Final Year Project

Software Requirement Specification

Title:

GlucoSense: Smart Non-invasive Glucose Monitoring System

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1. Introduction

The introduction of this Software Requirement Specification (SRS) document provides a comprehensive overview of the document. It is designed to encapsulate all the necessary information required for the design and implementation of the “GlucoSense: Smart Non-Invasive Glucose Monitoring System”. This document serves as a detailed guide, outlining the system's requirements, functionalities, constraints, and user interfaces.

1.1 Purpose

The purpose of this SRS is to present a detailed description of the “GlucoSense: Smart Non-Invasive Glucose Monitoring System”. It is intended for the development team, project stakeholders, including the supervising faculty, project sponsors, and potential users such as patients and healthcare providers. The document aims to ensure a clear understanding of the system's functionalities, requirements, and constraints, facilitating an efficient and effective development process.

1.2 Scope

The scope of this SRS includes the following:

(1) Software Product(s): The primary product is the “GlucoSense: Smart Non-Invasive Glucose Monitoring System”, a software-based solution for monitoring glucose levels using multifactorial skin analysis and machine learning algorithms.

(2) Functionality: The system will automate glucose level analysis by utilizing parameters such as skin color, texture and thickness through machine learning to accurately assess glucose levels without invasive methods. It will serve as an assistive tool to provide reliable glucose readings and alerts.

(3) Application: The system aims to offer benefits such as increased comfort, accuracy, and convenience in glucose monitoring, especially for diabetes management. Key objectives include reducing discomfort associated with invasive tests, minimizing human error, and providing quick, reliable alerts, aligning with broader healthcare goals.

1.3 Sustainable Development Goals (SDGs)

Aligned SDGs for this project:

- **SDG 3: Good Health and Well-being** – Enhances health outcomes through a painless, accessible glucose monitoring system.
- **SDG 9: Industry, Innovation, and Infrastructure** – Leverages innovative technologies like machine learning and mobile applications to advance healthcare infrastructure.

1.4 Definitions, Acronyms, and Abbreviations

This subsection will include definitions of terms like GlucoSense, ML (Machine Learning), NIR (Near-Infrared), GUI (Graphical User Interface), and other relevant acronyms and abbreviations to ensure the SRS is accurately interpreted by all stakeholders. A detailed list of these terms is provided in the appendix.

1.5 References

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[8] Singh, R., and Banerjee, S., **"Machine Learning Approaches in Non-Invasive Glucose Monitoring Systems: Current Progress and Future Prospects,"** IEEE Transactions on Biomedical Engineering, 68(9), 2890-2899, 2021.

1.6 Overview

This subsection provides an overview:

(1) SRS Contents: This document contains detailed descriptions of the system's functional and non-functional requirements, user interfaces, system models, and specific requirements for external interfaces, data handling, and performance metrics.

(2) Organization: The document is organized into sections covering the introduction, general description of the project, specific requirements (including functional and non-functional aspects), system models, analysis models, and appendices for additional reference material. This structure ensures that the SRS document is comprehensive, clear, and serves as a foundational guide for developing the "GlucoSense: Smart Non-Invasive Glucose Monitoring System".

2. General Description

This section outlines the general factors that influence the "GlucoSense: Smart Non-Invasive Glucose Monitoring System" and its requirements, providing context and background to understand the specific requirements better.

2.1 Product Perspective

The GlucoSense system is an innovative product in the field of medical diagnostic tools, particularly in glucose monitoring. It integrates seamlessly with existing healthcare infrastructures and distinguishes itself from traditional invasive glucose monitoring systems. The system is part of a broader ecosystem of healthcare technology, designed to enhance the efficiency, comfort, and accuracy of glucose monitoring in medical and personal settings.

- **Relation to Existing Products:** This system complements current glucose monitoring technologies, offering a more comfortable, non-invasive alternative to traditional glucose testing methods that require blood samples.
- **Integration with Healthcare Systems:** GlucoSense is designed for seamless integration with hospital and healthcare information systems, ensuring smooth data flow and management across healthcare platforms.

