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Université de Ghardaïa
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Department of Automatic and Electromechanics

Master's Thesis:

Smart Medication and Nutrition Management Refrigerator for Hospital and Home Use

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Abstract

The "Smart Medication and Nutrition Management Refrigerator" is an advanced solution for hospitalized and home patients. This compact refrigerator uses technology to manage medication timings, dosages, and meal schedules. Its user-friendly interface phone (for desktop also) app allows easy programming and tracking of medication and dietary plans. Key features include automated medication dispensing, reminders for meals and hydration, and real-time monitoring via a mobile app. The project aims to improve patient compliance, reduce medication errors, and enhance well-being by integrating smart notifications and technology into it, thus enhancing healthcare delivery and patient outcomes.

Key words: Smart refrigerator, patient, medication, nutrition, medication errors

ملخص:

الثلاجة الذكية لإدارة الأدوية والتغذية هي حل مطور مقدم لرعاية المرضى داخل المستشفيات والمنازل. تَستخدم هذه الثلاجة تكنولوجيا متقدمة مدمجة لإدارة مواقيت الأدوية، البرنامج الغذائي، وكذا كمية الجرعات. تتيح واجهتها سهلة الاستخدام وتطبيقها على الهاتف (والكمبيوتر أيضًا) برمجة ومتابعة الجرعات والنظام الغذائي لمقدمي الرعاية الصحية. تشمل الميزات الرئيسية توزيع الآلي للأدوية، التذكير بالوجبات، والمراقبة في الوقت الفعلي عبر التطبيق الالكتروني. يهدف المشروع إلى تحسين التزام المرضى وتقليل الأخطاء الطبية وتعزيز الرفاهية، مما يعزز تقديم الرعاية الصحية ونتائج المرضى.

الكلمات المفتاحية: الثلاجة الذكية، رعاية المرضى، النظام الغذائي، الأدوية، الأخطاء الطبية

LISTE OF FIGURES

Abbreviations

DPP-4: Dipeptidyl peptidase-4, an enzyme involved in the regulation of glucose metabolism by inactivating incretin hormones

GLP-1: Glucagon-like peptide-1, an incretin hormone that helps regulate glucose levels by stimulating insulin secretion and inhibiting glucagon release.

SGLT2: Sodium-glucose cotransporter-2, a protein responsible for glucose reabsorption in the kidneys.

CGM: Continuous Glucose Monitoring, a method of tracking glucose levels in real-time throughout the day and night.

CNNs: Convolutional Neural Networks, a type of artificial neural network often used for image recognition and classification tasks.

DR: Diabetic Retinopathy, a complication of diabetes affecting the eyes.

GANs: Generative Adversarial Networks, a type of machine learning framework where two neural networks compete against each other to generate new data that is similar to a given dataset.

RFIS : Retinal Fundus Image Segmentation

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General introduction

General introduction

Modern technology is revolutionizing the management of chronic diseases, significantly enhancing the quality of life for patients. The rapid proliferation of health care apps and smart devices enables patients to monitor their symptoms, adhere to medication schedules, and maintain communication with healthcare providers without frequent clinic visits. These advancements allow for precise self-monitoring of vital signs, remote support through video messages and text conversations, and access to reliable educational resources about chronic diseases. [1,2]

One chronic disease that has seen remarkable progress in management due to technological advancements is diabetes mellitus. Diabetes is characterized by high blood sugar levels due to inadequate insulin production or ineffective insulin action. Historically, diabetes has been a significant health issue, presenting numerous challenges to healthcare systems worldwide. The evolution of diabetes treatment from ancient herbal remedies to modern technologies offers valuable insights into current management practices. [3]

A noteworthy innovation in this field is the "Smart Medication and Nutrition Management Refrigerator," designed to enhance healthcare delivery for both hospitalized individuals and those receiving care at home. This compact refrigerator integrates advanced technology to regulate the timing and quantities of medications, as well as the scheduling of meals and hydration. Equipped with a user-friendly interface, it allows healthcare providers and patients to program medication schedules and dietary plans effortlessly. Key features include automated dispensing of medications at specified times, reminders for meal and hydration times, and real-time monitoring through a connected mobile application.

This exploration will delve into the historical context and latest innovations in diabetes care, showcasing how medical science and technology have transformed the prognosis and management of this prevalent disease. Additionally, it will address the risk factors and economic implications associated with diabetes. By examining the past and present landscapes of diabetes treatment, we can appreciate the ongoing efforts to improve patient outcomes and quality of life for those living with diabetes.

Chapter 1**:** explore a concise overview of diabetes, covering its historical evolution, complications associated with the disease, the latest advancements in treatment technology, as well as key statistics and risk factors related to diabetes.

Second chapter explores diabetes management through innovative technologies like the smart refrigerator with automated care systems. It highlights challenges such as cost and data security while emphasizing benefits like improved medication adherence and enhanced patient well-being. Detailed are the construction methods involving advanced materials and electronic components, along with the system's operational workflow from drug storage to real-time monitoring. Ultimately, these technologies aim to revolutionize healthcare by offering comprehensive support and improving the quality of life for patients managing chronic conditions like diabetes.

Finaly, the integration of smart technology is explored in chapter 3, such as the smart refrigerator system, in diabetes management to enhance patient care, medication adherence, and health outcomes. It details how smart refrigerators benefit both home and hospital settings by ensuring safe drug storage, inventory tracking, and patient medication reminders. Recommendations include user training, security measures, and cost reduction strategies to optimize system effectiveness. Future perspectives highlight advancements in AI, telehealth capabilities, and global health impact, promising personalized diabetes management and improved healthcare delivery worldwide.

Chapter 01

State of art on automatic care of patients, particularly diabetes

1.1 Introduction

Modern technology plays a vital role in helping chronic disease patients follow their condition and improve their quality of life. As the number of apps and smart devices dedicated to health care increases, patients can monitor their symptoms, take their medications, and communicate with their doctors without the need for frequent visits to clinics. Modern technology allows accurate self-monitoring of vital signs such as blood pressure and blood sugar level, with the possibility of sharing this data with a doctor. Applications contribute to reminding patients when to take their medications, and provide remote support through video messages and text conversations. Sources of education and education also provide reliable information on chronic diseases and their management methods. [4,5]

Diabetes, also known as diabetes mellitus, is a chronic metabolic disorder characterized by elevated levels of glucose in the blood (high blood sugar) due to inadequate insulin production, ineffective insulin action, or both. Throughout history, diabetes has been a significant health problem affecting millions of people worldwide and posing significant challenges to healthcare systems. [6]

The treatment of diabetes has evolved significantly over time, from ancient herbal remedies to modern technological advancements. Understanding the historical context and the evolution of treatment modalities provides valuable insights into the current approach to managing this complex condition.

In this overview, we will explore key historical events and the latest innovations in diabetes care, illustrating how advances in medical science and technology have transformed the management and prognosis of this prevalent disease. We will also discuss the risk factors associated with diabetes and the economic implications it imposes on individuals and societies.

By examining the past and present landscape of diabetes treatment, we can gain a deeper understanding of ongoing efforts to improve patient outcomes and enhance the quality of life for those living with diabetes. [7]

1.2 History of diabetes treatment

Throughout history, diabetes treatment has evolved in many stages, each contributing to improving patients' quality of life and increasing our understanding of the disease.
In ancient times, civilizations such as Egyptians, Indians and Chinese have resorted to the use of herbs and plants to relieve the symptoms of diabetes. Historical documents, such as the Egyptian Eppers papyrus dating back to 1550 BC [8], included recipes for herbal treatments that help treat excessive urination, which we now know is a symptom of diabetes. In India, ancient doctors used Ayurvedic medicine that involves the use of certain plants such as turmeric and beauty to relieve symptoms and improve patients' condition.

During the 19th century, treatment methods underwent a major shift as doctors began to focus on diet control. It was then believed that reducing carbohydrate intake and increasing protein and fat consumption could help control blood sugar levels. This approach was an important step towards understanding the relationship between food and diabetes management, and represents the beginning of more effective shifts in disease management [9].

The great transformation came in the early 20th century, with the discovery of insulin in 1921 by Canadian scientists Frederick Bunting and Charles Best. The discovery of insulin was a major turning point in the treatment of diabetes, enabling effective control of blood sugar levels and saving the lives of millions of type 1 diabetics, whose lives were significantly threatened before this discovery. Before the discovery of insulin, treatment options were very limited, and often included a harsh diet that lacked a lot of essential nutrients [10,11].

In the mid-to-late twentieth century, medical technology experienced major developments. Different types of insulin emerged, which were characterized by different working periods, allowing doctors and patients to allocate the treatment more accurately. In addition, blood sugar measurements have been developed, helping patients to monitor blood sugar levels themselves and regularly. This improvement in self-surveillance has had a significant impact on improving disease management and reducing its complications [12,13].

In terms of oral medicines, sulfonyl urea and metformin have been developed, two drugs that help improve the body's response to insulin and reduce blood sugar levels. These drugs represented an important step in the treatment of type 2 diabetes patients, who do not rely on insulin as much as type 1 patients.

In the 21st century, medical innovations continued to improve the lives of diabetics. Recent drugs have emerged such as DPP-4 inhibitors, which increase levels of hindrin hormones that help regulate blood glucose levels, GLP-1 agonists, which help promote insulin secretion and reduce glucagon secretion, and SGLT2 inhibitors, which help eliminate excess glucose through the kidneys. In addition to these drugs, insulin pump technology and continuous sugar monitors (CGM), which give patients the ability to better control blood sugar levels around the clock, have emerged, reducing the risk of sharp highs and lows in sugar level [14:17].

1.3 Complications of diabetes

Genetic factors such as family history are important factors that increase diabetes risk. If you have first-class relatives such as parents or brothers with diabetes, your likelihood of getting sick is higher. Besides, excess weight or obesity are prominent factors contributing to the development of diabetes, where the distribution of body fat plays a critical role; Fat accumulated around the abdomen is more dangerous than fat accumulated around the hips. Lack of physical activity also increases the risk of diabetes, as physical activity helps regulate blood sugar levels and enhances the effectiveness of insulin [18,19].

Regarding diabetes as a risk factor for hospitalization due to COVID-19, a systematic review of 300 studies showed that individuals with diabetes have a 3.6 times higher likelihood of hospitalization due to COVID-19 than non-people. These results are partly explained by differences in age and sex distribution between groups, and the presence of comorbidities such as cardiovascular disease and chronic kidney disease. However, even after adjusting for these factors, diabetes remained an independent indicator of hospitalization, with people with diabetes 1.7 times more likely to be hospitalized than those without [20,21].

