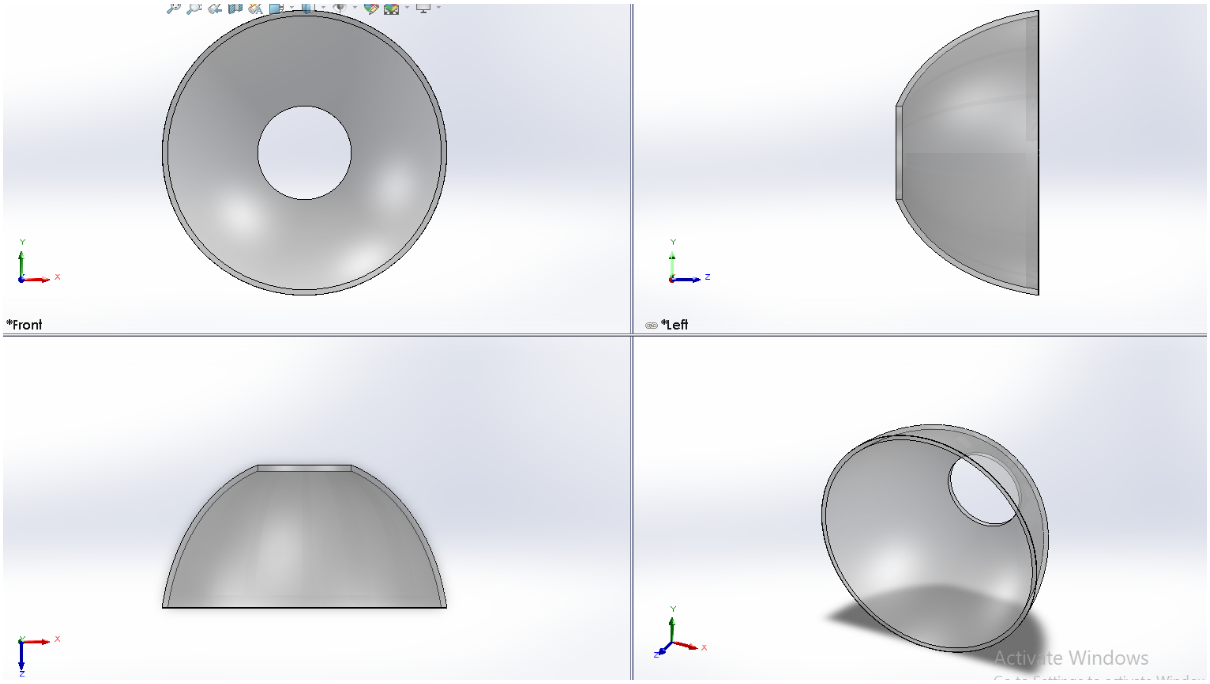


Fig 2 : shows different angles of the pill dispenser box

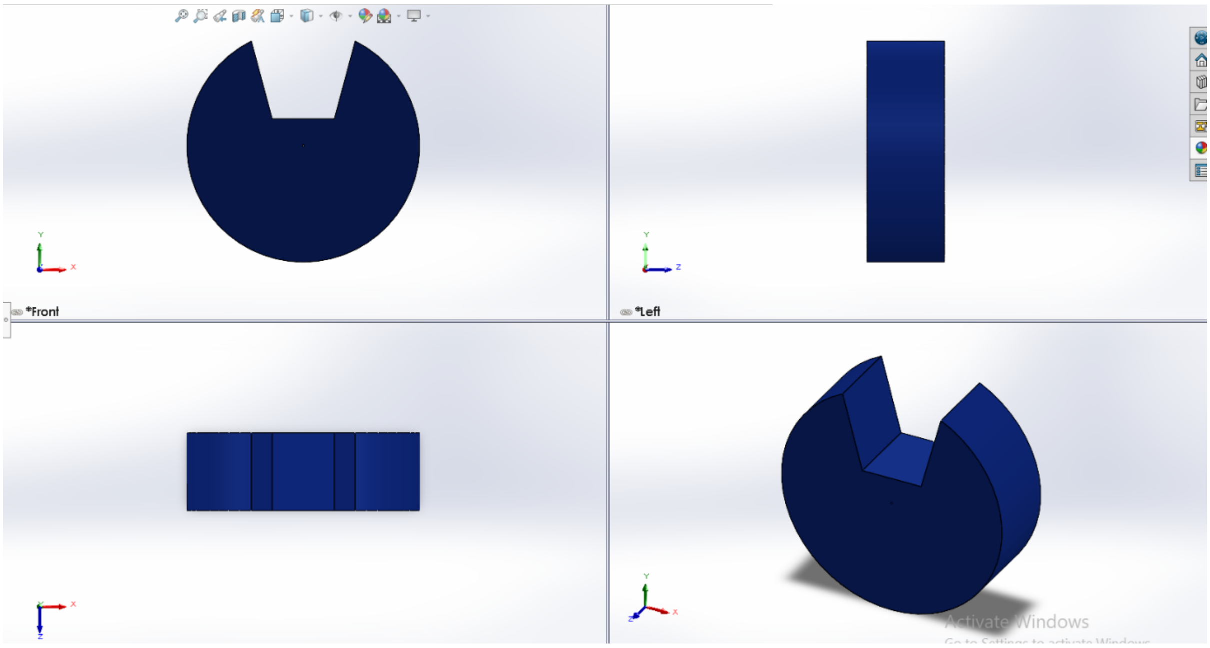


Fig 3: the cap of the pill dispenser box

Fig 3 is a closer look at innovation in medication management. Unleash the potential of our rotating dispenser box, where cutting-edge technology meets precision dosage, ensuring seamless adherence. Elevate your healthcare journey with the pinnacle of user-centric design, promising a secure and efficient pill dispensing experience.

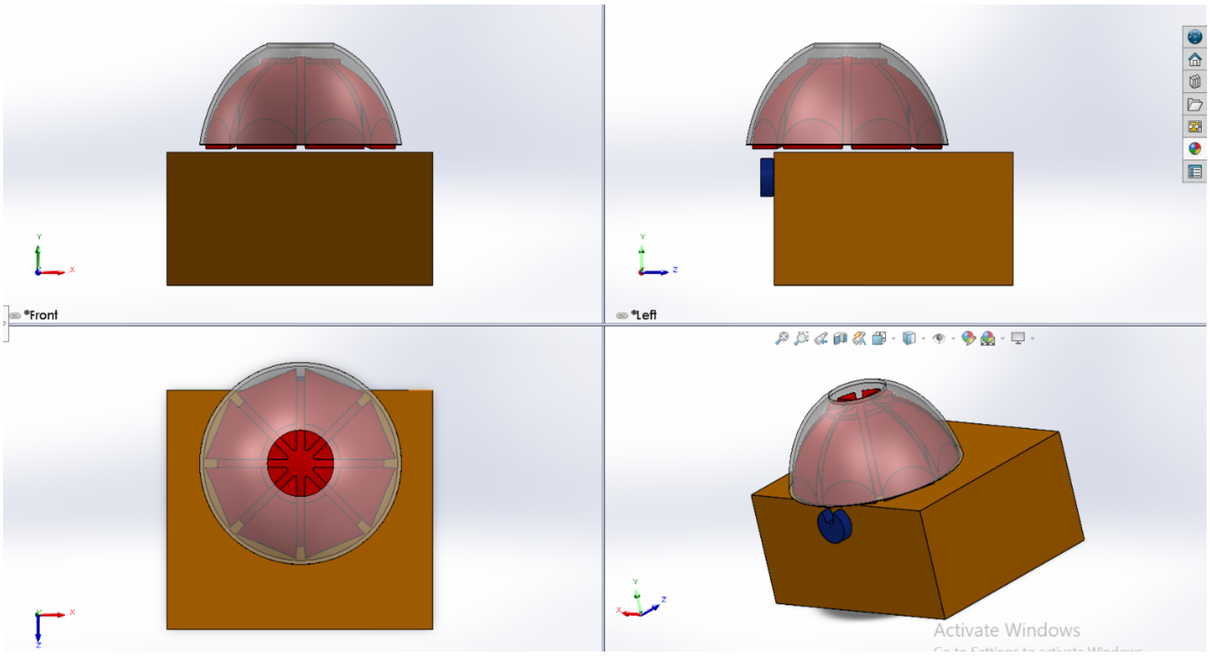


Fig 4: Precision in Medication Dosage

Fig 4 showcases the rotating mechanism of the dispenser box is a testament to the thoughtful integration of technology into healthcare solutions. This innovative design not only enhances the functionality of the Smart Pill Dispenser but also contributes to the overall user experience. Patients and caregivers alike benefit from the streamlined and secure pill dispensing process facilitated by the rotating dispenser box. Its user-friendly nature aligns with the overarching goal of making medication management more accessible and efficient for individuals with diverse healthcare needs.