2.2 Product Functions

The software primarily performs the following functions:

1. **Automated Glucose Level Analysis:** Uses multifactorial skin analysis and machine learning algorithms to provide accurate, non-invasive glucose measurements.
2. **Alert and Notification System:** Sends automated alerts to users and healthcare providers when glucose levels exceed safe thresholds, aiding in timely intervention.
3. **Data Management:** Efficiently manages user data and glucose readings, ensuring easy access, confidentiality, and secure storage.
4. **User Interface:** Offers a user-friendly interface for users to monitor glucose levels and interact with the system.
5. **Integration Capability:** Ensures compatibility with mobile devices and technology, allowing for continuous, real-time monitoring and user interaction.

2.3 User Characteristics

The primary users of the GlucoSense system will be individuals with diabetes and healthcare professionals such as endocrinologists and diabetes specialists. Users are expected to have:

- **Health Awareness:** Basic understanding of glucose levels and their importance in managing diabetes.
- **Adaptability:** Ability to adapt to new health-monitoring technology for improved diabetes management.

2.4 General Constraints

The development and implementation of GlucoSense are subject to several constraints:

1. **Hardware Compatibility:** The system must be compatible with standard mobile devices and sensors used in personal and healthcare settings.
2. **Regulatory Compliance:** The system must adhere to healthcare regulations, including data privacy and patient safety standards.
3. **Resource Limitations:** It relies on the availability and accuracy of digital sensors and processing capabilities.
4. **Environmental Factors:** Designed to function reliably across varying ambient conditions, including different lighting environments and physical activity levels.

2.5 Assumptions and Dependencies

Several assumptions underline the system's requirements:

1. **Operating System Availability:** The software is developed to be compatible with the Android operating system, ensuring that users can access the GlucoSense application on Android devices.
2. **Hardware Availability*:*** Assumes access to standard devices and mobile sensors for glucose monitoring.
3. **Stable Internet Connection:** Necessary for software updates, data synchronization, and remote access functionalities.
4. **Continued Relevance of Non-Invasive Glucose Monitoring:** Assumes that non-invasive glucose monitoring will remain a valuable tool in diabetes management.

   These assumptions and dependencies shape the requirements and potential adaptations of the SRS. Changes in these factors may necessitate revisions to accommodate new circumstances or constraints.

3. Specific Requirements

This section outlines the necessary requirements for the "GlucoSense: Smart Non-Invasive Glucose Monitoring System" to ensure successful design, implementation, and testing. Each requirement is designed to be clear, traceable, verifiable, complete, consistent, and prioritized for ease of use.

3.1 External Interface Requirements

These requirements define how the GlucoSense system interacts with users, hardware, software, and communication networks.

3.1.1 User Interfaces

- **Description:** Defines the interaction between the user and the GlucoSense mobile application.
- **Design and Layout:** The application interface is intuitive, designed for users with diabetes to easily monitor their glucose levels.
- **Login System:** The app requires user sign-in to access glucose readings, with data stored securely in a database.
- **Alerts and Notifications:** Real-time feedback for glucose levels and alerts for high readings.
- **Importance:** Essential for user-friendly access and clear visibility of glucose trends.
- **Data Visualization:** Displays glucose level trends and history to aid in user decision-making.

3.1.2 Hardware Interfaces

Description: The software interacts with multiple hardware components to obtain, process, and communicate glucose data.

Key Components:

- **IR Transmitter/Receiver:** We amplify the IR sensor readings using an amplifier circuit (with a low-pass filter) that functions as an NIR sensor for glucose analysis through skin interaction.
- **Arduino Nano:** Acts as the central processing unit, handling data from the IR sensor and interfacing with the mobile app.
- **Camera Module:** Captures skin color, thickness, and texture for image processing.
- **Amplification Circuit:** Ensures that low-frequency IR signals are amplified for accurate readings.
- **Importance:** Ensures compatibility and reliability of glucose readings.

- **Connectivity:** Ensures seamless data flow between the device and the mobile app via Bluetooth/Wi-Fi.

3.1.3 Software Interfaces

- **Description:** The software interacts with various modules and services for comprehensive operation.
- **Mobile App:** Interfaces with the main software module to display glucose data.
- **Data Management:** Stores user sign-in information and glucose data securely in a database.
- **Image Processing Algorithms:** Analyze inputs from the camera to assess skin color, thickness, and texture.
- **Integration:** Compatible with healthcare IT systems to facilitate data sharing with healthcare providers.
- **APIs:** Uses secure APIs for data exchange, allowing for real-time alerts and communication with healthcare providers.