Economically, diabetes imposes a significant burden on states, health systems, individuals with diabetes, and their families. The direct costs of diabetes include health expenses incurred by sufferers, whether paid out of their own pockets or by private or public billing payers, including governments [22,23].

1.4 Diabetes Statistics

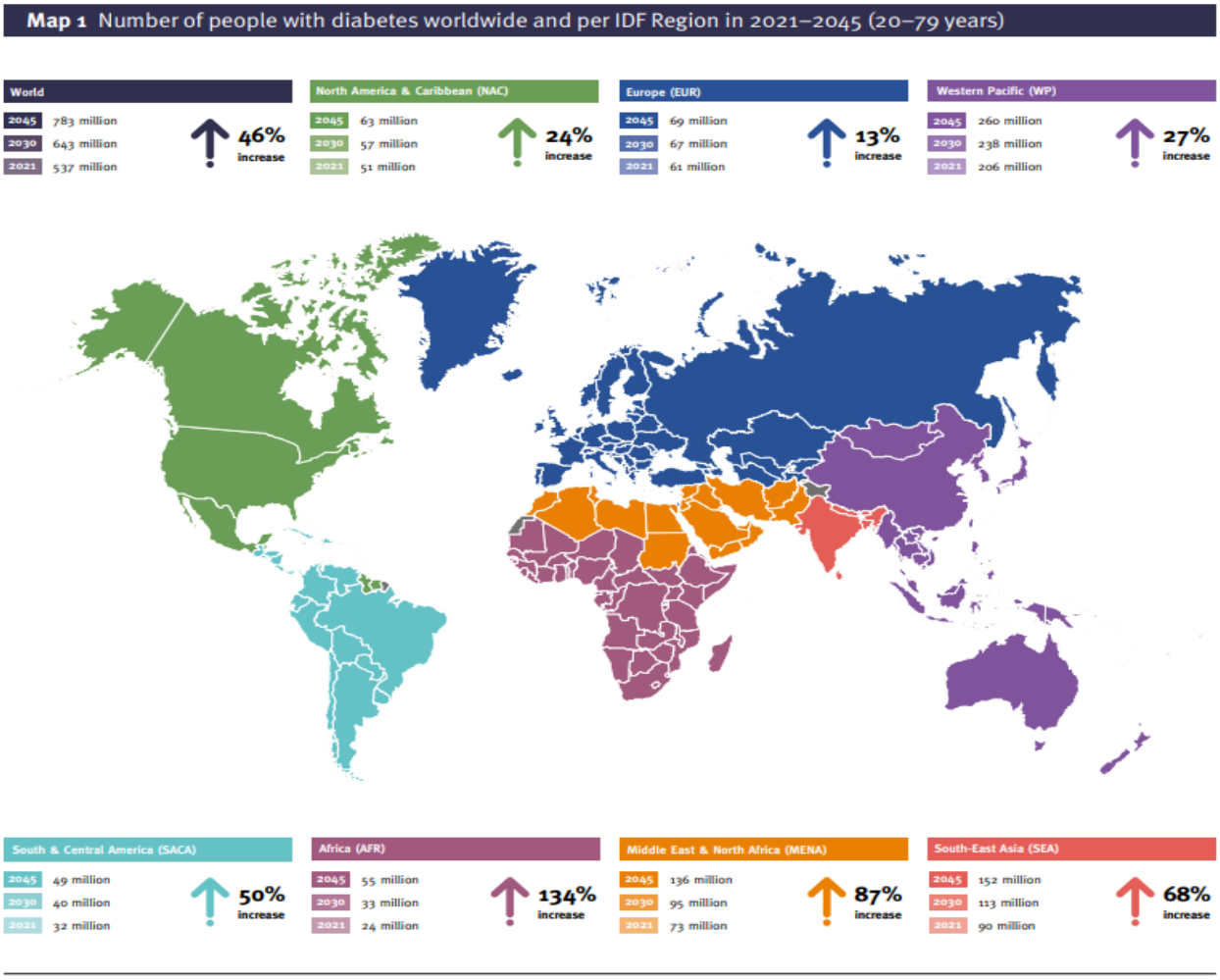

FIGURE 1.1: PREVALENCE OF DIABETES [24]

The image shows that diabetes is widespread throughout the world, but prevalence rates vary between regions. For example, in 2021, 10.5% of adults (20-79 years) worldwide had diabetes, but this proportion was 16.4% in the Middle East and North Africa region, and 13.6% in the Southeast Asia region.

Expected increase: The picture also shows that the number of diabetics is expected to increase in all regions in the coming years. For example, the number of diabetics in the MENA region is expected to rise from 73 million people in 2021 to 136 million people in 2045, an increase of 87%.

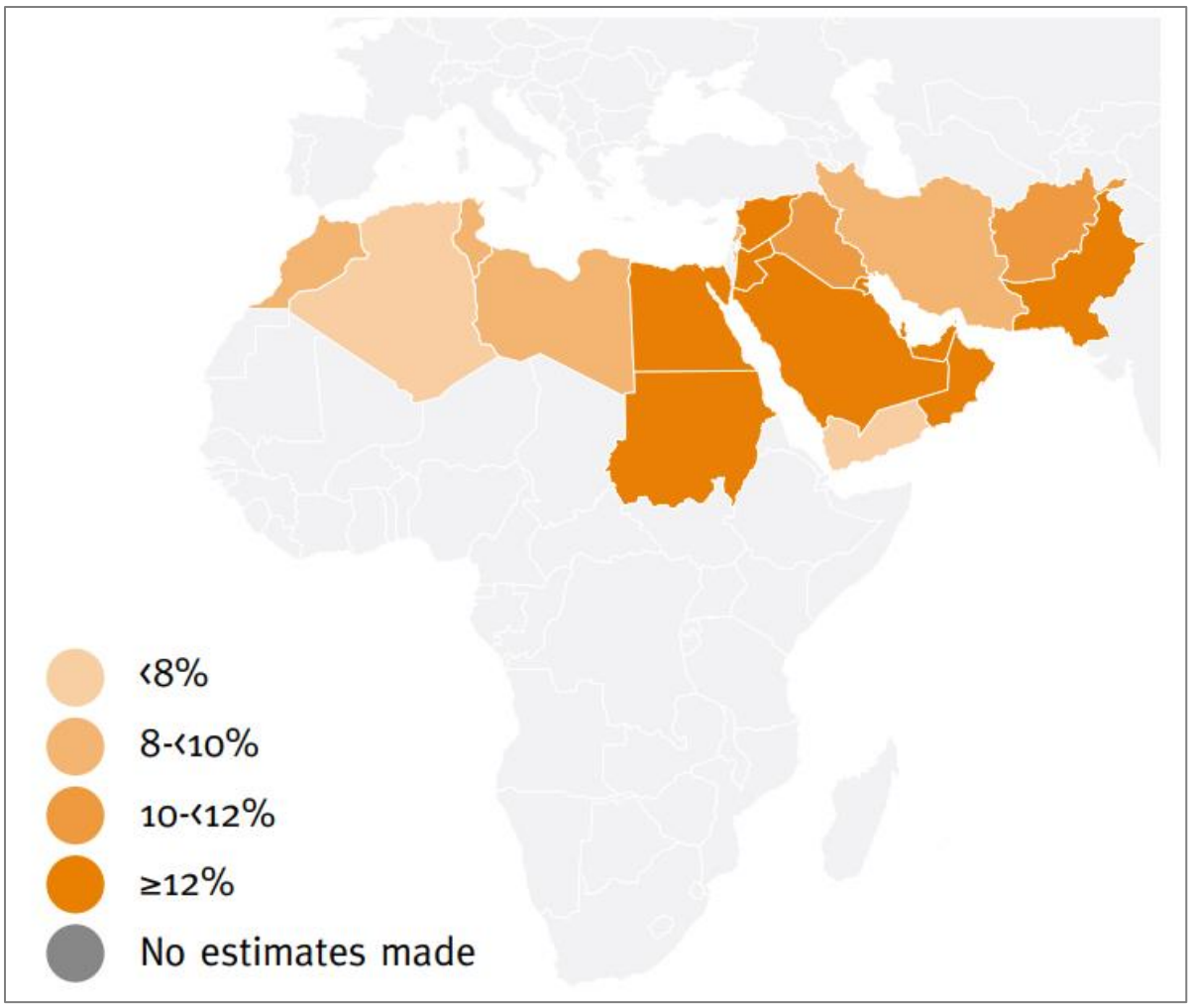

FIGURE 1.2: AGE-ADJUSTED COMPARATIVE PREVALENCE OF DIABETES (20-79 YEARS) IN IDF MIDDLE-EAST AND NORTH AFRICA REGION IN 2021 [24]

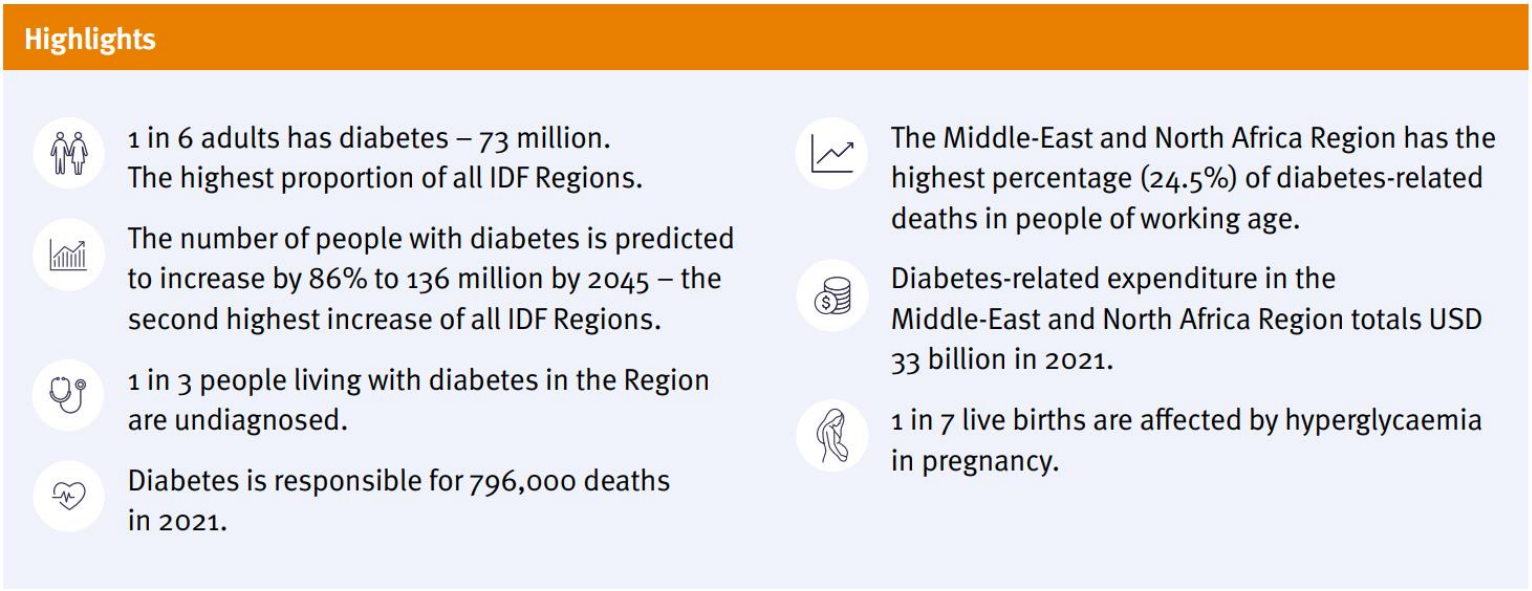

FIGURE 1.3: THE IMAGE PROVIDED PRESENTS A SNAPSHOT OF THE GLOBAL PREVALENCE OF DIABETES AND ITS ASSOCIATED ECONOMIC BURDEN [24]