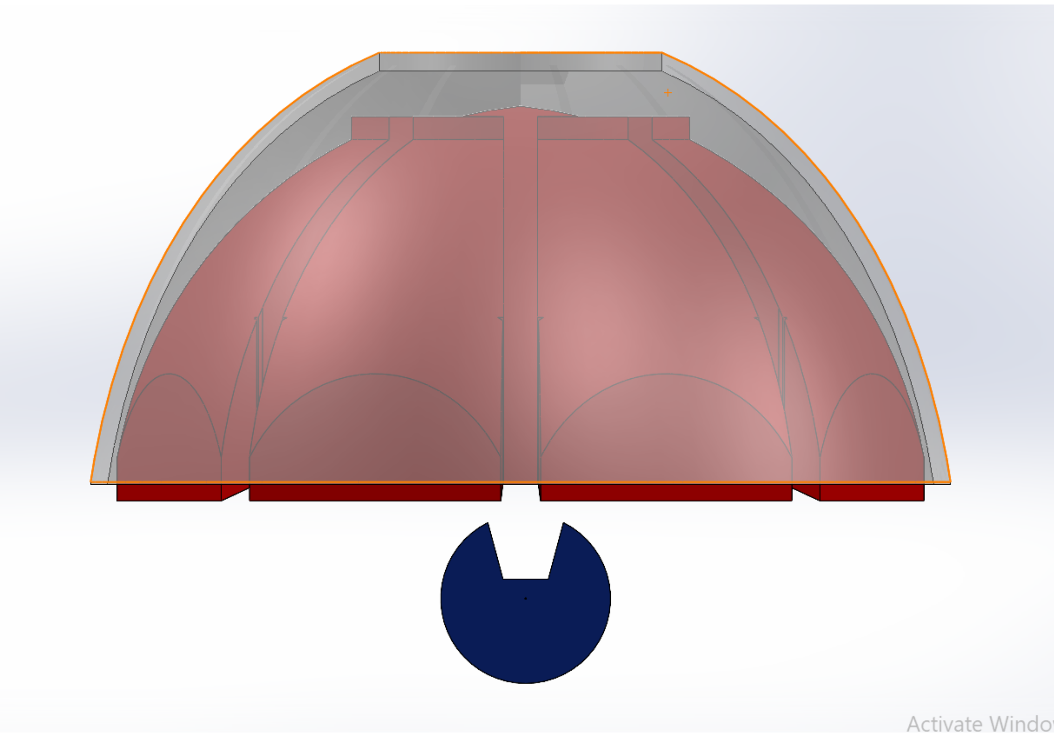


Fig 5: Collective image

Fig 5 is further examining the intricacies of our Smart Pill Dispenser 3D model, particular attention is drawn to the user interface (UI) of the dispenser box. The interface serves as the bridge between individuals and the advanced technology, prioritizing accessibility and ease of use. Marked by intuitive controls and a clear display, the UI empowers users with straightforward interactions. This thoughtful design choice ensures that individuals of varying technological aptitudes can navigate the Smart Pill Dispenser seamlessly. By prioritizing user-friendliness, our 3D model aims to enhance the overall experience, making medication management not only technologically advanced but also inclusive and user-centric. As we delve deeper into refining this aspect of the model, our commitment remains steadfast in creating a harmonious synergy between cutting-edge technology and user accessibility in the realm of healthcare solutions.