3.1.4 Communications Interfaces

- **Description:** Outlines network requirements for stable data transmission between the device, mobile application, and healthcare providers.
- **Network Requirements:** Secure Bluetooth for device-to-app connectivity and encrypted internet communication for data transfer.
- **Data Transmission:** Encrypted protocols for transmitting sensitive glucose data and alerts to ensure user privacy and data integrity.

3.2 Functional Requirements

This section describes the specific functionalities GlucoSense provides to users.

3.2.1 Non-Invasive Glucose Measurement

3.2.1.1 Introduction

GlucoSense captures non-invasive skin readings, processes them, and displays real-time glucose levels on a mobile application.

3.2.1.2 Inputs

- Amplified inputs from the IR sensors.
- Captures skin color, thickness, and texture through the attached camera for image processing.
- User information (initial calibration data).

3.2.1.3 Processing

- Data pre-processing to filter noise and interference.
- Arduino Nano processes sensor data and applies machine learning algorithms to calculate glucose levels.
- Integrates camera data for better correlation with glucose readings.
- The app uses this data to continuously monitor and assess glucose trends.

3.2.1.4 Outputs

- Real-time glucose level displayed on the mobile app.
- Alerts when glucose levels are above or below set thresholds.

3.2.1.5 Error Handling

- Mechanisms to handle and report errors when readings fall outside expected ranges.

3.2.2 Automated Alert System for High Glucose Levels

3.2.2.1 Introduction

The system automatically alerts the user and healthcare provider if glucose levels exceed safe thresholds.

3.2.2.2 Inputs

- Real-time processed glucose data.
- User-defined alert thresholds.

3.2.2.3 Processing

- Compares the current reading with safe glucose thresholds.
- Generates alerts if levels are consistently high, suggesting potential health risks.

3.2.2.4 Outputs

- Notification sent to the user and doctor’s system.
- Alert on the app with suggestions for follow-up action.

3.2.2.5 Error Handling

- Mechanisms to re-attempt sending the alert if it fails to send initially.

3.3 Use Cases

3.3.1 Use Case #1: User Monitors Glucose Levels

Description: A user checks their glucose levels through the mobile app.

Actors

- User (Patient)
- GlucoSense Device
- Mobile Application

Steps:

- The user logs into the app.
- The app retrieves data from the device via Bluetooth.
- The glucose level is displayed on the user interface.

Expected Outcome: User successfully views their glucose levels.

Alternate Flow: If the connection to the device fails, the user receives an error message prompting reconnection.

3.3.2 Use Case #2: High Glucose Alert and Follow-Up

Description: The system triggers an alert when high glucose levels are detected.

Actors

- User (Patient)
- Mobile Application
- Healthcare Provider

Steps

- Glucose level is measured and found to be above the safe threshold.
- The app triggers an alert to the user and healthcare provider.
- Healthcare provider receives the alert and reviews the patient data.
- Provider recommends follow-up actions or medications as needed.

Expected Outcome: User and healthcare provider are promptly informed.

Alternate Flow: If the alert fails to send, the app retries and notifies the user of the failure.

3.4 Classes / Objects

3.4.1 Class: Glucose Sensor

Attributes

- **SensorID:** Unique identifier for each sensor.
- **SkinColor:** Captured color data from the skin.
- **GlucoseReading:** Processed glucose level data.

Functions

- **captureData():** Collects raw sensor data.
- **analyzeData():** Processes data to determine glucose levels.
- **transmitData():** Sends data to the mobile application.

3.4.2 Class: Notification Manager

Attributes

- **AlertID:** Unique identifier for each alert.
- **ThresholdLevel:** Defined safe glucose range.
- **Status:** Status of alert (e.g., Sent, Failed).

Functions

- **checkThreshold():** Monitors glucose levels against safe thresholds.
- **sendAlert():** Triggers alert notifications to the user and healthcare provider.
- **logAlert():** Records alert attempts and outcomes in the system.

3.5 NON-FUNCTIONAL REQUIREMENTS

3.5.1 Performance

- **Description:** The system should efficiently process glucose readings, ensuring rapid and accurate data handling for users.
- **Response Time:** Glucose measurements should be processed and displayed on the mobile app within a few seconds.
- **Data Handling:** The system will use a database to manage multiple data points, ensuring efficient data insertion, retrieval, and processing.

