GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy

Capstone Project Proposal

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ABSTRACT

The Project titled “GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy” is a non-invasive way of Blood Glucose Level Measuring system that helps individuals to monitor blood glucose levels.

The prevalence of diabetes has been increasing globally, and with it, the need for monitoring blood glucose levels has become a vital part of managing the condition. The traditional method of monitoring blood glucose levels involves collecting blood samples, which is a painful and inconvenient process for patients. Therefore, the need for non-invasive methods to monitor blood glucose levels has arisen.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled '**GluCare**' is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Ashima Singh during the 6th semester (2024).

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Lastly, we would also like to thank our families for their unyielding love and encouragement.

They always wanted the best for us and we admire their determination and sacrifice.

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NIR	Near Infrared
ML	Machine Learning
GND	Ground

1. Introduction

1.1. Project Overview

The project titled "GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy" represents a transformative leap in diabetes management, introducing an entirely new dimension to how people with diabetes monitor their blood glucose levels. This pioneering device aims to replace the conventional finger-pricking method, which is not only painful and inconvenient but also a source of anxiety for many patients who need to check their glucose levels regularly. By offering a non-invasive solution, GLUCare aspires to deliver a seamless, painless, and highly efficient experience for individuals managing their condition, ultimately leading to better adherence and improved health outcomes.

The primary innovation lies in the integration of multiple technologies—spectroscopy, advanced sensors, wearable devices, and intelligent data processing—into a cohesive system designed to offer continuous, real-time glucose monitoring without the need for blood samples. At the heart of this technology is near-infrared (NIR) spectroscopy, a technique that examines the interactions between light and matter. Specifically, NIR light is selected for its ability to penetrate the skin and interact with the glucose molecules present in the interstitial fluid, which is a thin layer of fluid surrounding the body's cells and closely correlates with blood glucose levels.

The process begins when the device emits a beam of near-infrared light that passes through the user's skin. As this light travels through the tissue, it interacts with glucose molecules, leading to measurable changes in the light's behavior—specifically in terms of absorption and scattering.

Glucose molecules absorb light at specific wavelengths, and the extent of this absorption is directly related to the concentration of glucose in the interstitial fluid. Similarly, the scattering effect alters how light is deflected as it passes through the tissue. The combination of these interactions results in a transformed light signal that carries vital information about the glucose level.

The transformed light is then captured by a highly sensitive receiver sensor embedded in the device. This sensor is designed to detect subtle variations in light intensity and wavelength, which are subsequently analyzed using advanced algorithms to extract accurate glucose readings.

The use of such sophisticated data analysis techniques allows the system to continuously monitor glucose levels with high precision, providing a real-time snapshot of the user's glucose concentration. This real-time data can be crucial for users who need to manage their glucose levels tightly, as it allows them to make immediate adjustments to their diet, insulin dosage, or physical activity.

Once the glucose data is analyzed and processed, it is converted into easy-to-read metrics that can be displayed directly on the device's screen. For enhanced functionality, the system is also designed to communicate with external devices, such as smartphones or smartwatches, via a connected app.

This app can serve as a central hub where the user's glucose data is logged, tracked, and visualized over time. It offers a variety of features, including trend analysis, alerts for abnormal glucose levels, and personalized recommendations based on the user's data history. This connected ecosystem makes it easier for users to manage their health by providing them with a comprehensive overview of their glucose patterns, enabling them to take proactive steps to avoid complications.

One of the standout aspects of GLUCare is its emphasis on user comfort and accessibility. Unlike traditional monitoring systems, which often require the patient's active participation in drawing blood samples, GLUCare operates continuously in the background, allowing users to go about their daily lives without constant interruptions. This approach not only reduces the physical discomfort associated with frequent testing but also alleviates the psychological burden of managing a chronic condition. The wearable nature of the device ensures that it fits seamlessly into the user's lifestyle, offering continuous monitoring without being obtrusive.

In addition to its user-centric design, the device's data-sharing capabilities open up new possibilities for personalized healthcare. By securely transmitting data to healthcare providers, GLUCare enables a more collaborative approach to diabetes management, where doctors can monitor their patients' glucose levels remotely and intervene when necessary. This real-time data exchange can lead to more informed treatment plans, early detection of potential issues, and a more tailored approach to managing each individual's condition.

GLUCare represents a significant advancement in the field of non-invasive glucose monitoring. By leveraging the power of near-infrared spectroscopy, advanced sensing technologies, and data analytics, the system offers a more comfortable, accurate, and user-friendly alternative to traditional methods. This project holds the potential to revolutionize how diabetes is managed, not only improving the quality of life for individuals living with the condition but also setting new standards for innovation in the healthcare industry.
GLUCare stands as a beacon of innovation in the healthcare landscape, offering a groundbreaking solution to the longstanding challenges faced by individuals managing diabetes. By replacing the invasive and often painful finger-prick method with a sophisticated, non-invasive system, GLUCare not only enhances user comfort but also significantly improves the ease and efficiency of glucose monitoring. The integration of near-infrared spectroscopy with advanced sensor technology and real-time data analysis empowers users with continuous, accurate glucose readings, allowing for more informed and timely decision-making. The device's connectivity features further extend its capabilities, providing users with a comprehensive health management tool that seamlessly fits into their daily lives while enabling proactive healthcare through real-time data sharing with medical professionals.

As a result, GLUCare not only aims to transform individual diabetes care but also sets a new standard in the development of smart healthcare devices, paving the way for future innovations that prioritize patient comfort, accuracy, and accessibility. With its holistic approach, GLUCare promises to redefine the future of diabetes management, offering hope for millions around the world who seek a better, more humane way to monitor and control their health.

1.2. Need Analysis

Diabetes is a chronic condition which is characterized by high blood glucose in the blood. The main source of energy for the human body's cells is Glucose. When the glucose levels in the blood become too high, it can harm a number of the body's systems and organs. Moreover, glucose monitoring is required as uncontrolled high blood glucose levels can lead to serious long-term consequences, which includes damage to the eyes, cardiovascular system, nerves, and kidneys. Monitoring blood glucose levels and managing them effectively can also help in reducing the risk of these consequences.

About 422 million people in the world have diabetes or high blood glucose levels. The majority of people having diabetes are from low and middle-income countries. Every year, diabetes is directly responsible for nearly 1.5 million deaths. Over the past few decades, diabetes cases and prevalence have both been gradually rising. Regular testing is the need of the hour and is important to decrease this number.

Non-Invasive testing techniques can provide great amount of relief from the pain caused by skin pricking. The advantages of non-invasive device over traditional invasive approach are listed below:

- **Reduced pain and discomfort**: The Non-invasive methods of blood sugar monitoring do not require pricking the skin, which relieves from the pain and discomfort. This device can be particularly important for individuals who require frequent blood sugar monitoring, such as People having mostly high blood glucose and those who requires insulin injections.
- **Reduced risk of infection**: Traditional blood sugar monitoring methods require

pricking the skin, which can increase the chances of getting infected. Non-invasive methods eliminate this risk.

- **More frequent testing**: Non-invasive methods are less painful and more convenient. Diabetic Patients are more likely to test their blood sugar levels more frequently, which can also help them manage their condition more effectively.
- **Continuous testing:** Conventional systems typically rely on occasional testing that provides only irregular insights into glucose levels, and often lack the capacity for continuous monitoring. NIR spectroscopy, which makes it possible to continuously and in real time monitor glucose levels.

1.3. Research Gaps

Table1: Research Gaps

No.	**Research Gap**	**Explanation**	**Research Paper**
1	Lack of Accuracy and Precision	Non-invasive glucose monitoring struggles with accuracy due to skin and environmental factors. Bridging the gap requires innovative techniques for consistent precision across diverse individuals.	Development of sensor system and data analytic framework for non-invasive blood glucose prediction
2	Calibration	Non-invasive monitoring devices need calibration for accuracy, but this process is often time-consuming and neglects individual variations. Research is needed for personalized calibration	Non-invasive estimate of blood glucose and blood pressure from a photoplethysmograph by means of machine learning techniques

		techniques that adapt to an individual's biological characteristics, ensuring precise results without frequent recalibration	
3	Long-term Stability and Wearability	Non-invasive glucose monitoring devices need to be wearable, comfortable, and capable of providing stable readings over an extended period. Balancing accuracy and comfort pose a significant challenge, requiring solutions to maintain technology functionality without causing discomfort or skin irritation.	Non-invasive blood glucose measurement
4	Standardization and Regulatory Approval	Widespread adoption of non-invasive glucose monitoring systems is hindered by the absence of established evaluation procedures. Obtaining regulatory approval is challenging, demanding rigorous clinical validation to ensure the safety and efficacy of these medical devices.	Non-Invasive Glucose Monitoring Using Optical Sensor and Machine Learning Techniques for Diabetes Applications
5	Understanding Biological Mechanisms	Improved understanding of molecular mechanisms is essential to connect non-invasive measurements with actual blood glucose levels. This involves exploring factors	Non-invasive prediction of blood glucose trends during hypoglycemia

		like glucose transportation through skin tissue and the impact of physiological changes on measurement accuracy.	

1.4 Problem Definition and Scope

Globally, the prevalence of diabetes has increased. With it, the need for monitoring blood glucose levels has become a vital part of managing the condition. The traditional method of monitoring the blood glucose levels which involves pricking the skin for collecting blood samples, which is a painful and inconvenient process for patients. Therefore, the need for non-invasive methods to monitor blood glucose levels has arisen.

The scope of this project includes a variety of aspects which includes technological innovation to usability and healthcare impact. Firstly, the development of device/technology which can accurately and non-invasively measure blood glucose levels is the main goal of our project. Near-Infrared spectroscopy, Sensors and wearable technology that analyzes blood glucose without cutting the skin could all be used in this. The objective is to guarantee precision comparable to current invasive techniques and to reduce the discomfort.
The scope additionally involves usability and accessibility. The created system must be user-friendly, enabling people to readily and often monitor their glucose levels, improving diabetes management. This involves developing user-friendly interfaces, keeping the hardware simple, and making sure that users with different levels of technical knowledge can easily understand and use the collected data.

Additionally, financial and health aspects are an important part of the scope. When considering the costs of managing diabetes into account, the invention should be financially viable. No matter what their socioeconomic standing is, the ideal solution should be accessible at a reasonable price to a large number of people. The effect on medical procedures and patient outcomes is also quite important. More frequent monitoring enables healthcare professionals to make knowledgeable decisions in the moment, improving glucose control and possibly lowering the long-term problems of diabetes.

However certain constraints limit boundaries of the scope of this device. First off, even while non-invasive techniques aim for accuracy, they might not entirely take the place of invasive measurements in every situation.

Determining the circumstances in which invasive checks are still required is important. Furthermore, changes in the body, environmental factors, and variations in people may affect the precision of non-invasive assessments, making it important to have defined rules for their application and interpretation.