1. Diabetes Prevalence

- **Widespread Distribution:** Diabetes is a global health issue, affecting millions worldwide. The image shows that the prevalence of diabetes varies across regions, with the Middle East and North Africa (MENA) region having the highest proportion of diabetes-related deaths among working-age adults.
- **Expected Increase:** The image projects a significant rise in the number of people with diabetes by 2045, with the MENA region experiencing the second-highest increase globally.

2. Economic Impact:

- **Direct Expenditures:** Diabetes-related healthcare costs are substantial, reaching USD 33 billion in the MENA region in 2021.
- **Undiagnosed Cases:** A significant proportion of people with diabetes remain undiagnosed, hindering effective management and contributing to the overall economic burden.

3. Additional Insights:

- **Hyperglycemia in Pregnancy:** The image highlights the impact of diabetes on maternal health, with one in seven live births affected by hyperglycemia in pregnancy.
- **Diabetes-Related Deaths:** Diabetes is a leading cause of mortality, accounting for 796,000 deaths in 2021.

1.5 Method and material

1.5.1 Deep Learning Algorithms

- Convolutional Neural Network :CNNs are widely used for DR detection due to their ability to automatically learn features from images. Models such as EfficientNet and ResNet have been fine-tuned using transfer learning techniques to improve accuracy in detecting and grading DR from retinal images.
- Generative Adversarial Networks: GANs are employed to enhance the quality of retinal images and generate synthetic data to augment training datasets. This helps improve the robustness and accuracy of detection models.

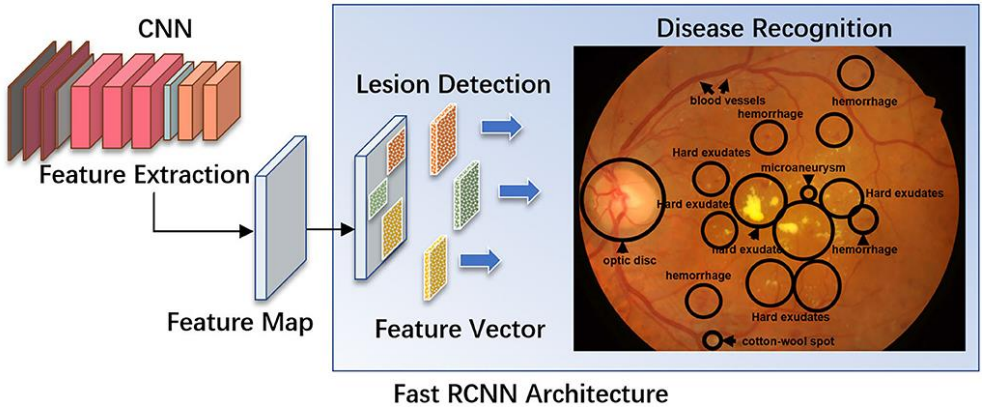

FIGURE 1.4: AN OVERVIEW OF ARTIFICIAL INTELLIGENCE IN DIABETIC RETINOPATHY AND OTHER OCULAR DISEASES (FRONTIERSIN.ORG)

1.5.2 Image Processing Techniques

- Segmentation: Accurate segmentation of retinal images is crucial. Techniques like retinal fundus image segmentation (RFIS) help isolate regions of interest such as blood vessels, microaneurysms, and exudates, which are critical indicators of DR.
- Feature Extraction: Features such as hemorrhages, exudates, and microaneurysms are extracted from segmented images using deep learning models. These features are then used to classify the severity of DR.

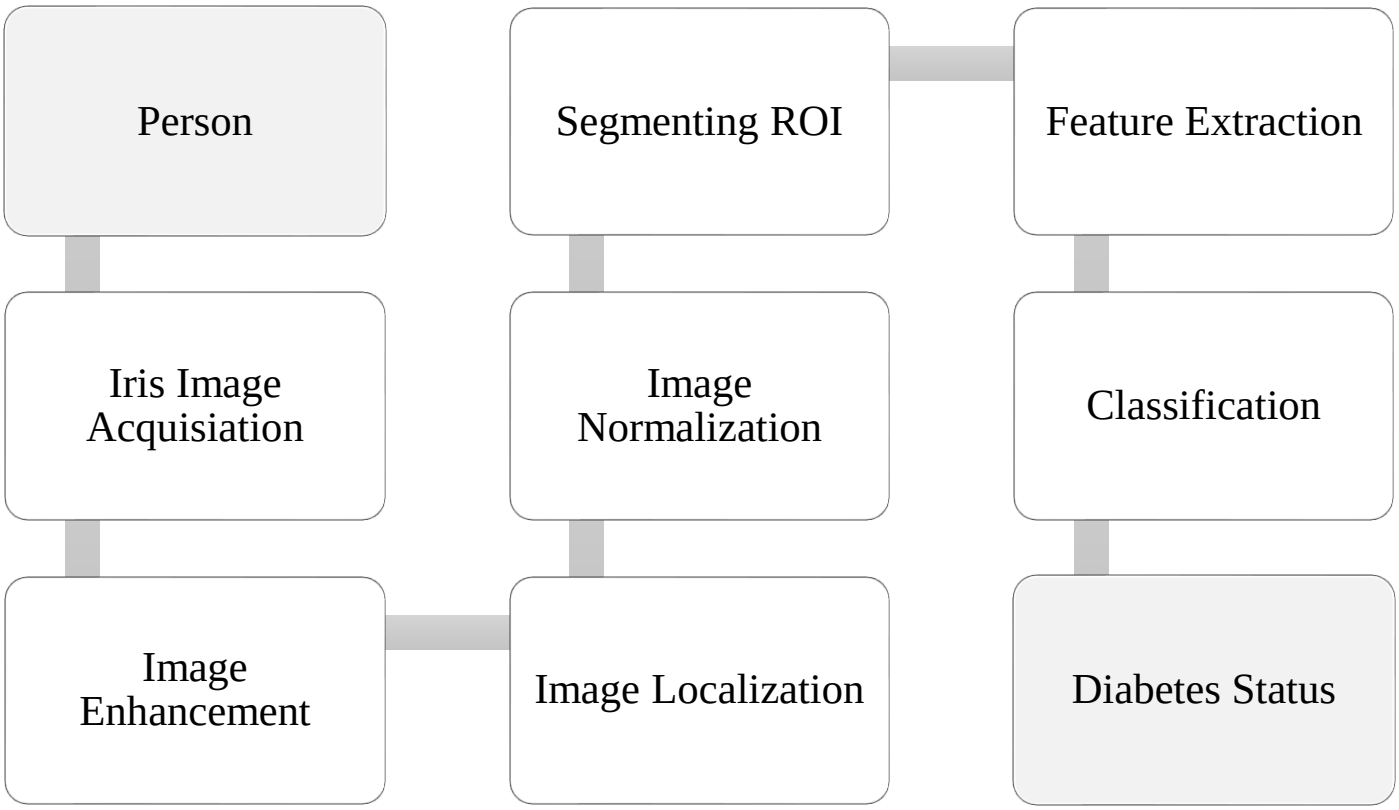

FIGURE 1.5: DIABETES PREDICTION SYSTEM BASED ON IRIDOLOGY USING MACHINE LEARNING (SEMANTIC SCHOLAR)

1.5.3 Continuous glucose monitors and insulin pumps

Basu is particularly interested in two diabetes management technologies, the continuous glucose monitor and the insulin pump.

Using a sensor on the arm or abdomen, a continuous glucose monitor, or CGM, provides readings to diabetics at continuous intervals throughout the day. These readings can be real-time or on-demand, whether the user chooses to get updates every five minutes or every few hours. The CGM sensor is usually changed every week or two.

An insulin pump is attached to the body, usually on the arm, abdomen, or near the hip, and can deliver insulin in a steady flow throughout the day, along with additional doses at mealtimes. Helps relieve the need for multiple insulin injections daily. Every two to three days, the user replaces the tube, refills the insulin cartridge, and moves the insulin pump to a different location [25].