3.5.2 Reliability

- **System Availability:** The system shall maintain high availability, minimizing downtime for consistent user access.
- **Measurement Accuracy:** The device should provide accurate glucose readings with a minimum error margin, ensuring reliable monitoring for patients.

3.5.3 Availability

- **Data Retrieval:** The system shall ensure reliable data retrieval from the database, maintaining data availability and preventing potential crashes.

3.5.4 Security

- **User Authentication:** The mobile app shall restrict access to authorized users, requiring patients to log into their accounts for secure data access.

3.5.5 Maintainability

- **Modular Design:** The system shall be modular, with components and documentation that enable ease of maintenance and updates.

3.5.6 Portability

- **Device Portability:** The device will be lightweight and easy to carry, with a simple setup that allows it to operate in various environments.

3.6 INVERSE REQUIREMENTS

- **Non-Usage Scenarios:** The system shall not measure or record data without user consent, preserving user autonomy and privacy.

3.7 LOGICAL DATABASE REQUIREMENTS

- **Data Format:** Glucose readings shall be stored in a standardized format within the database, facilitating accurate trend analysis.
- **Data Retention:** Data should be retained for a minimum of one year to support long-term monitoring, with options for the user to export or delete their data.

3.8 HARDWARE REQUIREMENTS

- **Sensors:** IR senders and receivers are used for non-invasive glucose level detection. Due to the high cost of NIR sensors, the system compensates by using multiple IR sensors along with an amplification circuit and a low-pass filter to achieve similar functionality.
- **Processing Unit:** Arduino Nano for data acquisition and processing.
- **Connectivity:** Bluetooth module for data transmission to the mobile app.
- **Power Supply:** 15-volt battery to provide necessary operating power for the device.

3.9 DESIGN CONSTRAINTS

- **Regulatory Compliance:** The system must meet healthcare regulations for non-invasive medical devices.

3.10 OTHER REQUIREMENTS

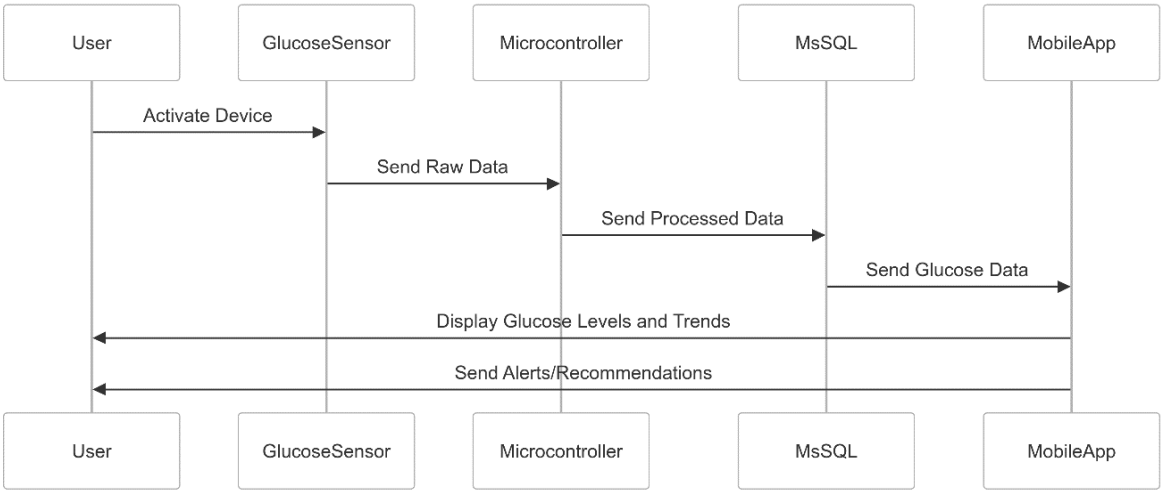
- **Localization:** The mobile app should support multiple languages to improve accessibility for diverse users.
- **User Documentation:** Detailed user guides shall be provided for both the device and mobile app to assist users in setup and operation.