In conclusion, the development of accurate and user-friendly technologies which allows

Diabetes patients to assess their blood glucose levels without invasive procedures fall in the scope of non-invasive blood glucose monitoring. The coverage includes the impact on healthcare, usability, economic viability, and technological innovation. However, problems concerning accuracy, usefulness, and variation among people need to be carefully considered. The effective implementation of this scope has the potential to transform the treatment of diabetes and improve the lives of millions of people throughout the world.

1.5 Assumptions and Constraints

Table 2: Assumptions and Constraints

S. No.	**Assumptions and Constraints**
1	Non-invasive blood glucose monitoring aims to reduce pain from frequent finger pricking but faces challenges requiring scrutiny of assumptions and limitations.

2	Assumptions include correlating blood glucose concentration with near-infrared light absorption patterns, impacted by individual differences, skin pigmentation, and tissue composition.
3	Consistent light-tissue interaction is assumed, but factors like skin moisture, temperature, and pressure during measurement can compromise accuracy.
4	Accurate glucose reference readings, obtained through invasive techniques, are necessary for near-infrared spectroscopy (NIRS) calibration.
5	Near-infrared light penetration is limited to surface tissue layers, potentially affecting accuracy as glucose levels vary in deeper tissues.
6	Factors like skin pigmentation, ambient light interference, and skin property variations can impact the reliability of non-invasive measurements.

1.6. Standards

Device design requirements focus on creating portable, convenient NIRS devices that may be easily incorporated into daily life. When taking into account elements like sensor positioning, light source stability, and low interference from external light sources, such devices need to display consistent optical performance.

- Developing reliable and representative calibration models is necessary for calibration standards. These models need thorough datasets collected from a variety of people, and they should be updated frequently to account for shifting physiological conditions.

- It is crucial to compare NIRS-derived glucose values to reference techniques like traditional blood sample devices as part of the validation standards process. The reliability of NIRS technology is ensured across a variety of scenarios through rigorous testing across multiple populations and under various real-world conditions. MARD (Mean Absolute Relative Difference) standards serve as a metric for evaluating the accuracy of non-invasive blood glucose monitoring using NIRS (Near-Infrared Spectroscopy) technology. MARD calculates the average percentage difference between NIRS readings and reference blood glucose values. Lower MARD values indicate higher accuracy, crucial for reliable and effective glucose monitoring devices.

• Clarke Error Grid Analysis assesses the accuracy of non-invasive blood glucose monitoring, like NIRS, by plotting reference glucose values against measured values. It divides the plot into zones, indicating clinical significance. Data points within zones A and B are clinically acceptable, while C, D, and E depict increasing deviations with potential clinical impact.

1.7. Approved Objectives

- To analyze and compare existing state of the art technologies for glucose monitoring.
- To design and implement a non-invasive device to monitor Blood Glucose level using Machine Learning.
- To create the test data and validate the performance of the device by comparing with clinical invasive techniques.
- To design and develop a web application/app to display the results.
- To work on input features like age, BMI, etc for glucose level prediction.

1.8. Methodology

- Research skin properties and blood glucose molecules to understand their relationship.

- Evaluate various non-invasive blood glucose monitoring methods, considering accuracy, cost, and usability.

- Design and develop a device based on NIR spectroscopy, ensuring it meets accuracy criteria.

- Validate device performance by comparing results with invasive techniques like fingerstick measurements.

- Develop a web application to display blood glucose results in a user-friendly manner.

- Continuously improve both the device and web application based on user feedback and technological advancements.

1.9. Project Outcomes and Deliverables

The project “GLUCare: A Smart Healthcare Device for Non-Invasive Blood Glucose Monitoring” aims to develop a non-invasive device for measuring blood glucose levels. The project also aims to eliminate the need for traditional invasive methods like finger pricking blood glucose monitoring. Both technological improvements and useful applications are included in the project's planned results and deliverables.

- The primary outcome of the project is the successful creation of a Near-Infrared Spectroscopy (NIRS) based device capable of accurately and non-invasively measuring blood glucose levels in real-time. This technological achievement holds the potential to significantly enhance the quality of life for individuals with diabetes by eliminating the discomfort and inconvenience of frequent blood testing.
- The project also aims to validate the accuracy and reliability of the NIRS-based blood glucose monitoring device. This includes a series of clinical trials

involving diverse participants to ensure the device's effectiveness across various demographics and physiological conditions. These validation efforts are crucial for gaining regulatory approvals and building trust within the medical community.

- Furthermore, the project's outcomes encompass the development of user-friendly web application on which both patients and doctors can login and users can redirect themselves to a website which displays and interpret the collected blood glucose data. These interfaces will enable users to track their glucose levels, set alerts for critical thresholds, and share data with healthcare professionals, fostering proactive diabetes management.
- In summary, the Deliverables of “GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy" is to create an innovative NIRS-based device for painlessly testing blood glucose levels. The development of the device itself, validating the device, and user-friendly web application are anticipated results that will collectively help in diabetes care and control with high precision and reduced discomfort.

1.10. Novelty of Work

Invasive glucose measurement describes techniques where blood samples are taken for glucose testing by puncturing the skin. Although these techniques are widely employed and generally reliable, they do have certain drawbacks. The following are a few disadvantages of invasive glucose testing:

- Pain and Discomfort: For those who require frequent glucose monitoring, the act of inserting a needle into the skin can cause pain and discomfort. Patient aversion and non-compliance with routine testing may result from this.
- Risk of Infection and Bruising: Piercing the skin increases the potential for infection and bruising, particularly if good hygiene is neglected. Bruising may cause more discomfort, and infections can result in more serious complications.

- Skin Irritation: Prolonged or recurrent punctures to the skin can cause irritation and eventual skin damage. People who have sensitive skin or skin conditions may find this to be especially concerning.

GLUCare offers painless glucose measurement and no risk of infection and skin irritation. NIRS (Near-Infrared Spectroscopy) for non-invasive blood glucose monitoring refers to the innovative approach of utilizing light in the near-infrared range to determine blood glucose levels without the need for traditional invasive methods like finger pricking. This method takes advantage of glucose's special ability to scatter and absorb near-infrared light to assess glucose concentrations below the skin's surface. NIRS offers a non-invasive, painless, and continuous monitoring solution for diabetes patients. It also boosts their quality of life, in contrast to traditional approaches that pricks the skin for blood samples. Use of mathematical algorithm that analyze how tissue interacts with near-infrared light to precisely measure glucose levels.

REQUIREMENT ANALYSIS

2.1 Literature Survey

Table3: Literature Survey

S. No.	Roll Number	Name	Paper Title	Tools/Technology	Findings	Citation
1	102103373	Anupriya Lathey	Non-Invasive Blood Glucose Monitoring Technology	Near-Infrared Spectroscopy (NIRS), Optical Coherence Tomography (OCT), Microwave/RF Spectroscopy, Electrochemical Sensors, Ultrasound, Thermal Sensors, Multispectral and Hyperspectral Imaging	**Non-Invasive Monitoring:** NIR spectroscopy offers a non-invasive alternative to traditional blood glucose testing, which can be more comfortable and convenient for patients. **Technological Advancements:** The technology has the potential to provide real-time glucose measurements without the need for blood samples, improving patient compliance and ease of use.	[1]
2			*Non-invasive*	Support vector regression (SVR),	*This paper examines non-invasive blood*	[2]

			methods of glucose measurement: current status and future perspectives.	Principal component regression (PCR) [39], and Artificial neural network (ANN)	*glucose monitoring as a means of improving diabetes care. It discusses the implications of tested devices and highlights the shortcomings of existing approaches.*	
3	102103377	Nitleen Kaur	Wearable-band type visible-near infrared optical biosensor for non-invasive blood glucose monitoring	NIR Sensor, Digital wavelet transform	*Visible-near infrared spectroscopy is used in the study to provide a wearable, reasonably priced blood glucose sensor for continuous monitoring. The sensor's potential for dependable, non-invasive, long-term blood glucose monitoring is demonstrated by its promising correlation coefficient of 0.86 and standard prediction error of 6.16 mg/dl in in vivo trials with 12 volunteers.*	[4]
4			*Blood glucose monitoring-*		*This paper investigates non-invasive blood*	[5]

			an overview of current and future non-invasive devices.		*glucose monitoring with the goal of enhancing device comfort and adherence in diabetes. It highlights the possible advantages and asks for more study to improve accuracy.*	
5	102103394	Pia Gupta	The Progress of Glucose Monitoring- A Review of Invasive to Minimally and Non-Invasive Techniques, Devices and Sensors	Corrective algorithms, Predictive algorithms	*This study examines cutting-edge non-invasive glucose monitoring devices and projects that they will soon surpass invasive techniques in adoption.*	[7]
6			Non-invasive wearable electrochemical sensors		*This paper discusses the promise of wearable electrochemical sensors for non-invasive on-body sensing, emphasizing their potential in health monitoring*	[8]

					through sweat, tears, or saliva for various applications.	
7	102103282	Riddhi Garg	*First human experiments with a novel non-invasive, non-optical continuous glucose monitoring system*	VNA (Vector Network Analyser), Glucose clamp technique	*This paper presents a non-invasive glucose monitoring system in the form of a wristwatch that uses impedance spectroscopy and shows encouraging correlations with variations in blood glucose.*	[10]
8			*Prospects and limitations of non-invasive blood glucose monitoring using near-infrared spectroscopy*		*This paper urges the development of a non-invasive, cost-effective glucose monitoring device, specifically focusing on near-infrared spectroscopy (NIRS) and its prospects, limitations, and technical challenges.*	[11]
9	102103485	Stuti Mittal	*A review of non-invasive optical systems for continuous blood*	Near-Infrared (NIR) Spectroscopy, Mid-Infrared (MIR) Spectroscopy,	*This paper addresses the need for painless and cost-effective substitutes for conventional invasive methods of blood glucose monitoring*	[12]

			glucose monitoring	Raman Spectroscopy	*by reviewing recent developments in non-invasive optical approaches.*	
10			*A new generation of sensors for non-invasive blood glucose monitoring*	Electrochemical techniques, Gold nanostructure-programmed flexible electrochemical biosensor	*This study examines the prevalence of diabetes worldwide, emphasises the importance of blood glucose monitoring, contrasts non-invasive methods, and predicts increased competition from wearable technology for effective monitoring.*	[13]

2.2 Software Requirements

2.2.1 Introduction

The Project titled "MyGLU: A smart Healthcare device for Non-Invasive Blood Glucose Monitoring" is a non-invasive way of Blood Glucose Level Measuring system that helps individuals to monitor blood glucose levels. The prevalence of diabetes has been increasing globally, and with it, the need for monitoring blood glucose levels has become a vital part of managing the condition. The traditional method of monitoring blood glucose levels involves collecting blood samples, which is a painful and inconvenient process for patients. Therefore, the need for non-invasive methods to monitor blood glucose levels has arisen.