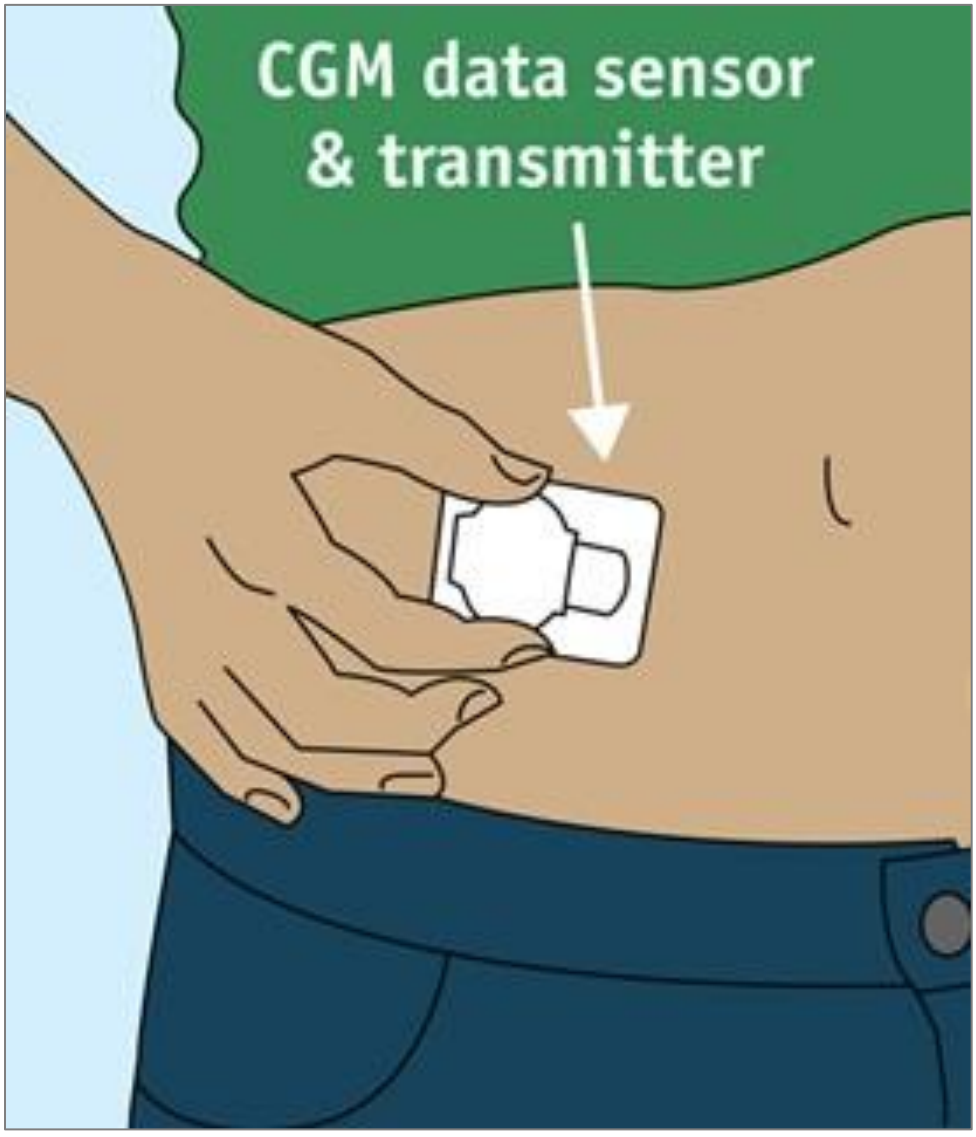

FIGURE1.6: CGM DATA SENSOR AND TRANSMITTER (UMASSMED.EDU)

1.5.4 Closed-loop insulin pumps

The insulin pump is connected to the body through a small tube known as a catheter. It is inserted directly under the skin. This insulin pump is battery operated and delivers a small amount of insulin throughout the day. The smartphone app controls and coordinates both the continuous CGM sensor and insulin pump well. This pump can also be manually controlled by the patient. One needs to self-inject insulin multiple times a day, which can be not only stressful but also psychologically exhausting, especially if the person has a needle phobia [26].

FIGURE 1.7: HYBRID CLOSED -LOOP SYSTEM ROLLOUT (DIABETESONTHENET.COM)

1.5.5 Remote Glucose Monitoring Devices

These devices allow patients and their doctors to remotely monitor blood sugar levels. These systems typically consist of a sensor placed under the skin to continuously measure glucose levels. The data is wirelessly transmitted to a receiver or a mobile app. In the event of significant changes in glucose levels, the system sends alerts and notifications via mobile apps or email to both patients and healthcare providers, enabling timely interventions and improved blood sugar management.

FIGURE1.8: REMOTE GLUCOSE MONITORING (CARESIMPLE.COM)

1.5.6 Insulin Injection Aids

These devices are designed to facilitate the insulin injection process and come in various types:

1.5.6.1 Automatic Insulin Injectors

These devices can deliver pre-programmed doses of insulin at specific times or based on real-time glucose readings, ensuring accurate and consistent insulin administration.

1.5.6.2 Injection Site Aids

These devices help identify the optimal injection sites on the body, using various methods such as markers or guides to ensure the injection is done in the correct spot, reducing the risk of complications and improving insulin absorption.

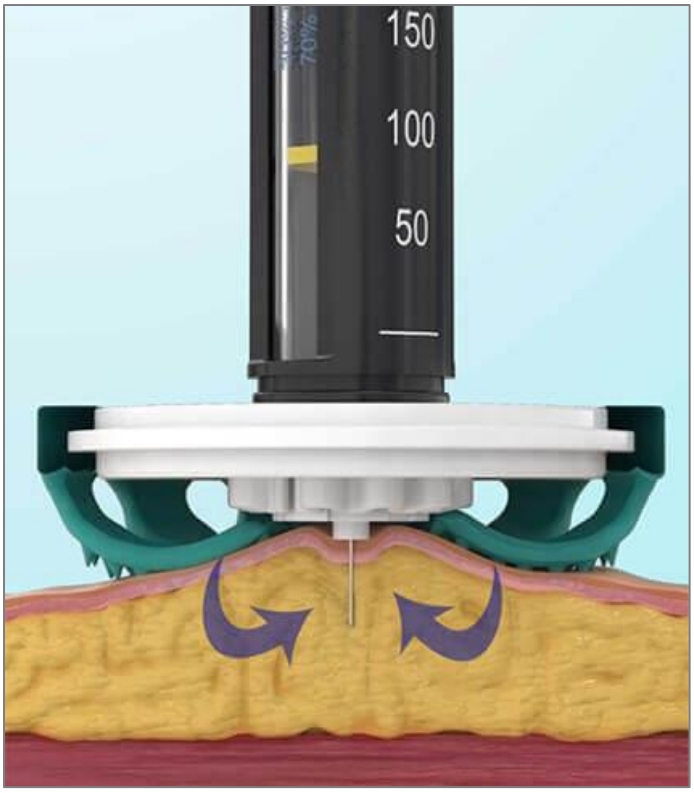

FIGURE1.9: INSULIN INJECTION AID PEOPLE WITH DIABETES (TICKLEFLEX.COM)

1.5.7 Smart Applications and Software

There are numerous applications and software designed to help patients manage diabetes more effectively. These tools typically offer the following features:

1.5.7.1 Blood Sugar Tracking

Patients can log their blood sugar levels, and the apps provide visual graphs and trends to help them understand their glucose patterns.

1.5.7.2 Diet and Nutrition Monitoring

Apps often include databases of foods and their nutritional content, allowing patients to track their meals and understand how different foods affect their blood sugar levels.

1.5.7.3 Physical Activity Tracking

Many apps integrate with fitness trackers to monitor physical activity, helping patients understand the impact of exercise on their blood sugar levels.

1.5.7.4 Reports and Guidance

The apps generate detailed reports that can be shared with healthcare providers. They also offer personalized tips and guidance based on the patient's data to improve diabetes management and control.

FIGURE 1.10: TREATMENT ECOSYSTEM (ELLOW.IO)

1.6 Conclusion

The journey of diabetes treatment has seen tremendous evolution throughout history, starting from ancient herbal remedies and advancing to modern technological innovations. Scientific breakthroughs, such as the discovery of insulin, have significantly enhanced the ability of doctors and patients to manage the disease more effectively. The 20th and 21st centuries witnessed significant developments in technologies and medications, making diabetes management more precise and comprehensive.

Despite these advancements, managing diabetes remains challenging due to genetic factors, obesity, and lack of physical activity. Therefore, the use of modern techniques such as remote glucose monitoring devices, insulin pumps, and smart applications is essential to improve patients' quality of life and reduce the risks of complications.

In general, continuous care, innovation, and comprehensive support are essential in improving diabetes care and enhancing patients' health.

Chapter 02

Modeling and creation of an automatic care system for diabetes

2.1 Introduction

Diabetes is one of the world's most prevalent chronic diseases, affecting millions of people. Although there is no definitive cure for this disease, it can be effectively controlled by a healthy diet, regular exercise and obligation to take medication in accordance with medical instructions. With rapid advances in health technology, innovative solutions have emerged to improve drug management for diabetics, including smart refrigerator with an automated care system. This technology promises to improve patients' commitment to their medicines and provide comprehensive support, contributing to improved disease management. However, this solution faces high-cost challenges, the need to ensure security and ease of use, and protect the privacy of patients' data, which must be addressed to ensure its success and widespread spread.

2.2 Construction Method

2.2.1 Main ingredients

- **Web application or mobile app (Figure 2.1/2.2):** allows patients to interact with the system.
- **Smart refrigerator (Figure 2.2):** equipped with temperature sensors, door sensors and weight sensors.
- **Database:** to store medicines and patients' information.
- **Alarm system:** inform patients or healthcare providers in case of problems.