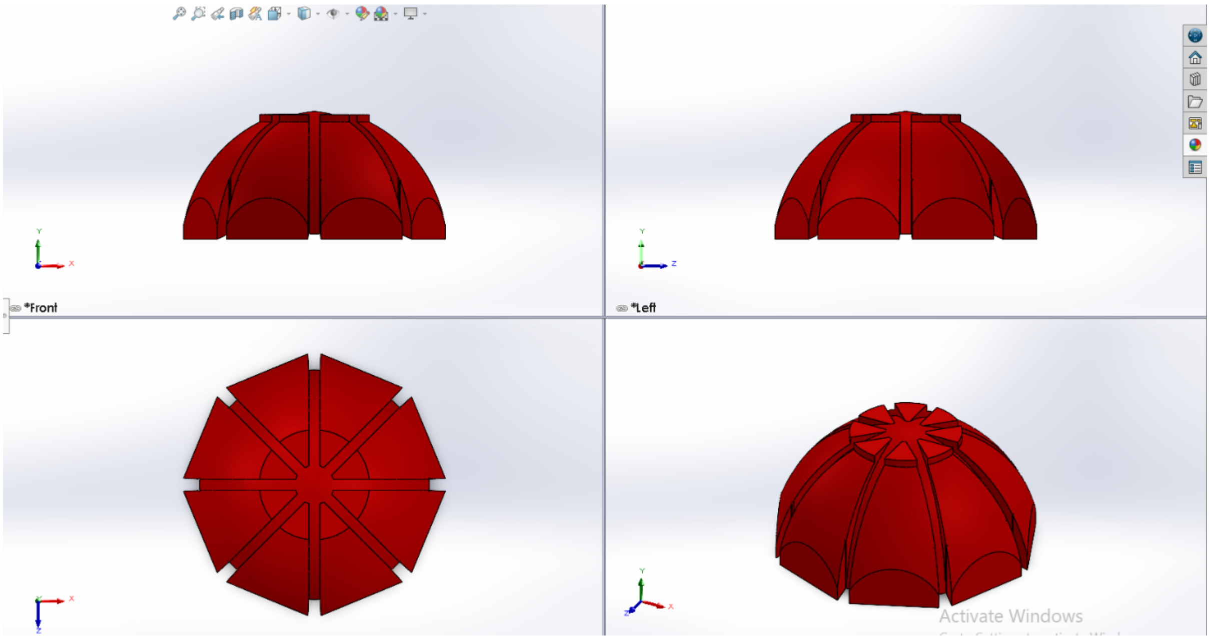


Fig 6: The Smart Pill Dispenser's Rotating Dispenser Box Redefining Medication Dosage Precision

In essence, the snapshots of our 3D model capture the essence of a transformative approach to medication dispensing. The rotating dispenser box stands as a symbol of precision and technological prowess, embodying the commitment to advancing healthcare solutions. As we continue to refine and develop this 3D model, the aim is to bring about positive changes in medication adherence, ensuring a seamless and secure experience for individuals relying on this innovative Smart Pill Dispenser.

Conclusion

The revolutionary Smart Pill Dispenser(SPD), incorporating biometric authentication, stands as a lamp of pledge in addressing the pervasive challenge of drugnon-adherence within healthcare systems. By guaranteeing the secure and precise allocating of specifics, this innovative device not only amplifies treatment efficacity but also significantly contributes to the overall well- being of cases.

In charting the course for unborn advancements, exploration trials should claw into the realms of slice- edge biometric technologies, exploring new authentication styles that can further fortify the SPD's capabilities. also, flawless integration into the Internet of effects(IoT) geography is pivotal, propelling the SPD beyond a bare dispenser to a comprehensive health operation system, fostering nonstop monitoring and data- driven perceptivity.The application of prophetic analytics adds another subcaste of complication, allowing the SPD to proactively identify implicitnon-adherence patterns and optimize drug rules. A global perspective is imperative, icing that the SPD adapts seamlessly to different healthcare systems and socioeconomic surrounds, promoting universal availability without compromising effectiveness.Ethical considerations and robust fabrics should bolster these technological advancements, icing responsible deployment and securing patient sequestration. Long- term health issues must be a focal point of exploration, furnishing a nuanced understanding of the SPD's impact on patient health and healthcare costs over extended ages.In substance, the SPD marks a significant stride in revolutionizing drug adherence, holding immense eventuality to appreciatively impact cases on a global scale. Through a multidimensional approach encompassing technological invention, ethical considerations, and expansive exploration, the SPD emerges not simply as a dispenser but as a transformative force in healthcare delivery and case issues