2.2.1.1 Purpose

Traditional glucose monitoring requires invasive finger pricks multiple times a day, leading to discomfort and inconvenience for patients. Non- invasive glucose monitoring sensors can eliminate these issues. The scope of this project is to develop a non-invasive glucose monitoring sensor that is accurate, reliable, and affordable for patients. The sensor will be designed to be easy to use and integrate with existing diabetes management systems. The objectives of this project are to improve patient comfort and convenience, reduce the risk of infection and other complications associated with traditional glucose monitoring, and ultimately improve patient outcomes. The sensor will be rigorously tested to ensure accuracy and reliability.

2.2.1.2 Intended Audience and Reading Suggestions

Intended Audience:

- Healthcare professionals
- Researchers in diabetes management
- Patients seeking non-invasive glucose monitoring solutions

Reading Suggestions:

- Clinical studies on non-invasive glucose monitoring
- Reviews of current technologies and advancements
- Patient testimonials and user experiences

2.2.1.3 Project Scope

The scope of this project is to develop a non-invasive glucose monitoring sensor that is accurate, reliable, and affordable for patients. The sensor will be designed to be easy to use and integrate with existing diabetes management systems. Also, along with that we will build a website where both patients and doctors can login and that will keep a track of patient's previous glucose levels and where they can make appointments with doctor

2.2.2 Overall Description

Our product is an accurate and reliable non-invasive blood sugar level monitoring device and a website which will track user's blood sugar level. The technique by which our device will measure the blood sugar levels is via spectroscopy using a NIRS. Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from 780 nm to 2500 nm). Our device will use tools like Arduino, IR transmitter, IR receiver, LCD, breadboard, resistors, wires. Through our website both patients and doctors can login and that will keep a track of patient's previous glucose levels and where they can make appointments with doctor.

2.2.2.1 Product Perspective

• User Convenience: The main advantage of non-invasive glucose monitoring is the level of user convenience it provides. Non-invasive devices often use technologies like spectroscopy, sensors, or wearable devices to detect glucose levels painlessly, in contrast to conventional procedures, which call for the user to prick their finger and extract a blood sample.

• Pain reduction: The elimination of the discomfort connected to conventional glucose monitoring is one of the largest benefits. People with diabetes frequently find fingerstick painful, and as a result, they may forego monitoring. Non-invasive techniques lessen or do away with this discomfort barrier, making it simpler for people to effectively manage their diabetes.

• Reduced Infection Risk: Traditional monitoring techniques include skin-breaking, which, if done improperly, increases the risk of infection. Non-invasive techniques eliminate this risk, improving user safety in general.

• Improved Quality of Life: Non-invasive monitoring can considerably enhance a person's quality of life for those who have diabetes. It lessens the burden, stress, and shame connected to conventional monitoring techniques, allowing people to concentrate on other facets of their lives.

2.2.2.2 Product Features

• Painless measurement: The main benefit of non-invasive glucose monitoring is that it causes no discomfort. Because users don't have to use needles or prick their finger’s, drawing blood is a more relaxed and unnerving operation.

• Sensor Technology: Measures glucose levels through the skin or other bodily fluids without the need for a blood sample. Examples of such advanced sensor technologies are optical sensors, spectroscopy, or bioimpedance.

• Real time data: Provides real-time glucose measurements, enabling users to dynamically monitor their levels and make quick dietary, pharmaceutical, or activity changes.

2.2.3 External Interface Requirements

Our device will use tools like Arduino, Power Supply, GSM, LCD, Buzzer.
Platforms required will be Arduino IDE, Embedded C, Thingspeak.

2.2.3.1 User Interfaces

There will a website on which both patient and doctor can login and can see the readings on a redirected thingspeak website and there will be an LCD display on our sensor to display the readings.

2.2.3.2 Hardware Interfaces

Device Display: Our device will have a screen; the display should clearly and prominently display glucose values. It ought to be simple to read.

2.2.3.3 Software Interfaces

Website: Both patients and doctors can login where they can make appointments with doctor and can be redirected to a Thingspeak website where they can keep a track of patient's previous glucose levels**.**

2.2.4 Other Non-Functional Requirements

2.2.4.1 Performance Requirements

• Reliability: The system should be reliable and accurate, with minimal measurement errors or false readings.
• Durability: The system should be able to withstand wear and tear, as well as environmental factors such as humidity, temperature and dust.
• Portability: The system should be portable and easy to carry around so that it can be used by the user whenever and wherever needed.

2.2.4.2 Safety Requirements

Comfort: The system should be comfortable to wear or use, without causing any discomfort or irritation to the user

2.2.4.3 Security Requirements

The system should have appropriate security measures in place to protect the user's sensitive glucose data from unauthorized access or hacking.

2.3 Cost Analysis

Table 4: Cost Analysis

S. No.	COMPONENT	COST	ISSUED
1	NIR Sensor	1600	No
2	Raspberry Pi	5500	Yes
3	Arduino UNO	1000	Yes
4	LCD	300	Yes
5	Wifi Board ESP8266	350	Yes
6	Lithium Battery	300	No
7	Buzzer and Button	220	Yes
8	SD Card 32GB	220	Yes
9	Connectors and Cables	200	No
	Total Cost	9700	2100

2.4 Risk Analysis

The primary concern is the accuracy of the device in measuring glucose levels, including variations caused by environmental factors (temperature and humidity). It is possible that the sensor is not operating efficiently. Additionally, the consistency of the sensor over time may cause a delay in the process of retrieving and updating data, which will cause a delay in the patient's and doctor's access to data. Risks arising from possible interference with medical equipment or other devices. Take into account compatibility problems with different smartphone platforms and other technologies as well. Risks associated with data storage, transmission, and accessibility as well. It is necessary to investigate any weaknesses that could allow hackers or other unauthorized parties to obtain private health information, which might jeopardize sensitive patient data.

3.1 Investigative Techniques

Table5: Investigative Techniques

S. No.	**Investigative Projects Techniques**	**Investigative Techniques Description**	**Investigative Project Examples**
1.	Descriptive	An investigation in which scientific questions are investigated and observations of phenomena are recorded and catalogued.	Projects based on designing completely new system models, concepts, algorithms, etc.
2.	Comparative	Investigations where observations are made that compare two objects or phenomena.	Comparison-based Projects (Algorithm based, System based, etc.)

3.	Experimental	An organized investigation that includes a control group and is designed to test a hypothesis, including independent and dependent variables.	Machine Learning, Deep Learning, or Artificial Intelligence based Projects.

For the purpose of this Project many Investigative techniques have been used in a combination to achieve our goal. The following are listed below.

• Literature Review: An investigation has been carried out to examine the different research articles that have been published in related fields. In order to find current projects or technologies that can serve as building blocks for our project.

• Hypothesis: Developing a hypothesis is a crucial first step in any kind of research project. We base several of our assumptions and concepts throughout this project on our comprehension of the available data and our familiarity with current practices. Throughout the course of this project, we have taken our hypothesis and have worked to support it with relevant information, real-world examples, and experiments.

• Analytical: After the project's fundamental concepts, diagrams, and structure have been established, it must be examined and validated. The approach has been critically analyzed, and well-considered solutions for the problem statements and project vision have been developed, with the assistance of numerous experts in various fields relevant to the project's requirements.

The technique by which our project measures the blood sugar levels is via spectroscopy using a NIRS. It is a unique and non-invasive way to get around the drawbacks of the current blood glucose monitoring techniques is to use NIR technology.
This system maps variations in heart rate using a heartbeat sensor and uses Near-Infrared (NIR) technology to identify variations in blood sugar. Using this correlation, it eliminates the need for invasive blood sampling and offers continuous, painless glucose level monitoring. The device sends out alerts when glucose levels get close to or above a predetermined threshold, allowing for prompt interventions.
An LCD display increases user awareness by providing instantaneous feedback on blood glucose levels. This creative method of monitoring glucose levels is more practical, less invasive, and has the potential to change the way diabetes is managed completely. Further research and rigorous testing are necessary to validate its accuracy and reliability for practical use in diabetes care.

• Direct Measurement of Glucose:
NIRS directly measures glucose levels in the bloodstream. This provides a more specific and accurate assessment of glucose concentration compared to some other non-invasive methods that rely on indirect measurements or correlations.

• Reduced Risk of Infections:
There is no risk of infection related with the use of NIRS because it doesn't require breaking the skin. Compared to techniques that involve skin penetration, this is favourable.

• Painless and Comfortable:
NIRs is painless and comfortable for users.
This is in contrast to some other techniques, such as microneedle-based methods or impedance spectroscopy, which may cause discomfort or irritation.

• Reduced Waste:
Test strips and lancets, used in traditional glucose monitoring techniques, are waste. By eliminating the requirement for disposable supplies, NIRS lessens its impact on the environment.

We will use Arduino because it has more potential and is more accessible in using it. Arduino sensors are often more budget-friendly compared to specialized sensors. This makes them accessible to hobbyists, students, and makers with limited budgets. Arduino sensors are designed to be user-friendly, with plug-and-play compatibility for most Arduino boards. Temperature, humidity, motion, light, sound, gas, and other detecting abilities are just a few of the things that Arduino sensors can detect. Due to its adaptability, users can experiment with various sensor kinds and applications. Small- and large-scale applications can both use Arduino sensors. Users can begin with one sensor and add more as their project progresses. Arduino sensors can often be integrated with other sensors, actuators, and components, Also Some Arduino sensors are made with minimal power consumption in mind, making them appropriate for battery-powered applications and projects that conserve energy.

3.2 Proposed Solution

As diabetes continues to become more prevalent globally, the demand for effective and user-friendly methods of blood glucose monitoring has grown exponentially. Traditional methods, which require patients to prick their fingers to collect blood samples, are both painful and inconvenient, leading to discomfort and a general reluctance to adhere to regular monitoring routines. This discomfort can have significant consequences, as consistent monitoring is essential for effective diabetes management. To address this critical issue, our project focuses on developing a non-invasive method for monitoring blood glucose levels, which could revolutionize the way diabetes is managed worldwide.

- **Technological Innovation and Development**

  The foundation of this proposed solution is the creation of an advanced device capable of accurately and non-invasively measuring blood glucose levels. This endeavor will harness the power of Near-Infrared (NIR) spectroscopy, combined with cutting-edge sensor technology and wearable devices. NIR spectroscopy is particularly promising because it enables the analysis of glucose concentrations in the interstitial fluid just beneath the skin’s surface by detecting how glucose molecules interact with light at specific wavelengths. The primary challenge lies in ensuring that the sensors are sensitive enough to detect subtle changes in light absorption patterns, which correlate directly with blood glucose levels. Achieving a high degree of accuracy with this method is crucial to providing a reliable alternative to invasive techniques, which have long been the gold standard in glucose monitoring.