4. Analysis Models

4.1 Sequence Diagrams

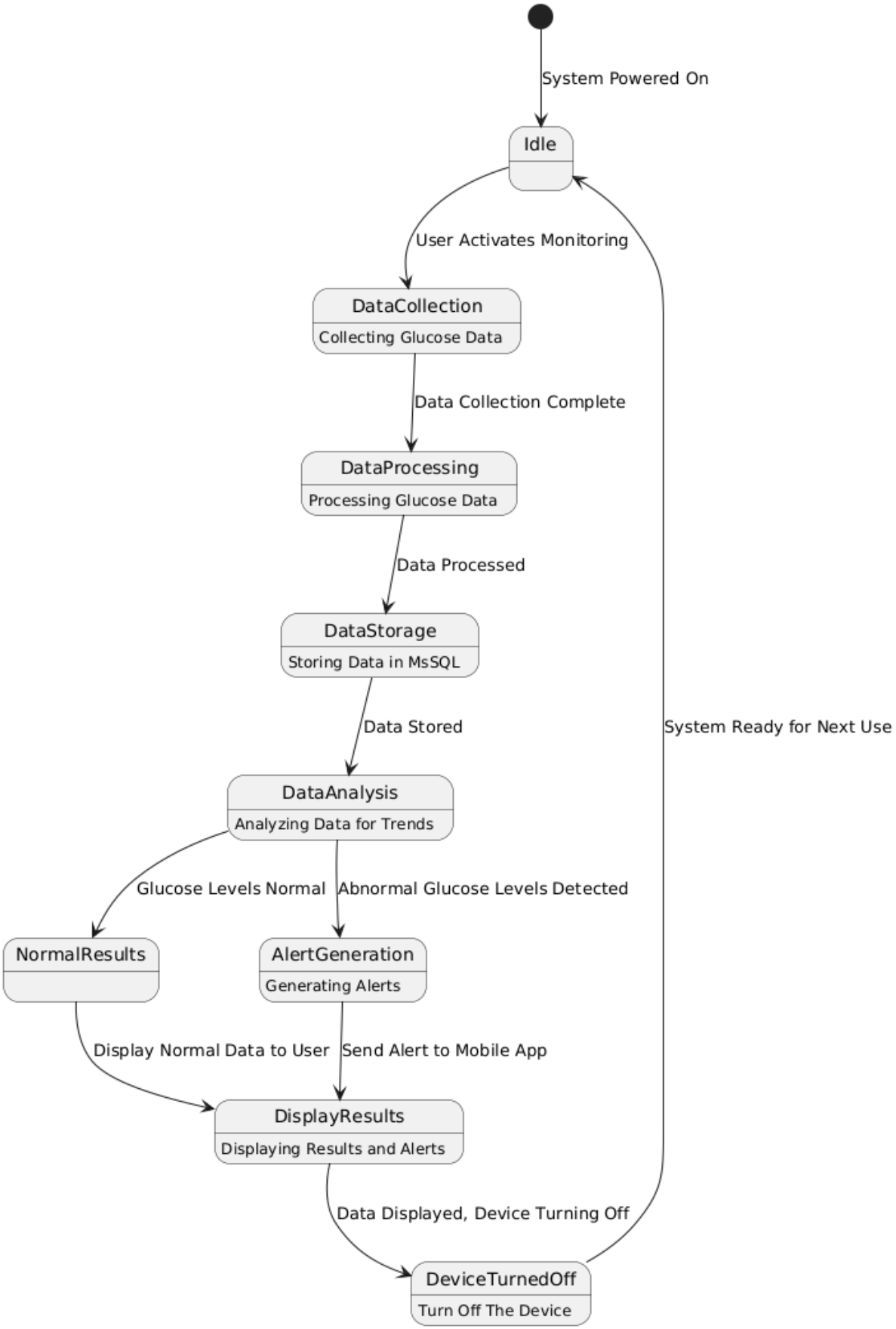
A **sequence diagram** is important for the GlucoSense system because it shows how different parts, like the glucose sensor, microcontroller, MS SQL database, and mobile app, work together. It helps explain what each part does and how data moves through the system. The diagram also helps

find any problems in data flow, making it easier to improve the system's performance. It makes communication between developers and interested parties easier and is useful in planning and testing, ensuring everything works smoothly for real-time glucose monitoring and timely alerts for the user.