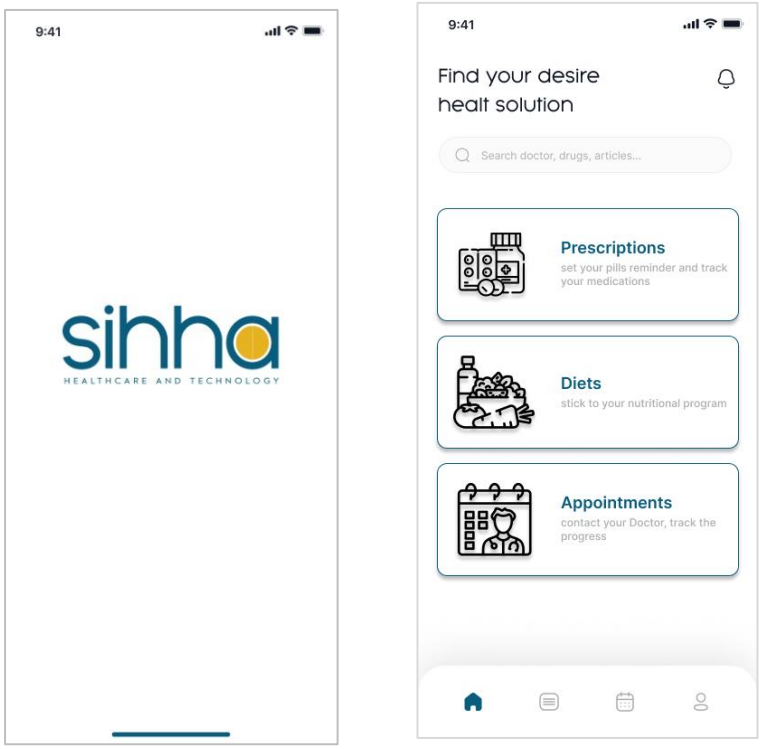

FIGURE 2.1: PHONE APP FOR PATIENT AND CAREGIVERS

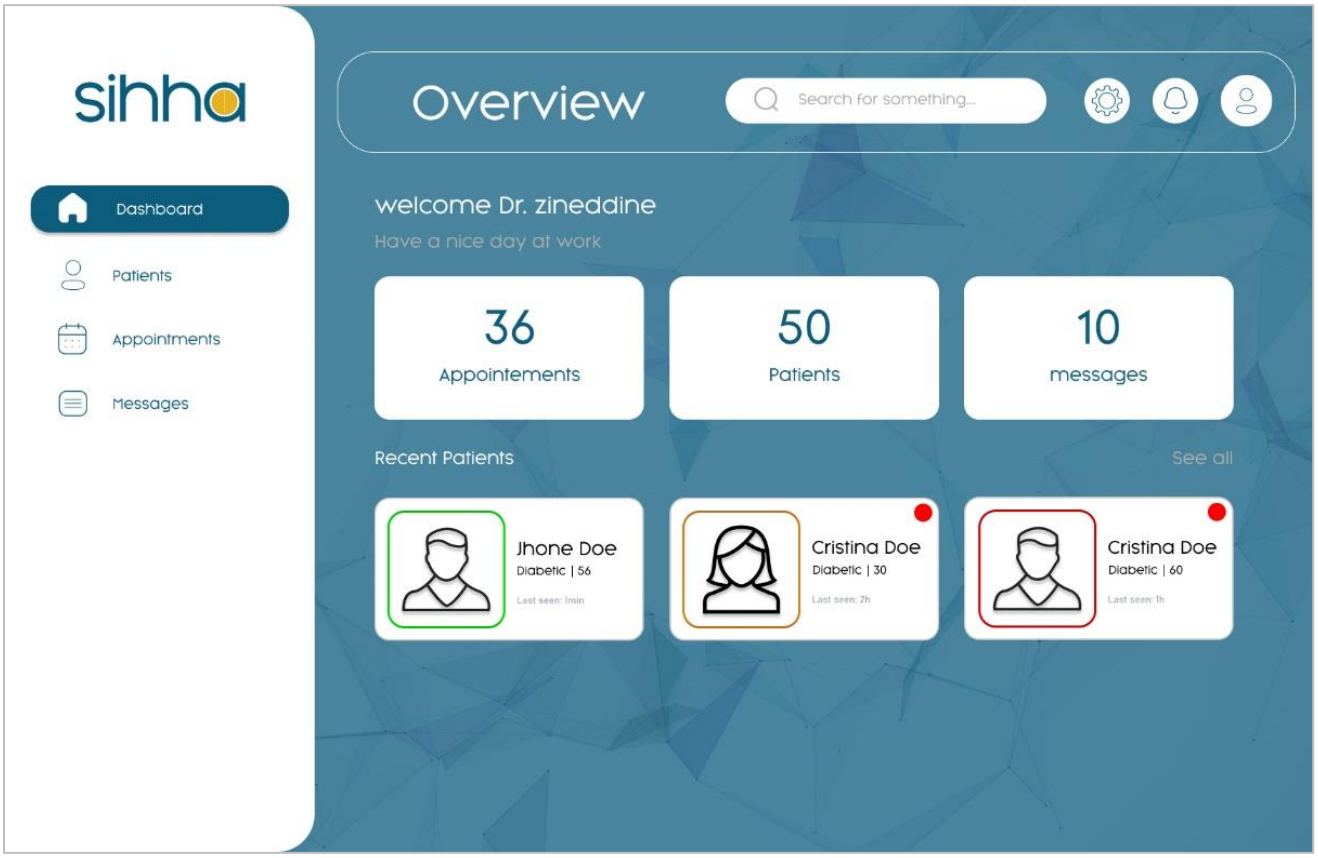

FIGURE 2.2: DESKTOP APPLICATION FOR DOCTORS TO HELP THEM TO PROVIDE THE BEST WITH THEIR CLIENTS

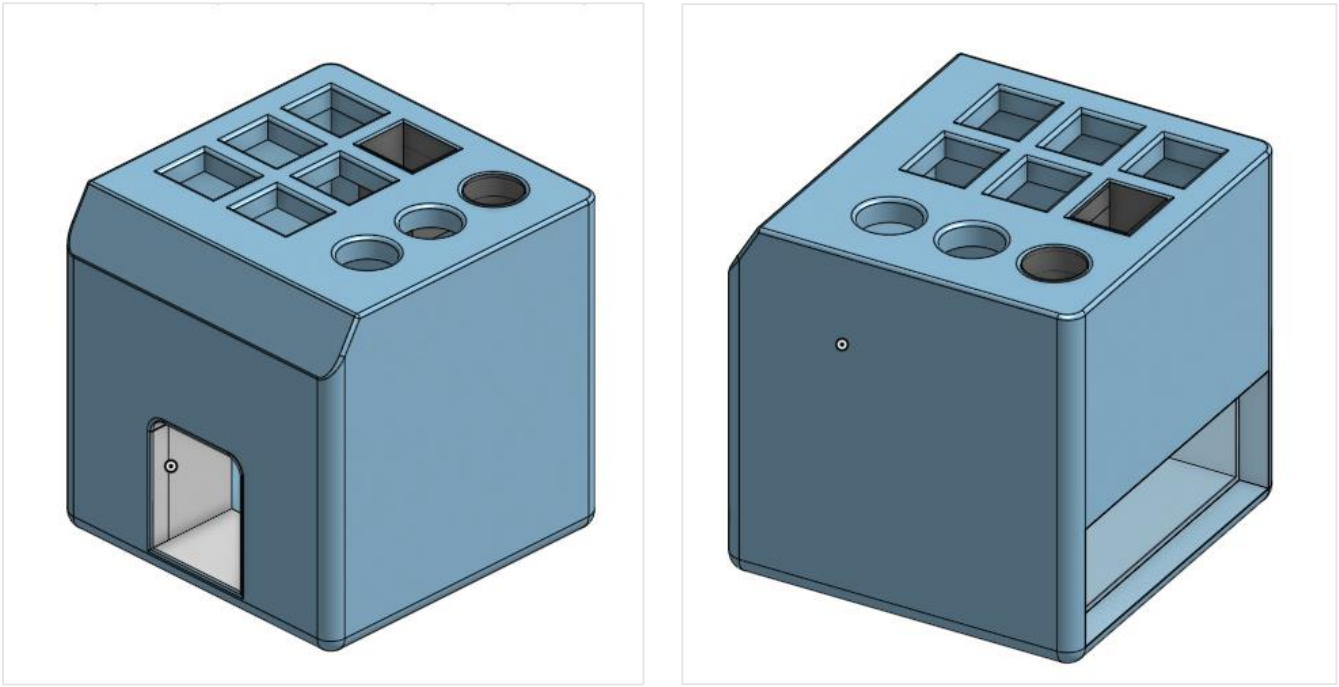

FIGURE 2.3: SMART MEDICATION AND NUTRITION MANAGEMENT REFRIGERATOR

2.2.2 Material

- **PLA (Polylactic Acid):** Biodegradable plastic material used to make the internal and external structure of the refrigerator.
- **Aluminum:** A lightweight, corrosion-resistant metal used to wrap the inside of the refrigerator to keep the air cool.
- **PCB board (printed circuit board) of FR4 material:** durable base to accommodate electronic components.

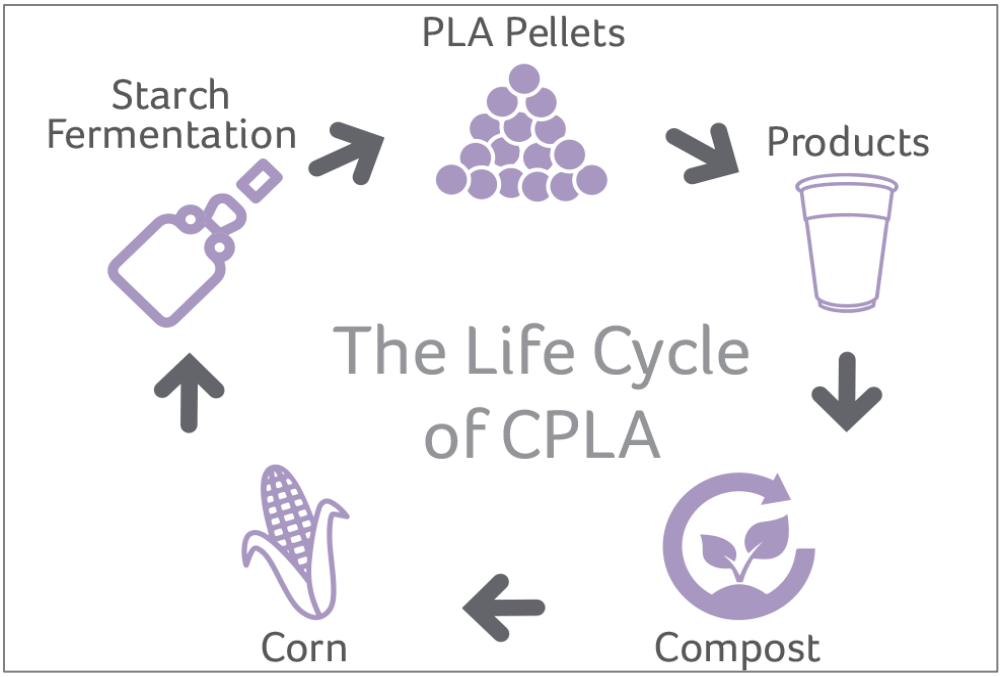

FIGURE 2.4: THE CYCLE OF PLA (KAELIS.WORLD)

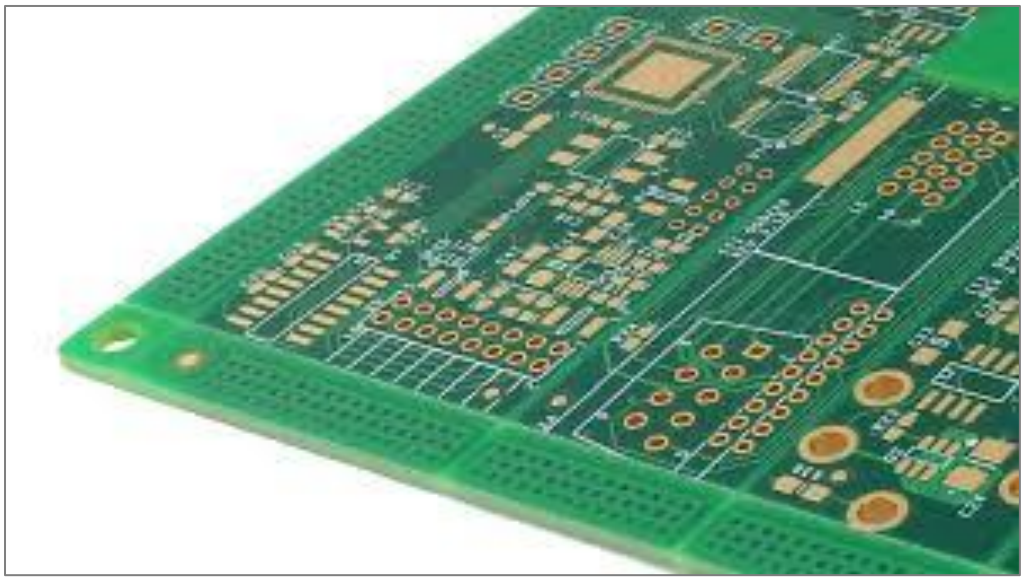

FIGURE 2.5: PCB PLATE EXAMPLE (ELEPCB.COM)

2.2.3 Electronic Components

- **Accurate controller (MCU):** The beating heart of the system, responsible for data processing and functioning execution.
- **Temperature sensors:** to monitor refrigerator temperatures and ensure ideal storage environment for drugs.
- **Weight sensors:** to track the quantity of remaining drugs and alert the user when need to restock.
- **Door sensors:** to monitor door openings and close them to maintain cooling efficiency.
- **Display screen:** to display information such as temperatures, drug levels, and alerts.
- **Keyboard or buttons:** to enter data and interact with the system.
- **Wireless Connection Unit:** to enable connectivity to smartphone app or remote monitoring system.
- **Electric motor:** to operate the cooling system.
- **Fan:** To distribute cold air inside the refrigerator.
- **Battery:** To save power to the system in case of power outage.