In addition to the core technology, the device will be designed as a wearable, making it convenient for patients to use throughout the day. This continuous monitoring capability will allow for the collection of real-time data, providing patients with immediate feedback on their glucose levels. The device's design will emphasize comfort, ensuring that it can be worn for extended periods without causing irritation or discomfort. This aspect is particularly important, as the success of wearable technology largely depends on user compliance.

To further enhance the device's functionality, we will explore the integration of additional sensors that can monitor other relevant physiological parameters, such as heart rate and skin temperature. These metrics can provide valuable context for interpreting glucose levels, especially in situations where external factors like stress or physical activity might influence readings. By combining multiple data points, the device will offer a more comprehensive view of the patient's overall health, potentially identifying trends and patterns that could inform better diabetes management strategies.

- **Usability, Accessibility, and User-Centred Design**

  While technological innovation is a significant focus, ensuring that the device is user-friendly and accessible is equally important. A key objective of our project is to design a system that is intuitive and easy to use, regardless of the user's technical expertise. This will involve developing a straightforward, user-centred interface that presents data in a clear and easily interpretable manner. For example, glucose readings could be displayed alongside simple indicators or alerts that help users quickly understand whether their levels are within a safe range.

  The usability aspect extends beyond the software interface to the physical design of the device. The hardware must be sleek, lightweight, and unobtrusive, allowing it to be integrated seamlessly into the daily lives of users. Additionally, the device should be compatible with a variety of platforms, including smartphones and computers, ensuring that users can access their data wherever and whenever they need it. By prioritizing ease of use, we aim to encourage regular monitoring, which is crucial for effective diabetes management.

Accessibility is another critical component of this proposed solution. The device will be designed with a diverse user base in mind, including individuals with varying levels of technical proficiency and those with physical limitations that might make traditional glucose monitoring methods difficult. This could involve offering features like voice-guided instructions or tactile feedback for users with visual impairments. By making the device as inclusive as possible, we hope to ensure that its benefits are available to the widest possible audience.

- **Healthcare Impact and Broader Implications**

  The introduction of a non-invasive glucose monitoring device has the potential to create a profound impact on healthcare, particularly in the management of diabetes. By providing patients with a painless, convenient method of monitoring their blood glucose levels, the device could significantly improve adherence to monitoring routines. This, in turn, would enable more precise management of blood glucose levels, reducing the risk of both short-term complications, such as hypoglycemia and hyperglycemia, and long-term complications, such as cardiovascular disease, kidney damage, and neuropathy.

  Moreover, the real-time data provided by the device would empower both patients and healthcare professionals to make more informed decisions about diabetes management. For instance, patients could receive immediate feedback on how specific foods, activities, or medications affect their glucose levels, allowing them to make adjustments in real-time. Healthcare providers, on the other hand, could use the continuous data to track patients' progress over time, identify patterns, and adjust treatment plans accordingly. This data-driven approach has the potential to improve overall outcomes and reduce the burden on healthcare systems by preventing complications that often require intensive and costly interventions.

The broader implications of this technology extend beyond individual patient care. The widespread adoption of non-invasive glucose monitoring could lead to a shift in the standard of care for diabetes management. As more patients gain access to this technology, the demand for traditional invasive methods may decrease, potentially leading to a reduction in the cost of diabetes care overall. Furthermore, the data collected by these devices could be anonymized and aggregated to contribute to large-scale studies on diabetes, providing valuable insights into the disease's progression and the effectiveness of various treatments.

- **Economic Viability and Accessibility**

  Economic considerations are a crucial aspect of this project. The development of this device must be cost-effective to ensure that it is accessible to a broad audience, including those in lower socioeconomic brackets. Our goal is to create a product that not only meets the needs of patients in developed countries but also addresses the challenges faced by those in developing regions, where access to affordable healthcare is often limited. This involves making strategic decisions during the design and manufacturing processes to minimize costs without compromising on quality or accuracy.

  One approach to achieving this goal is to leverage economies of scale in production. By designing the device in a way that allows for mass production, we can reduce the per-unit cost, making the device more affordable for consumers. Additionally, partnerships with healthcare providers, governments, and non-profit organizations could help subsidize the cost of the device for those who are unable to afford it, ensuring that its benefits are not limited to a privileged few.

- **Addressing Constraints and Challenges**

  Despite the promising potential of non-invasive glucose monitoring, several challenges and constraints must be addressed to ensure the success of this project. One of the primary challenges is achieving a level of accuracy that is comparable to traditional invasive methods. While NIR spectroscopy has shown promise, its effectiveness can be influenced by various factors, such as skin pigmentation, tissue composition, and external conditions like temperature and humidity. To mitigate these challenges, extensive research and testing will be required to refine the technology and develop algorithms that can account for these variables.

Another constraint is the limited penetration depth of NIR light, which primarily interacts with the surface layers of the skin. Since glucose levels in the interstitial fluid may differ from those in deeper tissues, it is essential to determine how closely the readings obtained from the device correlate with actual blood glucose levels. This may involve calibrating the device against invasive reference methods to ensure that the readings are accurate and reliable.

Moreover, it is important to recognize that non-invasive methods may not be suitable for all patients or situations. For example, individuals with certain skin conditions or those who require extremely precise glucose monitoring, such as pregnant women with gestational diabetes, may still need to rely on traditional methods. Therefore, the device should be positioned as a complementary tool rather than a complete replacement for invasive techniques. Clear guidelines should be established to help users and healthcare providers determine when and how to use the device effectively.

- **Conclusion**

  In conclusion, the proposed solution seeks to develop a non-invasive blood glucose monitoring system that combines technological innovation, user-centred design, healthcare impact, and economic viability. By addressing the pain and inconvenience associated with traditional glucose monitoring methods, this project aims to significantly improve the quality of life for millions of diabetes patients worldwide.

3.3 Work Breakdown Structure

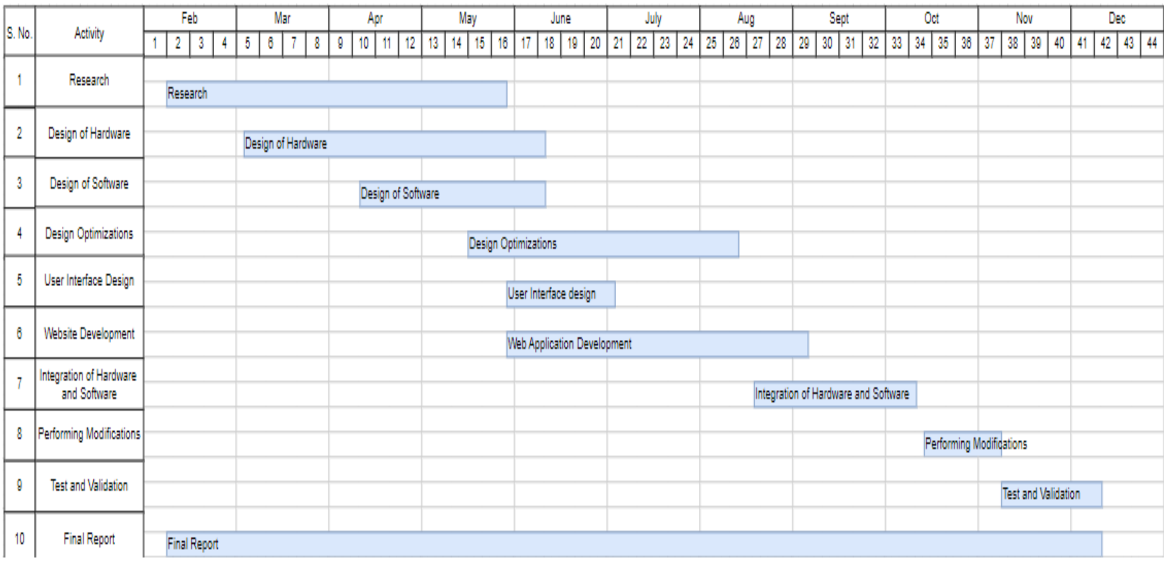

Figure1: Work Breakdown Structure

The hardware module of the non-invasive glucose monitoring system centres on the Raspberry Pi and NIR sensor. The Raspberry Pi processes data from the NIR sensor, which measures glucose levels by analysing light absorption. Key components include the power supply and an optional display unit for real-time readings. The development begins with a prototype to refine the design before finalizing the hardware.

The software module handles data acquisition and analysis. It includes software to collect data from the NIR sensor, algorithms for glucose level estimation, and a user interface for displaying results. Initial software prototypes will be tested and refined to ensure accurate and user-friendly performance.

System integration combines the hardware and software, ensuring that they work seamlessly together. This phase includes integration testing to verify that all components function correctly and efficiently as a unified system. The goal is to produce a fully operational system ready for real-world use.

For deployment and support, the system is installed and configured in user environments according to detailed procedures. Training materials will be provided to users, and ongoing technical support will be available to address any issues. Maintenance will be conducted to keep the system updated and functional.

3.4 Tools and Technology

Table6: Tools and Technology

S. No	Tool/Technology	Usage
1	React JS, Chakra UI, Mongo DB	We are utilizing React.js for a dynamic and responsive user interface, Chakra UI for streamlined and accessible component design, and MongoDB for efficient and scalable data management. This technology stack ensures a robust and user-friendly platform for monitoring and analyzing glucose levels.
2	Arduino IDE	An intuitive software platform called the Arduino Integrated Development Environment (IDE) is used to program and create applications for Arduino microcontroller boards.
3	NIR Sensor	Machines can learn about objects in the physical world through NIR-based sensing. An NIR sensor measures the distance, size, location, and distinguishing characteristics of objects in the three-dimensional environment by receiving the reflected light or light pattern that is produced when NIR light is emitted and reflected off of an object.

4	LCD	Liquid Crystal Display, or LCD For LCD screens, there are two types of RAM: DDRAM and CGRAM. It is used to display our readings
5	Arduino UNO	It has number of facilities for communicating other microcontrollers and another Arduino
6	Raspberry pi	We are using Raspberry Pi in this project due to its versatility and cost-effectiveness, making it an ideal platform for integrating sensors and processing data in real-time.
7	Buzzer	An audio signaling device, such as a buzzer or beeper can be piezoelectric, electromechanical, or mechanical. Buzzer alarm circuits are used in situations where the user needs to be alerted, such as in communication equipment, automobile electronics, and portable devices because of their small size.