4.2 State Transition Diagrams

A **state transition diagram** is used for the GlucoSense system to map out how the system shifts between different states, such as idle, data collection, processing, and alert generation. It helps visualize the system’s behavior in response to various events, ensuring that each state transitions smoothly to the next. This diagram assists in identifying potential issues, optimizing the workflow, and improving system design. It also ensures that the system correctly handles real-time data monitoring and user notifications, leading to more reliable performance and user experience.


System Powered On
Idle
User Activates Monitoring
DataCollection
Collecting Glucose Data
Data Collection Complete
DataProcessing
Processing Glucose Data
Data Processed
DataStorage
Storing Data in MsSQL
Data Stored
DataAnalysis
Analyzing Data for Trends
Glucose Levels Normal
Abnormal Glucose Levels Detected
NormalResults
AlertGeneration
Generating Alerts
Display Normal Data to User
Send Alert to Mobile App
DisplayResults
Displaying Results and Alerts
Data Displayed, Device Turning Off
DeviceTurnedOff
Turn Off The Device
System Ready for Next Use

4.3 Data Flow Diagrams

Data Flow Diagram (DFD) is a graphical representation of data flow in any system. It is capable of illustrating incoming data flow, outgoing data flow and store data. Data flow diagram describes anything about how data flows through the system.

Levels in Data Flow Diagram (DFD):

• Level 0 DFD

• Level 1 DFD

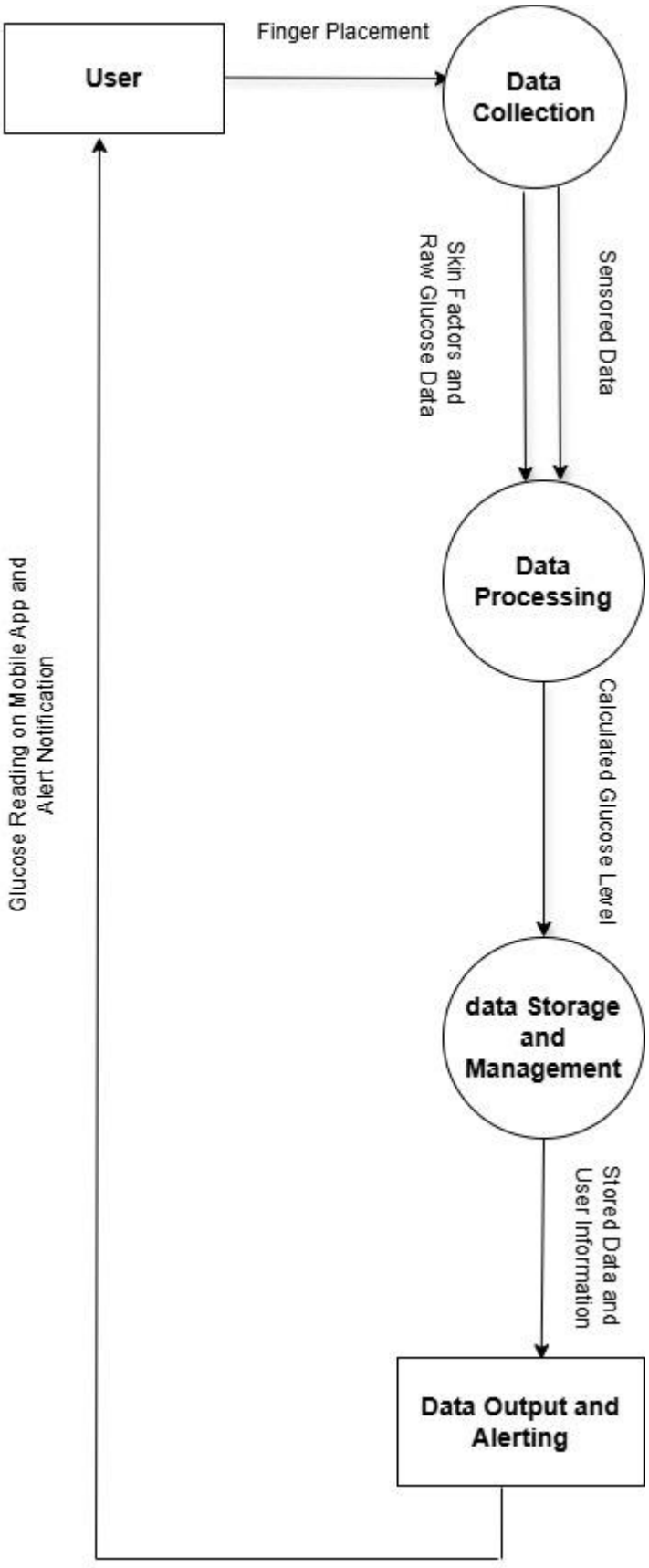
• Level 2 DFD

Level 0 DFD:

