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

Capstone Project Proposal

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1. Mentor Consent Form

I hereby agree to be the mentor of the following Capstone Project Team

Project Title: GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy		
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2. Project Overview

The project "GLUCare: An Advanced Non-Invasive Glucose Monitoring System using NIR Spectroscopy" is a non-invasive method of measuring blood glucose levels. It assists diabetics in monitoring their blood glucose levels. The concept behind our Smart healthcare device is to provide an efficient and painless alternative to the traditional finger-pricking method of measuring blood glucose levels, which causes people discomfort.

This device aids in the integration and combination of various technologies such as spectroscopy, sensors, wearable technology, and data analysis in order to create a better alternative. Spectroscopy is the study of how different molecules under the human skin interact with light at various wavelengths. In the non-invasive blood glucose monitoring device, a light source is used that emits near-infrared (NIR) light which can penetrate the skin's surface. When this light passes through the human skin, it interacts with the glucose molecules in the interstitial fluid. The fluid that surrounds the cells of the body is known as interstitial fluid. Light's interaction with glucose molecules causes noticeable changes in its properties, such as absorption of light by glucose molecules and scattering of light by glucose molecules. The penetrated light that has come into contact with the glucose molecules is transformed. The device's receiver sensor then captures it.

Modern techniques have been used to extract vital information about the amount of glucose in the interstitial fluid by analyzing changes in light characteristics such as intensity and wavelengths. After analysis, the data was converted into real-time glucose readings. The converted real-time glucose can then be displayed on the device's interface or sent to a linked web app, where it can be organized and managed for future analysis.

3. Problem Statement

The existing challenge in non-invasive glucose detection lies in the limited commercialization of NIR devices due to issues concerning accuracy. Current research suggests that NIR spectroscopy is a promising method for glucose monitoring, but its widespread adoption is hindered by a lack of precision. Our project addresses this gap by enhancing accuracy and reliability through the incorporation of clinical factors. By considering individual variations in physiology, our goal is to make NIR-based glucose detection more robust, thereby paving the way for the successful commercialization of non-invasive glucose monitoring solutions.

4. 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.

5. Literature Survey

Table 1: Literature Survey

Year	Author(s) name	Title of Research	Description
2023	J. Wu, Y. Liu, H. Yin and M. Guo	A new generation of sensors for non-invasive blood glucose monitoring	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.
2023	Daria Di Filippo, Frédérique N. Sunstrum, Jawairia Umar Khan and Alec W. Welsh 1,4	Non-Invasive Glucose Sensing Technologies and Products: A Comprehensive Review for Researchers and Clinicians	It analyzes recent literature to compare the effectiveness and feasibility of non-invasive techniques for glucose monitoring, aiming to advance the field of diabetes care and management.
2021	B. Alsunaidi, M. Althobaiti, M. Tamal, W. Albaker and I. Al-Naib	A review of non-invasive optical systems for continuous blood glucose monitoring	This paper addresses the need for painless and cost-effective substitutes for conventional invasive methods of blood glucose monitoring by reviewing recent developments in non-invasive optical approaches.
2020	Liu Tang, Shwu Jen	Non-Invasive	This research compares optical, microwave, and

	Chang, Ching-Jung Chen, and Jen-Tsai Liu1	Blood Glucose Monitoring Technology	electrochemistry technologies for non-invasive blood glucose measurement and looks at current developments. It also predicts increased efficiency with the development of biosensors and wearable technology.
2020	A. Bolla and R. Priefer,	Blood glucose monitoring-an overview of current and future non-invasive devices.	This paper investigates non-invasive blood 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.
2019	Vega Pradana Rachim, Wan-Young Chung	Wearable-band type visible-near infrared optical biosensor for non-invasive blood glucose monitoring	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.
2019	A. T. Mobashsher, A. Abbosh and	The Progress of Glucose	This study examines cutting-edge non-invasive glucose monitoring devices and projects

	W. Villena Gonzales	Monitoring-A Review of Invasive to Minimally and Non-Invasive Techniques, Devices and Sensors	that they will soon surpass invasive techniques in adoption.
2012	A. Ciudin, C. Hernández and R. Simó	Non-invasive methods of glucose measurement: current status and future perspectives.	This paper examines non-invasive blood glucose monitoring as a means of improving diabetes care. It discusses the implications of tested devices and highlights the shortcomings of existing approaches.
2014	A. J. Bandodkar and J. Wang	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 through sweat, tears, or saliva for various applications.
2015	J. Yadav, A. Rani, V. Singh and B. Mohan	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.