DESIGN SPECIFICATIONS

4.1 System Architecture

Block Diagram

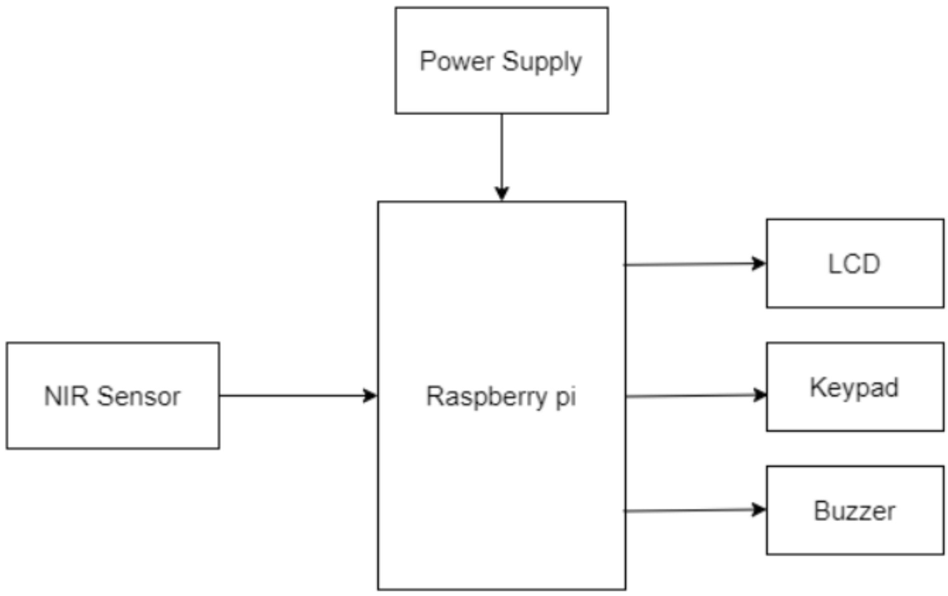

Figure 2: Block Diagram

The proposed implementation and design of non-invasive glucose monitoring system consist of these components: -

Hardware: It consists of Raspberry pi and Arduino Uno communicating with a computer and sensors.

• NIR Sensor:

Machines can learn about objects in the physical world through NIR-based sensing. An NIR sensor measures the distance, size, location, and distinguishing characteristics of objects in the three-dimensional environment by receiving the reflected light or light pattern that is produced when NIR light is emitted and reflected off of an object.

• Buzzer:

An audio signalling device, such as a buzzer or beeper, can be piezoelectric, electromechanical, or mechanical. Buzzer alarm circuits are used in situations where the user needs to be alerted, such as in communication equipment, automobile electronics, and portable devices because of their small size.

• LCD:

Liquid Crystal Display, or LCD For LCD screens, there are two types of RAM: DDRAM and CGRAM. The location of a character's display in an ASCII chart is recorded by DDRAM. Every byte in the DDRAM corresponds to a single position on the LCD display. The LCD controller reads the data from the DDRAM and shows it on the LCD screen. Users can define their own customized characters with CGRAM.

Website Architecture

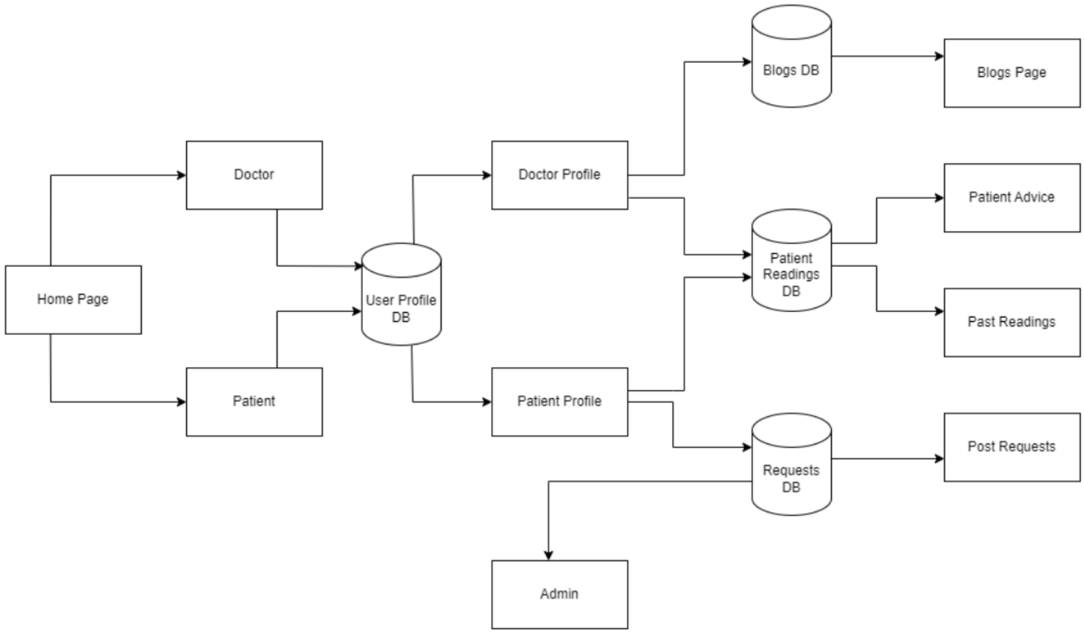

Figure 3: Website Architecture

Software: The software component comprises of IDE, Website tools, etc.

• Arduino IDE:

An intuitive software platform called the Arduino Integrated Development Environment (IDE) is used to program and create applications for Arduino microcontroller boards. It is well-liked by both novice and seasoned developers in the maker and electronics communities because it offers an easy-to-use environment for writing, compiling, and uploading code to Arduino devices.

Since the Arduino IDE is open-source software, a committed user and development community works together to continuously improve it. It enables developers to work on a variety of hardware projects with ease by supporting a large selection of Arduino-compatible boards and shields. All things considered, the Arduino IDE is essential for helping professionals and hobbyists realize their ideas for electronic and embedded systems in an effective and user-friendly way.

• Website:
The front-end part of our website is handled by React JS, Chakra UI and backend part by MongoDB and Firebase.

Overview:

• To use NIRS, first of all we will study and understand the properties of the skin and blood glucose molecules to get vast knowledge about the different layers of the skin, with what
wavelength we can penetrate up to which skin layers.

• The foundation of NIRS is the idea that various substances, such as glucose, absorb and scatter near-infrared light differently. Wavelengths of near-infrared light range from roughly 700 to 2500 nano-meters. When near-infrared light is shone on biological tissues, some of it is scattered and some of it is absorbed by the tissues' molecules.

• Being a molecule with particular molecular bonds, glucose has distinct near-infrared absorption properties. After the light interacts with the tissue, NIRS devices use spectroscopy to examine the reflected or transmitted light.

• In spectroscopy, the tissue is illuminated with near-infrared light, and the amount of light that is absorbed and dispersed at various wavelengths is measured. Through data processing, the overall signal will be separated from the glucose-specific absorption signal. Continuous glucose monitoring (CGM), which provides real-time or frequent glucose readings throughout the day and night, may be possible with NIRS devices.