Level 0 is the highest-level Data Flow Diagram (DFD), which provides an overview of the entire system. It shows the major processes, data flows, and data stores in the system, without providing any details about the internal workings of these processes.

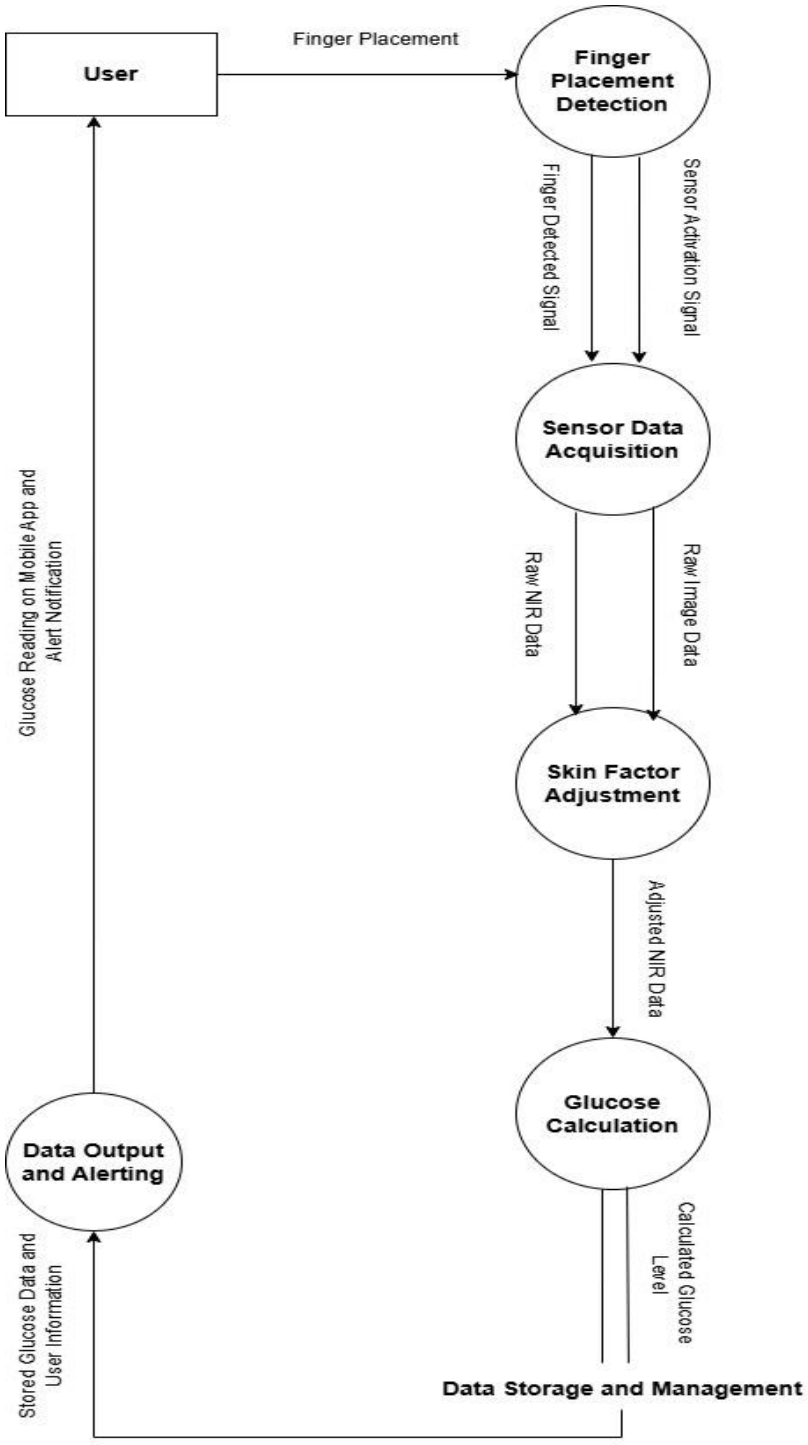
Level 1 DFD:

1-Level provides a more detailed view of the system by breaking down the major processes identified in the level 0 Data Flow Diagram (DFD) into sub-processes. Each sub-process is depicted as a separate process on the level 1 Data Flow Diagram (DFD). The data flows and data stores associated with each sub-process are also shown.