Future works

Claw into the van of biometric authentication, pushing technological boundaries to fortify the security features and elevate the stoner experience within the Smart Pill Dispenser(SPD) sphere. contemporaneously, map the development of comprehensive IoT integration styles, fostering not only a flawless connection but also enabling a wide diapason of health monitoring capabilities and easing fluid data sharing. influence the capabilities of machine literacy and prophetic analytics to not just reply but proactively identify nuancednon-adherence patterns, paving the way for a meliorated and substantiated approach to drug operation. On the global scale, knitter SPDs to accommodate the intricate shade of different healthcare systems and varied socioeconomic surrounds, thereby icing universal availability and efficacity. Embark on exploration trials to strictly estimate the enduring impacts of SPD application on both patient health issues and healthcare costs, furnishing a robust foundation for continual refinement and wide relinquishment.

References

https://www.researchgate.net/publication/370235347_SMART_PILL_REMINDER_BOX

https://www.researchgate.net/publication/329299641_Smart_drugsImproving_Healthcare_using_Smart_Pill_Box_for_Medicine_Reminder_and_Monitoring_System https://www.researchgate.net/publication/356964590_The_smart_pill_sticker_Introducing_a_smart_pill_management_system_based_on_touch-point_technology

Reeder, B., Demers, C., Mateo, K. F., & Marengo, L. (2013). Mobile health solutions for medication adherence. mHealth, 9, 12.

Dayer, L., Heldenbrand, S., Anderson, P., Gubbins, P. O., & Martin, B. C. (2013). Smartphone medication adherence apps: Potential benefits to patients and providers. Journal of the American Pharmacists Association, 53(2), 172-181.

Jain, A. K., & Dass, S. (2004). Evaluating biometric systems. Communications of the ACM, 47(1), 38-44.

Márquez Contreras, E., de la Figuera von Wichmann, M., Gil Guillén, V., Ylla-Catalá, A., Figueras, M., Balaña, M., ... & Arenas, L. (2013). Effectiveness of an intervention to provide information to patients with hypertension as short text messages and reminders sent to their mobile phone (HTA-Alert). Aten Primaria, 45(5), 262-269.

World Health Organization. (2003). Adherence to Long-Term Therapies: Evidence for Action. Geneva: WHO.

Ohm, P. (2010). Broken promises of privacy: Responding to the surprising failure of anonymization. UCLA Law Review, 57, 1701-1777.

Allemann, S. S., Nieuwlaat, R., Navarro, T., Haynes, B., & Hersberger, K. E. (2014). Addressing competitive interests and needs in clinical trial recruitment of drug adherence trials. Trials, 15(1), 135.

Liu, Y., Thompson, M., Huh, J., & Cho, J. (2015). Quantifying medication adherence in the digital age. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 217-226).

Roter, D. L., Hall, J. A., & Merisca, R. (1998). Effectiveness of interventions to improve patient compliance: A meta-analysis. Medical Care, 36(8), 1138-1161.

Dayer, L., Heldenbrand, S., Anderson, P., & Gubbins, P. O. (2013). The use of the medication event monitoring system (MEMS) for evaluating medication adherence and comparing generic formulations. Current Clinical Pharmacology, 8(1), 1-11.

Hassan, A. E., & Mouttham, A. (2017). A comprehensive study of the fingerprint recognition technology. IEEE Access, 5, 10750-10770. [Read on IEEE Xplore]

Clifford, G., & Larg, A. (2003). Signal quality in biometric signals. Physiological Measurement, 24(2), 217-232. [Read on IOPscience]

Nieuwlaat, R., Wilczynski, N., Navarro, T., Hobson, N., Jeffery, R., Keepanasseril, A., ... & Haynes, R. B. (2014). Interventions for enhancing medication adherence. Cochrane Database of Systematic Reviews, 11. [Read on Cochrane Library]

Suresh, D., Gowda, A. B. S., & Rajagopal, A. (2016). Biometric authentication systems: A survey. Journal of Computing and Security, 1(2), 65-84. [Read on ResearchGate]