4.2 Design Level Diagrams

DFD 0

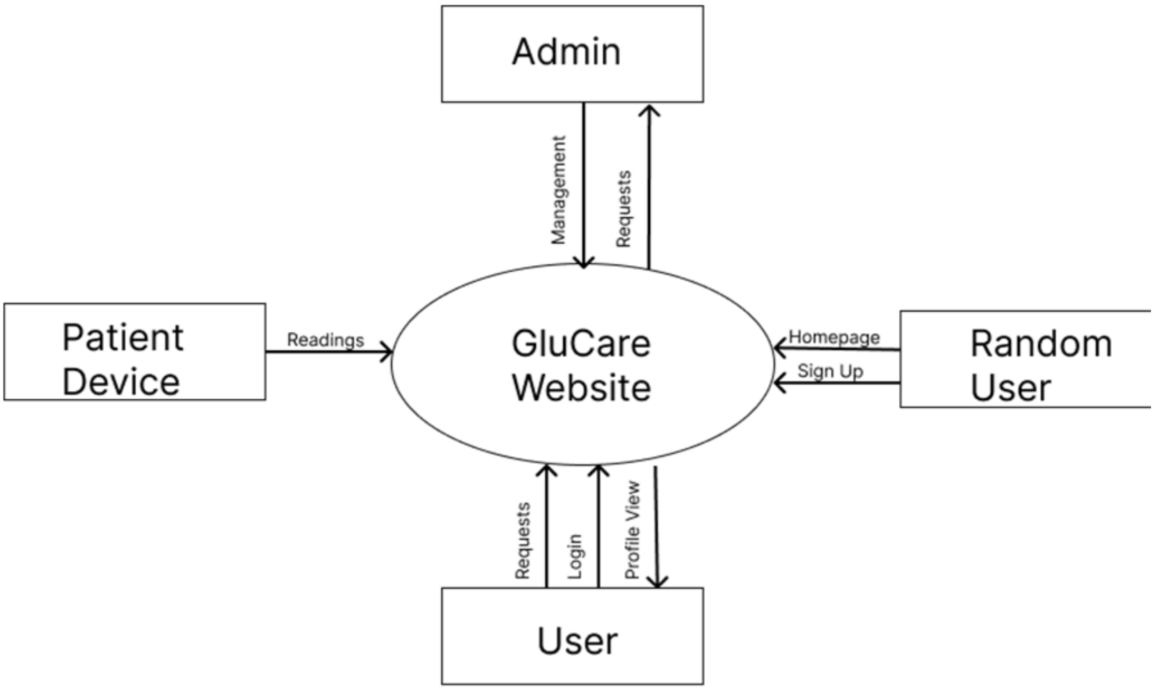

Figure 4: DFD0

DFD 1

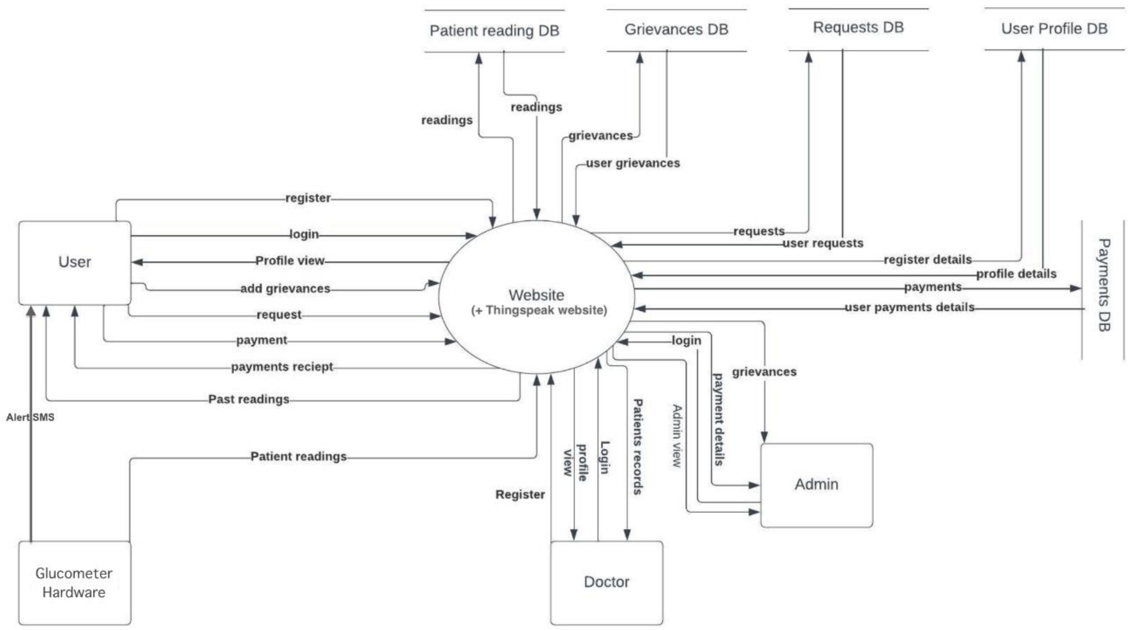

Figure 5: DFD1

Component Diagram

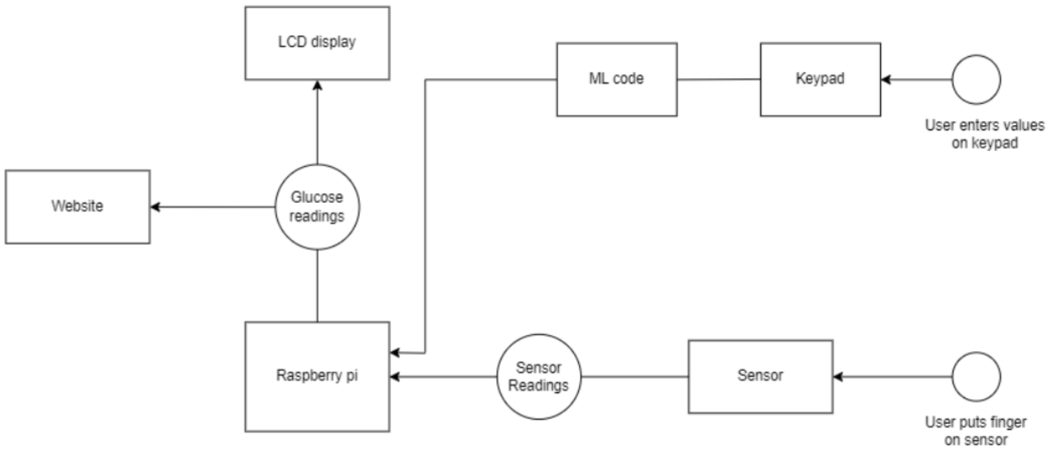

Figure 6: Component Diagram

Class Diagram

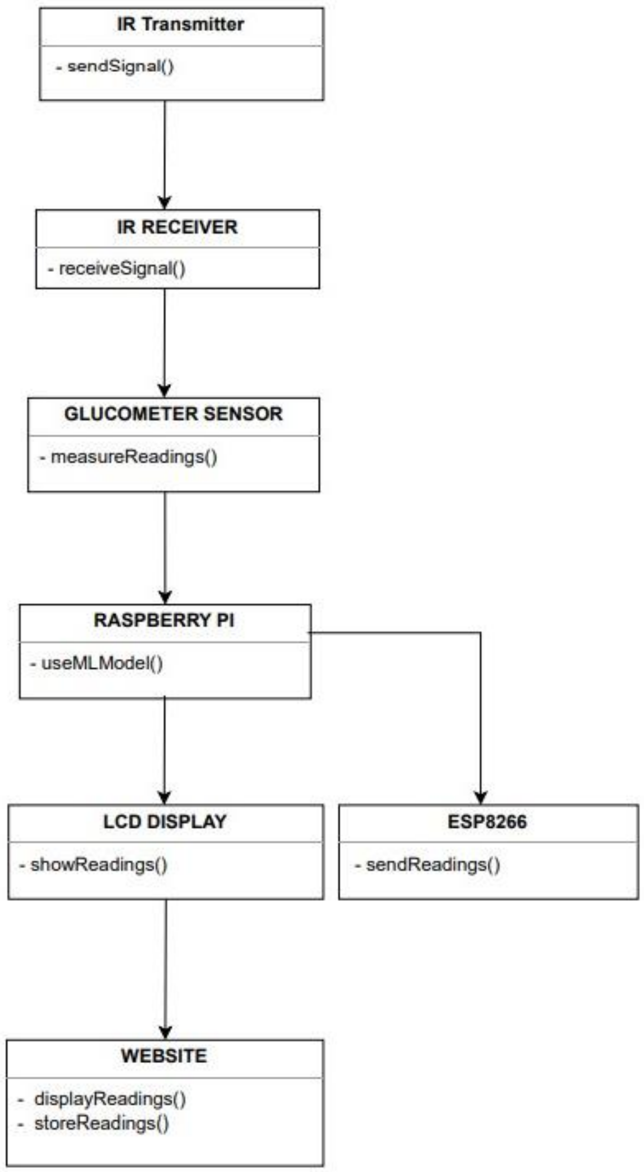

Figure7: Class Diagram

Activity Diagram

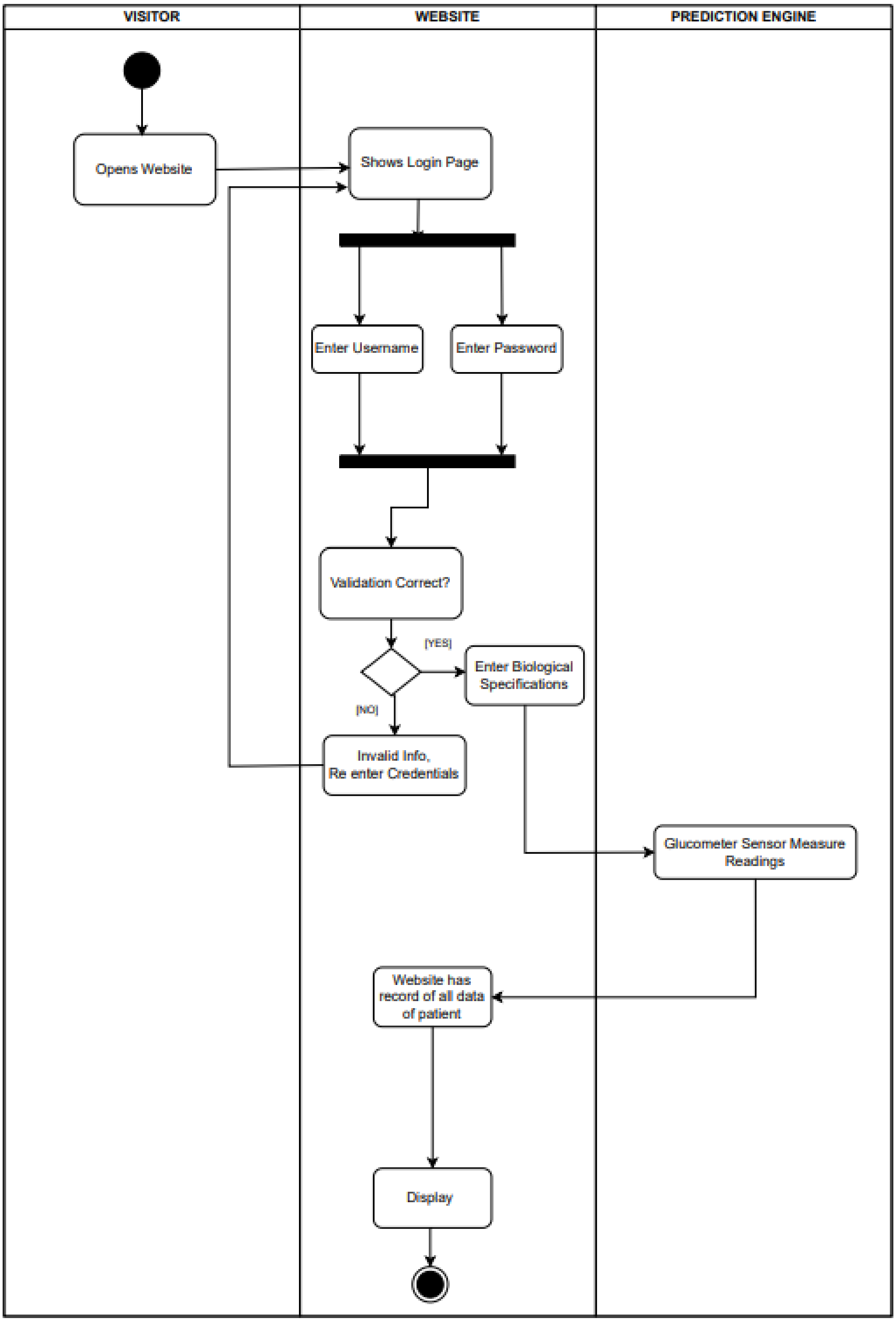

Figure8: Activity Diagram

<u>**Sequence Diagram**</u>

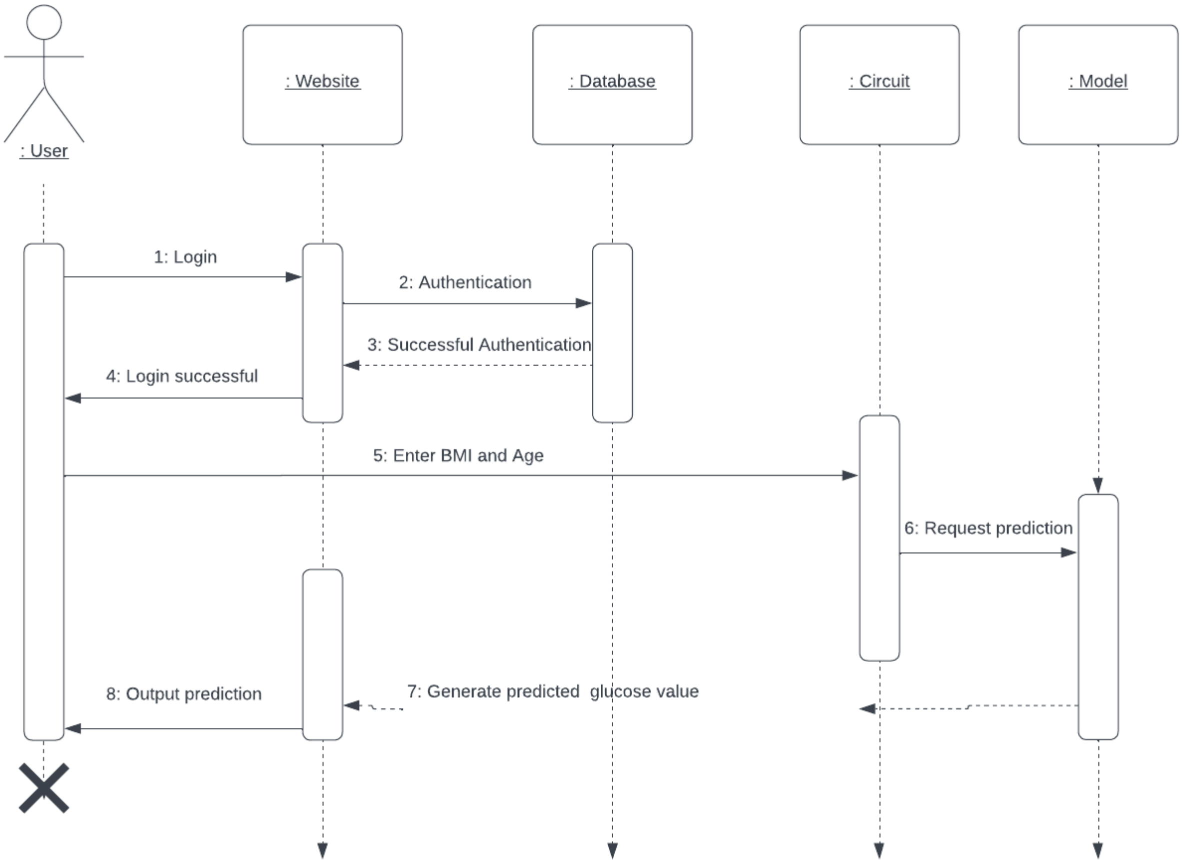

Figure9:Sequence Diagram

4.3 User Interface Diagrams

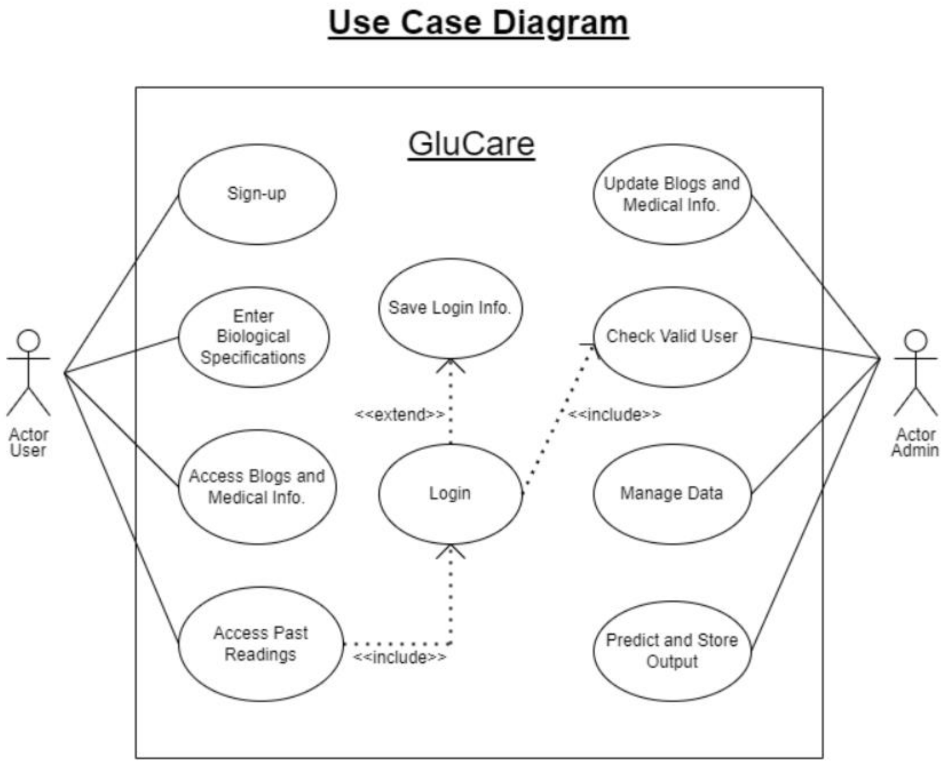

Figure 10: Use Case Diagram

Use Case Templates

Template 1

1. Use Case Title	Sign-up
2. Abbreviated Title	Sign-up
3. Use Case ID	1
4. Actors	User
5. Description	User must enter personal information like name, email id, etc.
5.1. Pre-Conditions	Set attributes which user must enter.
5.2. Task Sequence	a) User Info form will be displayed on the page. b) User must enter corresponding details.
5.3. Post Conditions	If successful, user is signed up for the next step.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Table7: Use Case Diagram Template 1

Template 2

1. Use Case Title	Enter Biological Specifications
2. Abbreviated Title	Enter Biological Specifications
3. Use Case ID	2
4. Actors	User
5. Description	User must enter biological specifications like BMI, Age, etc to predict the blood glucose level.
5.1. Pre-Conditions	Blood Glucose relationship with biological details.
5.2. Task Sequence	a) Fields corresponding to factors will be displayed. b) User must enter details.
5.3. Post Conditions	Blood Glucose levels will be displayed.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Table 8 : Use Case Diagram Template 2

Template 3

1. Use Case Title	Access Blogs and Medical Information
2. Abbreviated Title	Access Blogs and Medical Info.
3. Use Case ID	3
4. Actors	User
5. Description	User can read diabetes related blogs and access information regarding doctors and clinics.
5.1. Pre-Conditions	Blogs and medical contacts should be available.
5.2. Task Sequence	a) Click on the Blogs and Info. section. b) Access desired information.
5.3. Post Conditions	User is equipped with latest information.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Table 9 : Use Case Diagram Template 3

Template 4

1. Use Case Title	Access Past Readings
2. Abbreviated Title	Access Past Readings
3. Use Case ID	4
4. Actors	User
5. Description	User can view past readings with infographics.
5.1. Pre-Conditions	There must be a set of the user's readings in the database.
5.2. Task Sequence	a) User can login with valid login ID. b) Access readings which have been calculated by the model in the past.
5.3. Post Conditions	User has a visual idea of his glucose fluctuations in the past.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Table10: Use Case Diagram Template 4

Template 5

1. Use Case Title	Login
2. Abbreviated Title	Login
3. Use Case ID	5
4. Actors	User
5. Description	User must enter personal information like name, email id, etc. Enables Admin to find out which user is valid to access the model.