6. Research Gap

Table 2: Research Gap

No.	Research Gap	Explanation
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.
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 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.
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.

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

7. Novelty

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.

8. 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.

9. Methodology

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

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

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

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

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

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

10. Project Outcomes & Individual Roles

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.

Table 3: Individual Roles

S No.	Role	Team Member
1	Research Work	Anupriya, Nitleen, Pia, Stuti
2	Design and study of hardware	Nitleen, Pia , Stuti
3	Model Training	Riddhi, Nitleen, Pia, Stuti
4	Web application development	Riddhi, Anupriya, Nitleen, Pia,
5	Integration of hardware & software	Riddhi, Anupriya, Nitleen, Pia, Stuti
6	Testing	Anupriya, Nitleen, Pia, Stuti

11. Work Plan

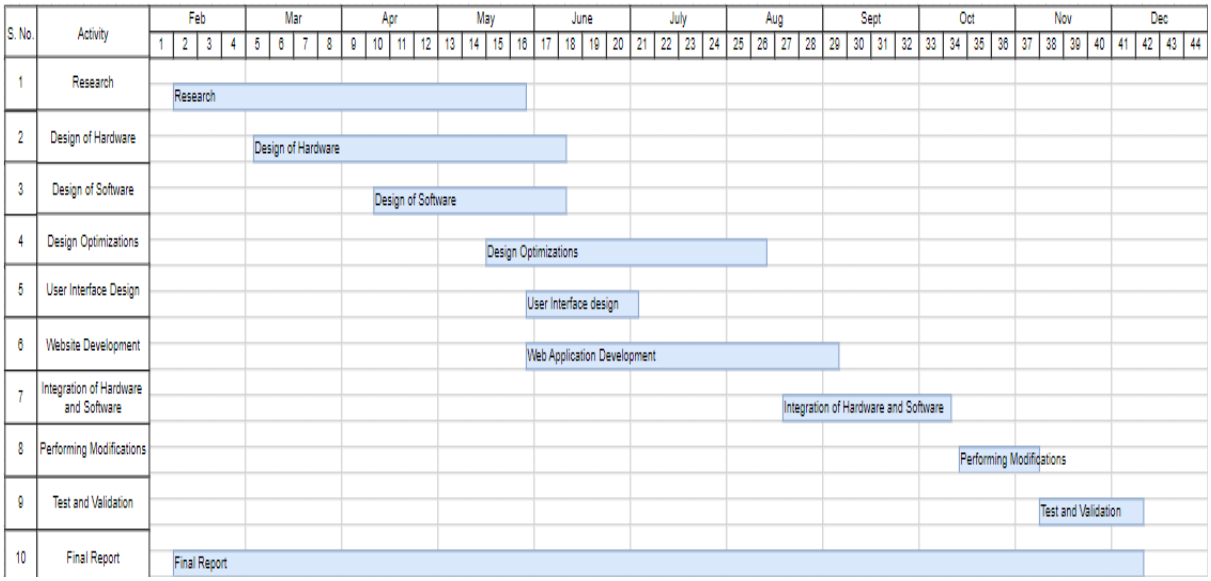

Figure 1: Work Plan

12. Course Subjects

Machine Learning

Machine learning is essential in training a non-invasive glucose monitoring device using NIR spectroscopy. By processing and extracting clinical features from diverse datasets, it optimizes model performance, enabling accurate glucose predictions. This approach enhances the device's accuracy, providing valuable insights for non-invasive glucose monitoring and improving overall diabetes care.

Software Engineering

Applying software management methodologies to organize and execute the project efficiently. This might include tools like Agile, Scrum, or Kanban.

Aruino UNO & Sensors

In the project integrating NIR spectroscopy for non-invasive glucose monitoring, Arduino and sensors play pivotal roles. Arduino serves as the microcontroller, facilitating data acquisition from NIR sensors. These sensors capture near-infrared

spectra, and Arduino processes and transmits the data to the machine learning model for real-time analysis, enabling accurate and continuous glucose monitoring.

UI & UX

Craft a user-centric interface for the non-invasive glucose monitoring project using NIR spectroscopy. Prioritize real-time data visualization, customization options, and accessible controls. Implement alerts, mobile responsiveness, and educational features, ensuring a secure and intuitive experience for users managing their glucose levels.

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