2.3 Steps to work

2.3.1 Drug Storage

- Diabetes medications are stored in a customized refrigerated compartment inside the smart refrigerator.
- Temperature sensors ensure that drugs are kept at ideal temperatures to ensure their effectiveness.
- Sensors monitor the patient's alarm when the quantity falls below a certain limit.

2.3.2 Drug Management

- Healthcare providers can add information about their medications to the database, including name, dosage, and frequency.
- Healthcare providers can monitor the levels of medications and track their history of taking medications through application.
- The system sends notifications to patients via the app or smart speaker to remind them when to take the next dose.

2.3.3 Medication Information

- The system provides detailed information on diabetes medications, including doses, and instructions for use.

2.3.4 Alerts

- The system alerts the patient in case of problems such as running out of medication, or not taking the dose on time.

2.3.5 Tele-care support

- Doctors and healthcare providers can monitor the progress of diabetes patients remotely through the system.
- Doctors can receive alerts about drug problems and modify treatment plans as needed.
- Patients can communicate with healthcare providers directly through the app.

2.4 Manufacturing Steps

2.4.1 Design

- Create a 3D model for refrigerator structure using CAD software (Figure 2.6 as an example).
- Microcontroller programming (MCU) to implement system functions (Figure 2.7 as an example).
- FR4 PCB panel design to fit electronic components (Autodesk Fusion 360 (Figure 2.8)).

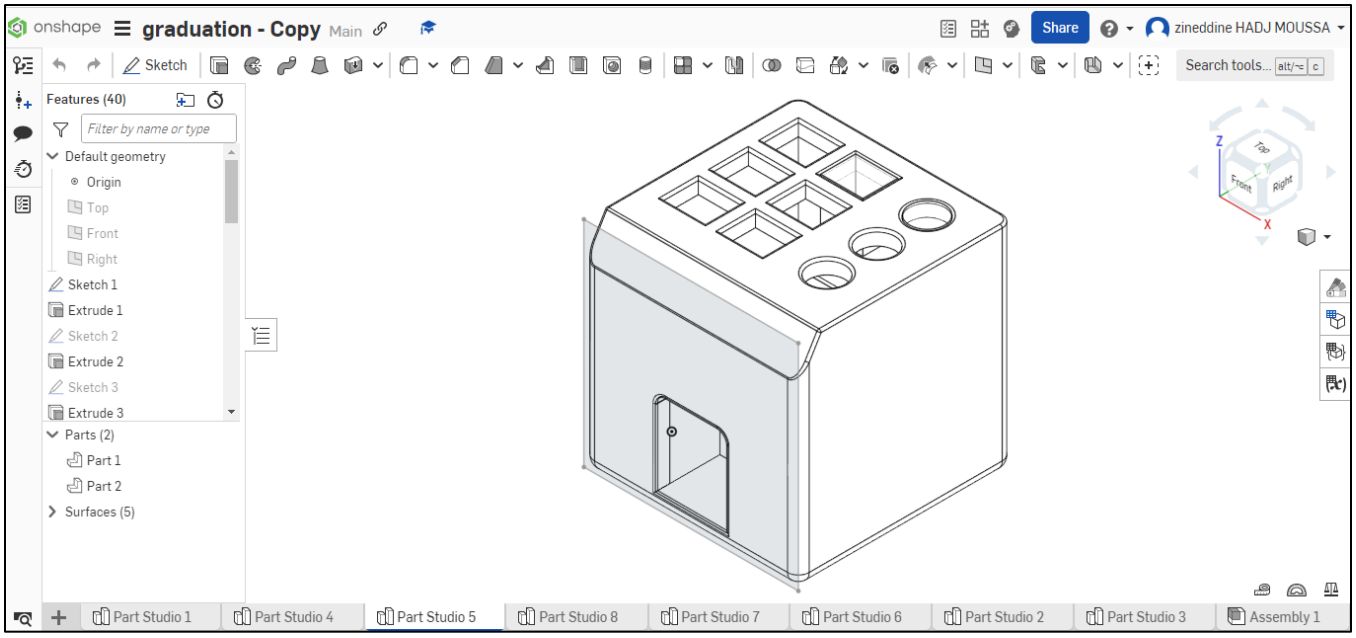

FIGURE 2.6: 3D DESIGN OF SMART MEDICATION AND NUTRITION MANAGEMENT REFRIGERATOR ON ONSHAPE

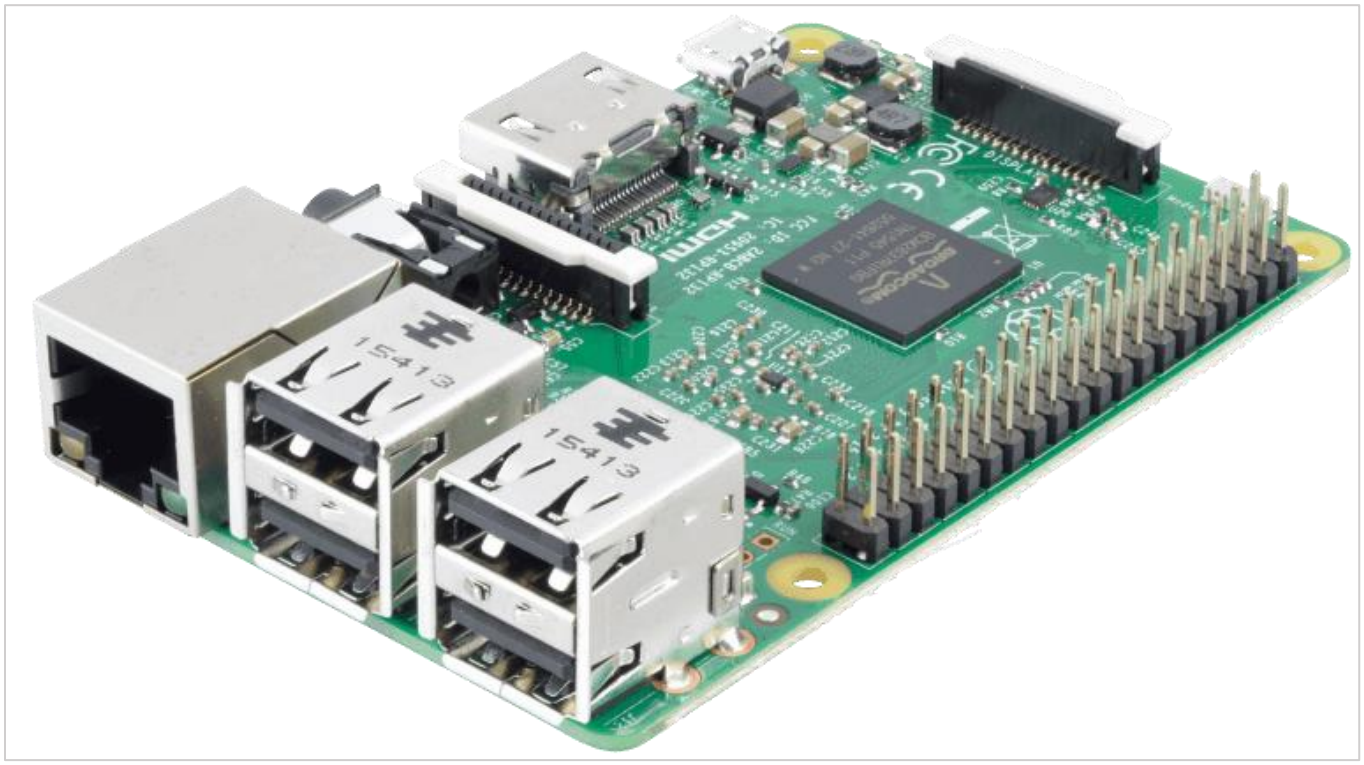

FIGURE 2.7: RASPBERRY PI (REICHELT.COM)