5.1. Pre-Conditions	Set attributes which user must enter.
5.2. Task Sequence	a) User Info form will be displayed on the page. b) User must enter corresponding details.
5.3. Post Conditions	If successful, user is logged in for the next step.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Table11: Use Case Diagram Template 5

Template 6

1. Use Case Title	Save Login Information
2. Abbreviated Title	Save Login Info.
3. Use Case ID	6
4. Actors	User
5. Description	User can choose whether or not to store his login info for future login.
5.1. Pre-Conditions	User must have entered some information prior to this.
5.2. Task Sequence	a) User must select the option whether or not he wants his information saved for future. b) Click login button
5.3. Post Conditions	User information is saved for future.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Figure 12: Use Case Diagram Template 6

Template 7

1. Use Case Title	Update Blogs and Medical Information
2. Abbreviated Title	Update Blogs and Medical Info.
3. Use Case ID	7
4. Actors	Admin
5. Description	Admin must design a system which can replace old information with the latest.
5.1. Pre-Conditions	There must be a section on the portal accessible and dedicated for the same.
5.2. Task Sequence	Continuous updating using APIs.
5.3. Post Conditions	Portal is up to date with the necessary information.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Figure 13: Use Case Diagram Template 7

Template 8

1. Use Case Title	Check Valid User
2. Abbreviated Title	Check Valid User
3. Use Case ID	8
4. Actors	Admin
5. Description	Admin must check if user is allowed access or not depending upon his login ID.
5.1. Pre-Conditions	A set sequence of login IDs for users who are to be allowed access.
5.2. Task Sequence	Followed by entering of Login details. Admin must display message if user invalid.
5.3. Post Conditions	If valid, user accepted for next step.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Figure 14: Use Case Diagram Template 8

Template 9

1. Use Case Title	Manage Data
2. Abbreviated Title	Manage Data
3. Use Case ID	9
4. Actors	Admin
5. Description	Admin must manage and store database on which the model is built and results are stored. Graphs and plots can be used to show variations.
5.1. Pre-Conditions	Glucose values are predicted.
5.2. Task Sequence	User outputs are maintained as a database.
5.3. Post Conditions	Model is learned to be implemented and user results are stored.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Figure 15: Use Case Diagram Template 9

Template 10

1. Use Case Title	Predict and Store Output
2. Abbreviated Title	Predict and Store Output
3. Use Case ID	10
4. Actors	Admin
5. Description	Output for which the model is built is calculated and stored.
5.1. Pre-Conditions	All processes must be executed successfully.
5.2. Task Sequence	a) Model must calculate the result. b) The result must be displayed on the screen, visible to the user.
5.3. Post Conditions	User can apply this model for blood glucose level prediction.
6. Modification History	May 2, 2024
7. Author	Nitleen, Pia, Anupriya, Stuti, Riddhi