User
Finger Placement
Data Collection
Skin Factors and Raw Glucose Data
Sensored Data
Data Processing
Calculated Glucose Level
data Storage and Management
Stored Data and User Information
Data Output and Alerting
Glucose Reading on Mobile App and Alert Notification

Level 2 DFD:

2-Level provides an even more detailed view of the system by breaking down the sub-processes identified in the level 1 Data Flow Diagram (DFD) into further sub-processes. Each sub-process is depicted as a separate process on the level 2 DFD. The data flows and data stores associated with each sub-process are also shown.



5. Change Management Process

In the context of this Software Requirement Specification (SRS) for GlucoSense: Smart Non-Invasive Glucose Monitoring System, a robust change management process is implemented to manage any modifications to the documented requirements. This process ensures that changes are thoroughly reviewed, assessed, and approved to protect the integrity and quality of the project.

- **Submission of Changes:** Any project stakeholder, including members of the development team, quality assurance team, project manager, or external stakeholders, can submit proposed changes.
- **Means of Submission:** Change requests can be submitted through a designated change request form or an established system. These forms should include essential details such as the type of change, its rationale, and the anticipated impact on the system's functionality or performance.
- **Change Evaluation and Approval:** Proposed changes will be reviewed by a Change Control Board (CCB), consisting of key project stakeholders. The CCB will evaluate each change based on its impact on project scope, timeline, budget, and overall goals specific to GlucoSense. Changes will be classified according to their complexity and effect:
  - Minor changes with limited impact may be approved by the project manager.
  - Moderate changes may require approval from the project sponsor or a senior authority.
  - Major changes with substantial impact will undergo a comprehensive review by the CCB and may necessitate formal project re-evaluation and approval.

Documentation: All change requests, along with their status (approved, pending, rejected), will be recorded in a centralized change log. Approved changes will be incorporated into the SRS, and updates will be made to the SRS document to reflect these adjustments.

A. Appendices

A.1 Appendix 1

A.1.1 Definitions

- **IR Sensor**

  An Infrared (IR) sensor detects glucose levels by emitting infrared light and measuring how much is absorbed by the skin. The tiny electrical signals generated by the IR sensor, which correlate to glucose concentration, are then amplified using an amplifier circuit. This amplification process boosts the signal strength, making it easier to accurately interpret glucose levels in the system's processing unit. This amplified signal is crucial for precise and reliable glucose monitoring in a non-invasive manner.

- **Arduino Nano**

  An Arduino Nano acts as the core processing unit, gathering data from the IR sensor. It processes the amplified signals from the sensor to estimate glucose levels, enabling real-time analysis. The compact size and powerful functionality of the Arduino Nano make it ideal for integrating into a portable, non-invasive glucose monitoring device, allowing for efficient data processing and communication with the system’s interface.

- **Machine Learning (ML):**

  Machine learning is a field of study in artificial intelligence concerned with the development and study of statistical algorithms that can effectively generalize and thus perform tasks without explicit instructions.

- **Graphical User Interface (GUI):**

  A graphical user interface, or GUI, is a form of user interface that allows users to interact with electronic devices through graphical icons and audio indicators such as primary notation.

- **Detection:**

  Detection is a process of finding those rare items, data points, events, or observations that make suspicions by being different from the rest data points or observations.

- **Prediction:**

  Prediction in machine learning allows organizations to make predictions about possible outcomes based on historical data. These assumptions allow the organization to make decisions resulting in tangible business results.

A.1.2 Future Work

The GlucoSense: Smart Non-Invasive Glucose Monitoring System currently focuses on detecting and measuring glucose levels using IR sensors and machine learning algorithms, taking into account factors like skin color, texture, and thickness.

A.2 Appendix 2

A.2.1 Figure Table

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