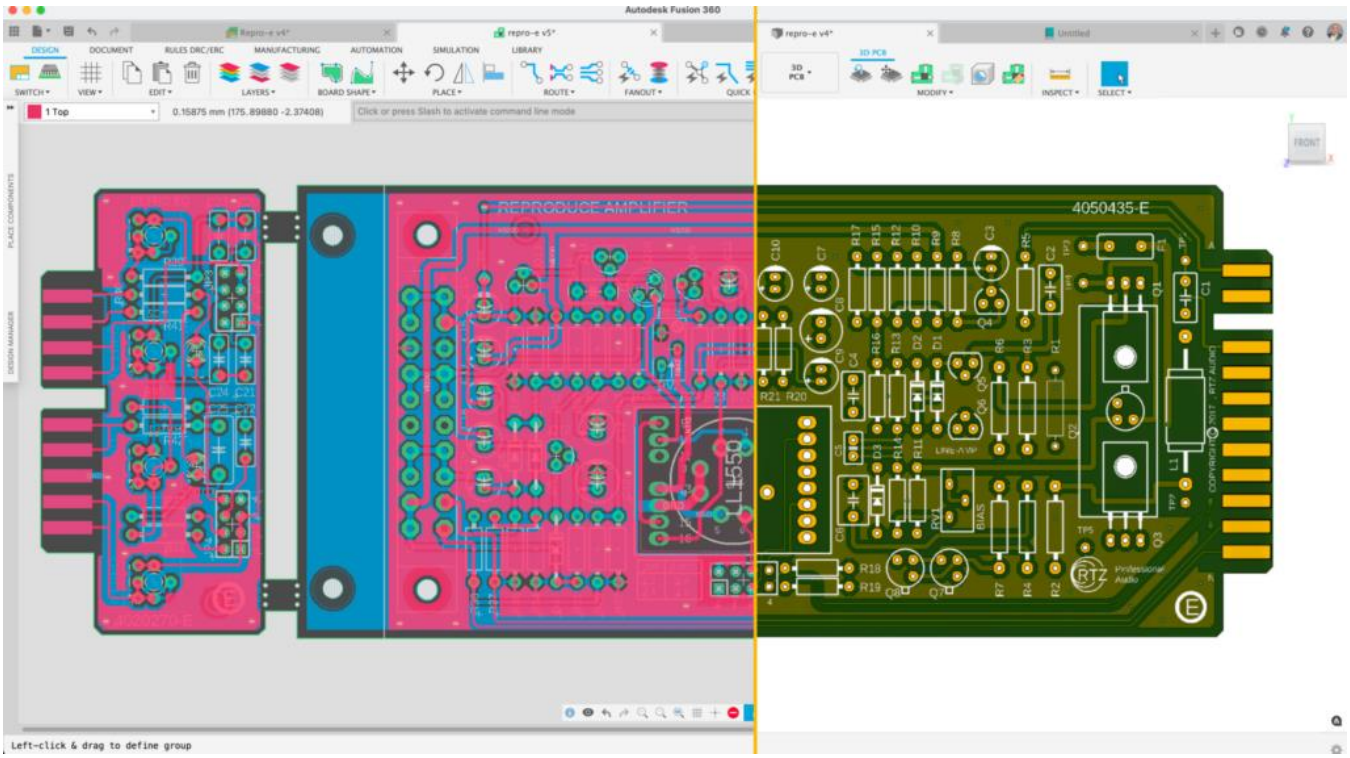

FIGURE 2.8: AUTODESK VISION 360 DASHBOARD (AUTODESK)

2.4.2 PLA printing

- Printing internal and external refrigerator structure parts using PLA 3D printer.
- Ensure printing accuracy and structure strength.

2.4.3 Structure Assembly

- Connect PLA chassis parts together using a suitable adhesive.
- Installation of FR4 PCB panel inside the chassis.

2.4.4 Installation of electronic components

- Installation of micro-controller (MCU) (Texas Instruments MSP430), sensors, sensors, front panel, screen, battery inside FR4 PCB panel.
- Connect ingredients to each other using appropriate wires and connections.

2.4.5 Installation of cooling system

- Installation of electric motor and fan inside the chassis.
- Connect the cooling system to the precision control unit (MCU).

2.4.6 Test System

Operation and testing of the system's functions, including:

- Temperature measurement inside the refrigerator.
- Monitor drug levels.
- Receive and send alerts.
- Interact with keyboard or buttons.
- Communicate with smartphone app or remote monitoring system.

2.4.7 Refrigerator packaging

- Install an aluminum layer on the inside of the refrigerator structure to improve cooling efficiency.
- Installation of the exterior structure of the refrigerator made of PLA.

2.4.8 Final Test

- Test the system again to fully ensure its functions.
- Ensure the safety and efficiency of the refrigerator.

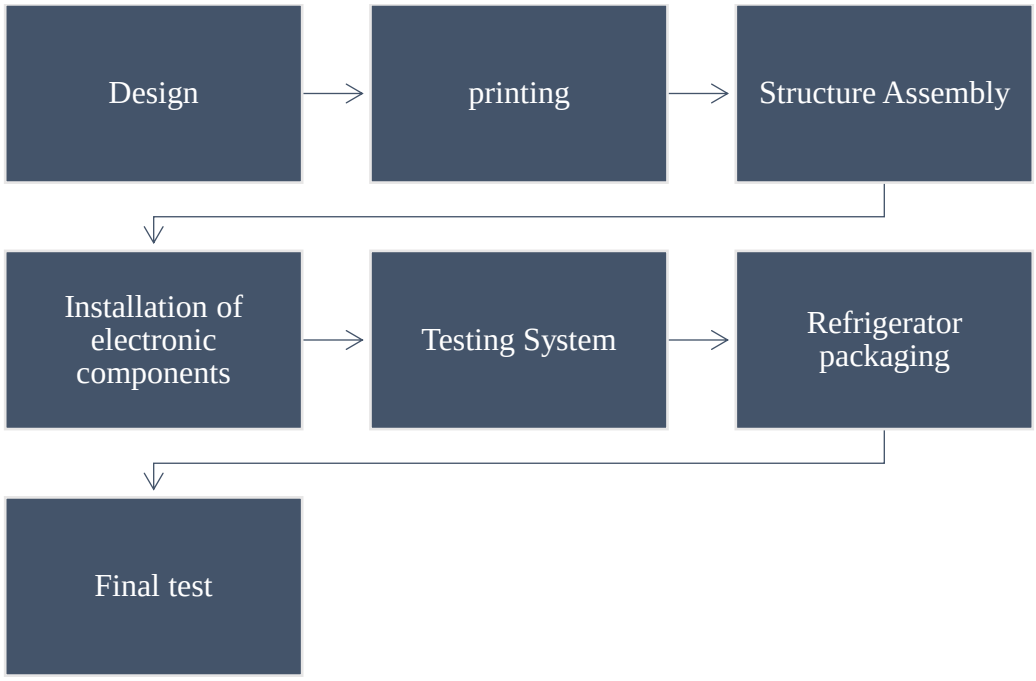

FIGURE 2.9: MANUFACTURING STEPS

2.5 Benefits of the system

2.5.1 Improving drug compliance

- The system helps strengthen patients' commitment to take their medications regularly, contributing to better control of blood sugar levels and reducing the risk of complications.
- Provides accurate reminders of when to take doses, reducing the likelihood of forgetting medications.
- Patients can track their medication levels, helping them avoid running out of medication at inappropriate times.

2.5.2 Peace of mind for patients

- The system ensures that drugs are taken properly and on time, giving patients peace of mind.
- Reduces anxiety and stress associated with diabetes management.
- It promotes patients' sense of control over their health.

2.5.4 Additional Benefits

- Improving quality of life: Better control of blood sugar levels and reduced risk of complications contribute to improving the quality of life of people with diabetes.
- Reducing health care costs: Better drug compliance and reduced complications lower health care costs.
- Strengthening disease prevention: The system helps prevent the development of diabetes complications, such as heart disease, stroke and kidney failure.

2.6 Electronic Application

2.6.1 Patient App

2.6.1.1 Personal dashboard

provides an overview of the patient's health, including:

- **Recent blood sugar levels:** blood sugar readings entered by hand or received from a smart blood sugar meter.
- **Deserving drug doses:** A reminder of when to take medication.
- **Health Goals:** Personal goals to control blood sugar and weight.

2.6.1.2 Monitoring blood sugar levels

- Introduce blood sugar readings manually.
- Connect the smart blood sugar meter for automatic readings.
- View a record of blood sugar readings with graphs and trends.

2.6.1.3 Drug tracking

- Create a list of drugs with dosing details.
- Set reminders for medication.
- Tracking compliance with the drug schedule.
- Access to information about medications, such as side effects and interactions.

2.6.1.4 Food and activity records

- Record meals and drinks with carbohydrate and calorie content.
- Analysis of the effect of food and activity on blood sugar levels.

2.6.1.5 Instructions and support

- Access to a comprehensive library of educational resources on diabetes.
- Watch videos and articles about diet, physical activity, blood sugar control.

2.6.1.6 Communicate with healthcare providers

- Send direct letters to the doctor or care specialist.
- Ask questions and get medical advice.
- Share health data with caregivers.

2.6.1.7 Benefits for patients

- Improve blood sugar control.
- Reduce the risk of diabetes complications.
- Improve the quality of life.
- Increase self-confidence and improve self-control ability.
- Promote communication with healthcare providers.

2.6.2 Doctor Application

2.6.2.1 Monitoring Health Trends

- Real-time presentation of patient data
- Vital signs: Monitoring blood pressure and heart rate in real time from the patient's intelligent device.
- Health trends: Analysis of patient data over time to identify any areas of concern.

- Follow changes in blood sugar levels and vital signs over time.
- Identify patterns and predict potential risks.
- Early intervention to prevent complications.

2.6.2.2 Remote Care Department

- Provide telemedical advice to patients.
- Modify treatment plans as needed.
- Send prescriptions electronically.
- Monitor compliance with treatment.

2.6.2.4 Communication with patients

- Send direct messages to patients to provide instructions and support.
- Make video or audio calls for remote review.
- Answer patients' questions and advise.

2.6.3 How do the two apps interact?

- The patient application communicates with the doctor application through a secure online connection.
- The patient application transfers the patient's data to the doctor's application, allowing health care providers to view and analyze them.
- Healthcare providers can also send letters and instructions to patients through the doctor's application, which will appear in the patient's application.

2.7 Conclusion

Using modern technology and innovation in healthcare, diabetes management can be greatly improved through an automatic care system for a smart fridge. This system is more than just a tool to regulate the storage of medicines and a reminder to take them, it also represents a qualitative shift in improving the quality of life of diabetics and others with chronic conditions.

By offering comprehensive applications beyond simply taking medication, an intelligent care system can contribute to improving public lifestyle and health care. Despite the challenges of cost, safety and integration, continuous development and improvement of the system can lead to more effective and effective patient health care.

Thus, an automatic diabetes care system for a smart fridge is not only a technical innovation, it is a real tool in improving the quality of health care and promoting the health and well-being of patients.

Chapter 03

Uses, recommendations and perspectives of the system

3.1 Introduction

The advent of smart technology in diabetes management presents unprecedented opportunities for enhancing patient care, improving medication adherence, and optimizing health outcomes. This chapter explores the practical applications, provides recommendations for maximizing the system's effectiveness, and discusses future perspectives in the field of diabetes management using advanced technological solutions.

3.2 Uses of Smart refrigerator

Smart refrigerator offers many important advantages for effectively managing medicines both at home and in hospital.

3.2.1 Use of smart refrigerator at home

3.2.1.1 Safe Drug Storage

- Optimal environment: Smart refrigerator maintains a constant temperature and suitable for medicines that need cooling, such as insulin, eye drops and some vaccines, ensuring the effectiveness of drugs and preventing their damage.
- Temperature alerts: Alerts are issued when the temperature changes from the desired range, helping to take the necessary measures to preserve the drugs.