Figure 16: Use Case Diagram Template 10

4.4 Snapshots of Working Prototype

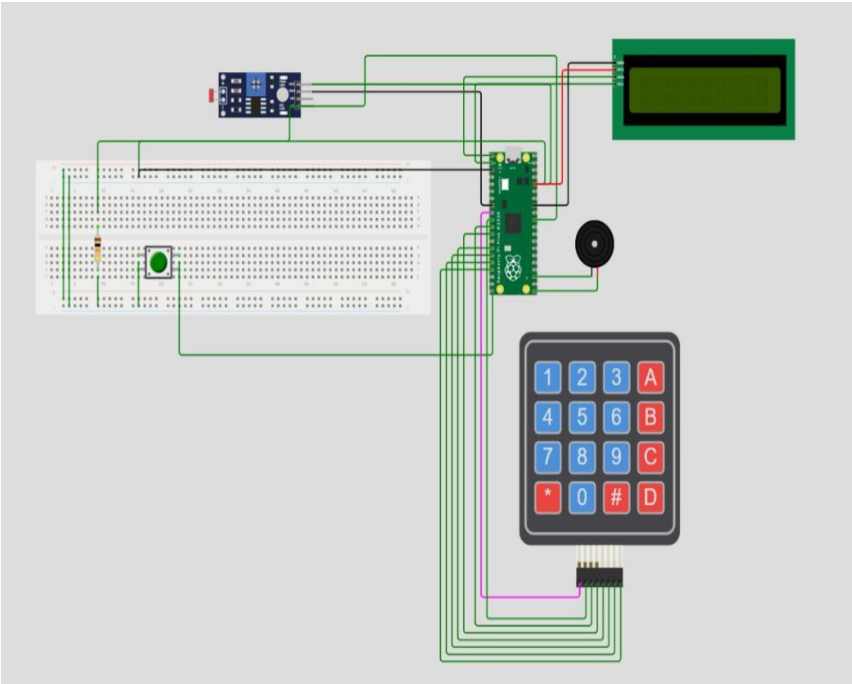

Figure11: Simulation of Circuit

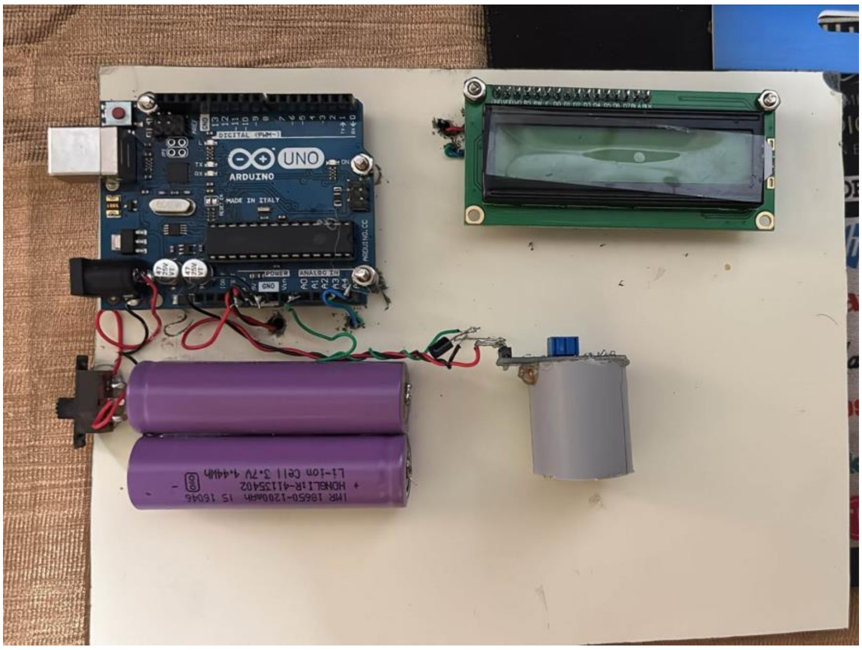

Figure 12: Circuit

<u>Overview of the System</u>:

The system measures glucose levels using a glucometer sensor, processes the readings using an Arduino, displays the readings on an LCD, and sends the data to a remote server via the ESP8266 Wi-Fi module. The data can be accessed online, and notifications or alerts can be sent through web-based methods.

<u>Components and Circuit Overview:</u>

IR Transmitter and IR Receiver:

Purpose: These components detect when the glucose sensor is ready to take a measurement. The IR Transmitter sends out a signal, and the IR Receiver detects this signal to trigger the measurement process.

Working: When the sensor is in place, the IR Receiver receives the signal from the IR Transmitter, triggering the Arduino to start the glucose measurement process.

Glucometer Sensor:

Purpose: Measures the glucose levels in the blood sample.

Working: The sensor detects the glucose concentration in the blood and sends this raw data to the Arduino for processing. The sensor might be connected to the Arduino via analog or digital input pins.

Arduino:

Purpose: The main controller of the system.

Working:

1. Data Processing: Once the Arduino receives the raw glucose data from the sensor, it processes this data using its convertReadings() function. This could involve converting analog signals into digital values and possibly calibrating the readings based on predefined values.
2. Display: The Arduino then sends the processed glucose readings to the LCD Display using I2C communication.
3. Data Transmission: The Arduino also sends the glucose readings to the ESP8266 module for transmission to a remote server via Wi-Fi.

I2C LCD Display:

Purpose: Displays the glucose readings in real-time for the user.

Working: The LCD Display is connected to the Arduino through an I2C interface. It receives the glucose readings and displays them, allowing the user to view their glucose levels immediately after measurement.

ESP8266 WiFi Module:

Purpose: Handles all WiFi-based communication, sending glucose data to a remote server or cloud platform.

Working:

1. WiFi Connection: The ESP8266 connects to a local WiFi network using the connectToNetwork() function. It can store the network credentials in memory and reconnect automatically when powered on.
2. Data Transmission: Once connected, the ESP8266 sends the glucose readings to a web server using the sendData() function. This could be done using HTTP POST requests or MQTT protocol, depending on the server setup.
3. Notifications: While the ESP8266 doesn't support SMS, it can trigger email alerts, push notifications, or other web-based notifications via the server.

Website:

Purpose: Acts as a remote storage and display platform for the glucose readings.

Working:

1. Data Reception and Storage: The website receives data from the ESP8266 via the internet. It stores these readings in a database, which can be accessed later by the user or healthcare providers.
2. User Interface: The website provides a user-friendly interface where users can log in to view their glucose readings over time, track trends, and possibly receive advice based on the data.
3. Alerts: The website can be configured to send alerts if readings are abnormal. For instance, if a reading is too high or too low, the server can send an email or push notification to the user's mobile device.

User Mobile:

Purpose: Receives notifications and provides access to the website.

Working:

1. Notifications: The user's mobile device receives web-based notifications (e.g., email, push notifications) triggered by the website when certain thresholds are met.
2. Web Access: Users can access the website through a mobile browser or a dedicated app, allowing them to view their glucose data in real-time or historical context.

Power Supply (Lithium Battery):

Purpose: Provides portable power to the entire system.

Working: The Lithium Battery powers the Arduino, ESP8266, and other components. The Arduino may include a power management function to monitor battery levels and ensure efficient energy use.

<u>System Operation Flow</u>:

Start-up:

The user powers on the device, and the Arduino initializes all connected components (IR Transmitter, IR Receiver, Glucometer Sensor, I2C LCD, and ESP8266).

Measurement Trigger:

The IR Receiver detects the presence of the sensor (or the user's action), triggering the measurement process.

Glucose Measurement:

The Glucometer Sensor measures the glucose level and sends the raw data to the Arduino.

Data Processing:

The Arduino processes the raw data to convert it into a readable glucose level.

Display and Transmission:

The processed glucose reading is displayed on the LCD for the user to view immediately.

Simultaneously, the Arduino sends the data to the ESP8266, which transmits it to the remote server over WiFi.

Data Storage and Access:

The server stores the glucose readings in a database. Users and healthcare providers can access this data through a secure web interface.

Alerts and Notifications:

If the glucose reading is abnormal, the server triggers an alert, sending a notification to the user’s mobile device.

Continuous Monitoring:

The system is designed for continuous or regular use, with the user checking their glucose levels as needed and the data being sent to the server each time.

CONCLUSIONS AND FUTURE SCOPE

5.1 Work Accomplished

1. **Research on NIR Spectroscopy (940 nm):**
    - Conducted in-depth research on Near-Infrared (NIR) spectroscopy, focusing on the 940 nm wavelength.
    - Analysed relevant studies and literature to understand its applications and limitations.
2. **Schematic Design, Simulation, and Circuit Construction:**
    - Developed schematics for the project.
    - Simulated the circuits to ensure proper functionality and performance.
    - Successfully constructed the physical circuit based on the simulations.
3. **Research and Deployment of Machine Learning Models:**
    - Researched suitable machine learning models tailored for the project's requirements.
    - Implemented and deployed these models, ensuring they are optimized for the project's specific needs.
4. **Feature Development on Website:**
    - Added and integrated new features into the website, enhancing its functionality and user experience.

5.2 Conclusions

A smart healthcare device for non-invasive blood glucose monitoring signals the beginning of a new era in diabetes care. These devices enable patients to check their glucose levels more easily and accurately by avoiding the discomfort of repeated finger pricking. Continuous monitoring, real-time data presentation, and connectivity features enhance the benefits, allowing for better diabetes management and patient outcomes. As technology and research develop, we should expect more enhancements in accuracy, affordability, and accessibility, ultimately altering the diabetes management landscape.

5.3 Environmental, Economic & Social Benefits

1. Environmental Benefits

- Reduced waste: Traditional blood glucose monitoring methods involve finger pricks and disposable test strips, which generate a large quantity of medical waste. A non-invasive NIRS gadget reduces the need for single-use goods, resulting in less waste and a lower environmental footprint.
- Less Energy Consumption: When compared to more invasive or resource-intensive approaches, such as laboratory tests, NIRS technology often consumes less energy. This can help to conserve energy and reduce overall energy-related environmental consequences.

2. Economic Benefits

- Cost-Savings: Individuals with diabetes require continuous blood glucose monitoring. Using a non-invasive NIRS device may reduce the overall cost of diabetes management by reducing the need for frequent purchases of test strips and lancets.
- Increased Productivity: Diabetes patients frequently spend a significant amount of time controlling their glucose levels. A non-invasive monitoring gadget could free up time and attention for other productive assignments, helping the economy by increasing workforce participation.

3. Social Benefits

- Enhanced quality of life: For diabetics, finger pricks can be unpleasant and uncomfortable. A non-invasive NIRS system provides a more pleasant and less intrusive means of blood glucose monitoring, enhancing the quality of life for people who live with diabetes.
- Accessibility: Traditional blood glucose testing methods may be difficult for some people, such as kids or seniors. A non-invasive glucose monitoring gadget could make glucose monitoring more accessible to a broader spectrum of people, boosting participation in the treatment of diabetes.

5.4 Future Work Plan

1. **Improve Circuit Accuracy Using Deep Learning:**
    - Explore and implement deep learning techniques to enhance the accuracy and reliability of the circuit.
    - Train and fine-tune models to optimize circuit performance.
2. **Validation of Circuit Using Pricking:**
    - Conduct thorough validation of the circuit through pricking techniques.
    - Ensure the integrity and accuracy of the circuit's operation by identifying potential issues.
3. **Machine Learning for Validation; Accuracy & Error Analysis:**
    - Apply machine learning models to validate circuit performance.
    - Focus on accuracy improvement and conduct comprehensive error analysis to refine the model's predictions.
4. **Data Reflection on Website & User Profile Integration:**
    - Integrate and display relevant data on the website, ensuring that user profiles reflect updated and accurate information.
    - Enhance user interaction with personalized data representation.
5. **Website Testing for Bug-Free Performance:**
    - Perform extensive testing of the website to identify and fix any bugs.
    - Ensure a smooth and seamless user experience by maintaining a bug-free environment.

APPENDIX A: REFERENCES

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APPENDIX B: PLAGIARISM REPORT

I, Pia Gupta, affirm the originality and authenticity of the content presented in the document titled "GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy". As one of the authors of this work and leader of the group, along with Nitleen Kaur, Anupriya Lathey, Ridhi Garg and Stuti Mittal, I assert that every word, sentence, and idea contained within this document has been collectively created by us and reflects our own intellectual contributions. Throughout the process of crafting this document, we have meticulously upheld the principles of academic integrity by avoiding any form of plagiarism. This document is a manifestation of our collaborative research, creative thinking, and dedicated effort on our Capstone Group Project. We have conscientiously undertaken measures to verify the uniqueness of the content, ensuring that it remains distinct from any pre-existing works. Any semblance between this document and other works is purely coincidental, unintentional, and a testament to the shared exploration of the subject matter. We acknowledge the severe implications of plagiarism in academic and professional contexts, including its negative impact on the credibility of our work and the erosion of ethical values. We are committed to upholding the principles of academic honesty, integrity, and responsible scholarship. With the highest regard for intellectual authenticity, we submit this document as an authentic representation of our own contributions.

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