3.2.1.2 Drug inventory tracking

- Inventory shortage notifications: Notifications are sent when the amount of medicine stored decreases, allowing users to order the drugs before they run out.
- Usage records: Keep records of the quantity of drugs consumed, helping to plan future requests and avoid interruption in treatment.

3.2.1.3 Remind patients to take medications

- Scheduling reminders: The refrigerator can be programmed to send reminders via the smartphone app to alert patients about the time of taking medication.
- Acoustic and optical notifications: Contains acoustic and optical alerts to remind patients of medication doses on time.

3.2.1.4 Prohibition of unauthorized access to medicines

- Safety locks: Equipped with safety locks that can be controlled via applications to prevent unauthorized access, especially by children.
- User recognition: Some models have fingerprint or facial recognition features to ensure only the right person is reached by medication.

3.2.2 Use of smart refrigerator in hospitals

3.2.2.1 Pharmaceutical Drug Inventory Management

- Accurate stock tracking: Smart refrigerator facilitates accurate tracking of the quantities available from each type of medicine.
- Analytical reports: Analytical reports on drug consumption are available, helping to improve inventory management and avoid surplus or shortage.

3.2.2.2 Tracking drugs given to patients

- Automatic registration: Automatic registration of medicines withdrawn from the refrigerator and accurate reporting of medicines given to patients.
- Integration with hospital management system: Integration with electronic hospital management systems to automatically update patient records with doses of given drugs.

3.2.2.3 Improving patient safety

- Automatic verification of medications: Verification of prescribed medications and doses per patient to avoid errors in administering medications.
- Alerts and notifications: Send alerts to the medical team in case of any possible error in administering the drugs.

3.2.2.4 Cost reduction

- Wastage prevention: Through effective management of drug stockpile, waste from expired medicines can be reduced.
- Increased efficiency: Improved work efficiency in pharmacies by reducing the time taken to track and manage medicines.

3.3 Recommendations

To take full advantage of the capabilities of the smart refrigerator system to manage medicines in both homes and hospitals, we offer the following recommendations:

3.3.1 User training and support

3.3.1.1 Comprehensive training

- Detailed training should be provided to patients and caregivers on how to use the system, including preparing medication reminders, understanding health data, and solving common problems.

3.3.1.2 Continuous support

- Provide ongoing technical support and resources to assist users in addressing any challenges that may arise.

3.3.2 Security and privacy measures

3.3.2.1 Data protection

- Implement robust encryption and security protocols to protect sensitive data from unauthorized access.

3.3.2.2 Compliance with regulations

- Ensure that the system complies with health regulations and standards such as HIPAA to keep patients confidential and confident.

3.3.2.3 Tight security system

- Installation of an electronic lock to prevent unauthorized access to medicines.
- Install an alarm system to detect any temperature dysfunction or unlawful opening of the refrigerator door.
- Tracking logins to monitor who opened the refrigerator and when.

3.3.3 Affordability and accessibility

3.3.3.1 Cost reduction strategies

- Looking for ways to reduce manufacturing and maintenance costs to make the system more suitable for more patients.

3.3.3.2 Support and insurance coverage

- Cooperation with health-care providers and insurance companies to incorporate the system into insurance plans and government support, thereby increasing the accessibility of patients from different economic backgrounds.

3.3.4 Personalized customization

3.3.4.1 Customized features

- Develop customizable features that meet individual patients' needs, such as language options, personal alerts, and adjustable drug schedules.

3.3.4.2 Feedback mechanism

- Establishing a feedback mechanism that allows users to provide feedback on system performance, contributing to continuous improvements and updates based on the user's experience.

3.3.5 Interdisciplinary cooperation

3.3.5.1 Health care integration

- Cooperate with health-care providers, technicians and pharmacists to ensure the system's smooth integration with current health practices.

3.3.5.2 Patients' participation

- Involve patients in the design and development process to ensure that the system meets their needs and preferences effectively.

3.3.6 Basic Features

3.3.6.1 Structured storage system

- Divide the refrigerator into shelves and compartments to store medicines according to their type and method of storage (such as liquid medicines, pill-shaped medicines, medicines that need to be cooled).
- The possibility of adjusting the temperatures of each cabin independently.
- Use RFID technology to track drugs and determine their expiration date.

3.3.6.2 Intelligent management system

- Connecting the refrigerator to the drug management system at home or hospital to follow up on the stock and identify the need for re-ordering.
- Send alerts to users when the drugs expire or when the amount of drugs is small.
- Provide information about medicines and their use through contact with a medical system.

3.3.7 Additional features

3.3.7.1 Drug distribution system

- Enable the distribution of medications automatically to patients at the specified times.
- Connecting the refrigerator to a medical system to prescribe medicines and determine the appropriate dosage.
- Send alerts to patients when it is time to take the drug.

3.3.7.2 Data Analysis System

- Analysis of drug use data to identify consumption patterns and detect potential problems.
- Preparation of reports on the use of medicines for users and officials.
- Using data to improve inventory management and reduce waste.

3.3.8 Smart refrigerator Applications

3.3.8.1 Smart refrigerator applications for healthcare home

- Help the elderly and chronically ill to properly manage their medications.
- Prevention of misuse or overuse of medicines.
- Ensure patients' access to appropriate medicines in a timely manner.

3.3.8.2 Smart refrigerator applications in hospitals

- Improve the efficiency of drug management and reduce medical errors.
- Ensure patients' access to appropriate medicines in a timely manner.
- Reduce the waste of medicines.

3.3.9 Challenges in Implementing smart refrigerators

- **Cost:** The cost of a smart refrigerator may be high, which may limit its spread.
- **Privacy:** Users may have concerns about the privacy of their health data.
- **Security:** Smart refrigerator safety must be ensured from electronic hacks.

By implementing these recommendations, the smart refrigerator system can be improved to effectively manage medicines, ensuring safety, efficiency and easy access for users in home and hospital environments.

3.4 Future Views

The future of diabetes management using smart technology holds promising possibilities. Possible developments include:

3.4.1 Enhanced interoperability

- Integration with other devices: Future systems can integrate with a wider range of health monitors, such as fitness trackers and smart watches, providing a comprehensive view of the patient's health.
- Sharing data smoothly: Improving interoperability between different healthcare systems and devices can facilitate the seamless sharing of data, enhancing coordinated care.

3.4.2 Artificial intelligence and machine learning

- Predictive analyses: AI and machine learning algorithms can analyze health data to predict potential complications, propose preventive measures, and improve proactive care.
- Personal treatment plans: * Advanced analysis can help design treatment plans based on individual patient diabetes ", leading to more effective and personal management of diabetes.

3.4.3 Expanded telehealth capabilities

- Virtual consulting: The system can support the most advanced telehealth services, including virtual consultations with specialists and multidisciplinary care teams.
- Remote modifications: Healthcare providers can modify drug doses and telemedicine plans based on real-time data, reducing the need for frequent in-person visits.

3.4.4 Community and peer support

- Patients' communities: develop online platforms or forums integrated with the system where patients can share experiences, provide mutual support and access to peer-reviewed information.
- Support groups: Facilitating virtual support groups and online educational seminars led by healthcare professionals and experienced patients.

3.4.5 Research and Development

- Clinical trials: Use the system to collect anonymous data for clinical research, helping to promote understanding of diabetes and develop new treatments.
- User-centric design: continuously optimize the system based on feedback from diverse user groups, ensuring it remains relevant and effective.

3.4.6 Global Health Impact

- Scalability: Adapting the system for use in various health care settings around the world, including low-resource environments, to address the global diabetes epidemic.
- Local solutions: Allocate characteristics and support materials to meet the cultural and linguistic needs of different populations and promote widespread adoption.

3.5 Finale

Integrating smart technology into diabetes management through a smart refrigerator automated care system represents great progress in this area. This innovative approach not only promotes adherence to and storage of medicines, but also provides comprehensive support through the integration of telehealth and educational resources. By addressing cost, security and accessibility challenges, and by integrating recommendations for user support, data protection and interdisciplinary collaboration, the system can achieve widespread adoption and significantly improve the quality of life for diabetics.

Looking ahead, the system's future perspectives include artificial intelligence integration and machine learning, enhancing interoperability, expanding telehealth capabilities, and creating community support networks. These developments hold the potential to revolutionize diabetes care, making it more personalized, effective and accessible worldwide. Through continuous innovation and patient-centered design, a smart refrigerator system can play a pivotal role in global efforts to manage and eventually alleviate the burden of diabetes.

General conclusion

General conclusion

Integration of modern technology in chronic disease management, particularly diabetes, has ushered in a new era of healthcare. Innovations such as health care apps, smart devices, and automated medication management systems have empowered patients to take control of their health, leading to better disease management and improved quality of life. These technological advancements have not only enhanced self-monitoring and medication adherence but have also facilitated continuous communication with healthcare providers and access to reliable educational resources. [27]

The "Smart Medication and Nutrition Management Refrigerator" exemplifies this progress, offering a sophisticated solution to enhance healthcare delivery in both hospital and home care settings. By regulating medication timing and quantities, scheduling meals and hydration, and enabling real-time monitoring through a mobile application, this smart refrigerator addresses unique patient needs, improving compliance and reducing medication errors. Its intelligent notifications keep both patients and healthcare providers informed and proactive in managing medication and nutritional requirements.

Despite these advancements, challenges remain, including the high cost of new technologies, the need to ensure data security and patient privacy, and the importance of user-friendly designs. Addressing these challenges is crucial for the widespread adoption and success of these innovative solutions[27,28]. [28] [29]

The journey of diabetes management from ancient remedies to cutting-edge technology highlights the remarkable progress made in medical science. By understanding the historical context and embracing the latest innovations, we can continue to improve outcomes for diabetes patients and reduce the burden of this chronic disease on individuals and society. The future of diabetes care lies in further integrating smart technology, ensuring accessibility, and maintaining a patient-centered approach to enhance the quality of life for all those affected by this condition. [30]

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Université de Ghardaïa

غرداية في: 04/07/2024

إذن بالطباعة (مذكرة ماستر)

بعد الاطلاع على محتوى المذكرة المنجزة من طرف الطلبة التالية أسماؤهم:

1. الطالب (ة): الحاج موسى زين الدين
2. الطالب (ة): قصبي محمد

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الإذن بطباعة النسخة النهائية لمذكرة ماستر الموسومة بعنوان

Smart Medication and Nutrition Management Refrigerator for Hospitals and Home

إمضاء رئيس القسم

العلمي عبد اللطيف
رئيس قسم الآلية
و الكهروميكانيك