NON-INVASIVE HAEMOGLOBIN MEASURING DEVICE WITH MOBILE APPLICATION (IOT & FLUTTER)

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Introduction:

Haemoglobin, an essential component of red blood cells, plays a critical role in transporting oxygen throughout the human body. Accurate and timely measurement of haemoglobin levels is vital for diagnosing and managing a range of medical conditions, including anaemia, polycythaemia, chronic kidney disease, and other hematologic disorders. Traditionally, haemoglobin is measured through invasive blood tests, which require venipuncture, specialized equipment, and trained personnel. While effective, these conventional methods can be uncomfortable, carry a risk of infection, and are not always feasible in remote or resource-constrained settings. To address these limitations, this project aims to develop a non-invasive, real-time haemoglobin monitoring device using optical sensors and Internet of Things (IoT) technologies. The device utilizes sensors such as the MAX30102 and AS7262, along with an ESP32 microcontroller, to capture photoplethysmographic (PPG) and spectral data from the user's fingertip. These signals are processed and analyzed using advanced machine learning algorithms to estimate haemoglobin levels without the need for blood samples.

The data is then transmitted to a mobile application developed using Flutter, which displays the results and provides personalized health insights, including diet recommendations. This innovative approach not only eliminates the discomfort and risks associated with needle-based tests but also improves accessibility to haemoglobin monitoring in rural and underserved areas. By providing a user-friendly, portable, and cost-effective solution, the project seeks to empower individuals with chronic health conditions to manage their health more efficiently. Additionally, the system supports early detection of haemoglobin-related disorders, contributing to improved public health outcomes and reducing the burden on healthcare facilities. Through the integration of biomedical sensors, IoT, this project represents a significant advancement in the field of non-invasive health monitoring.

Objectives:

- Enhance the precision of non-invasive haemoglobin measurements by optimizing the pulse oximeter module through better calibration, signal processing, and machine learning algorithms.

- Create a compact, easy-to-use IOT Device that requires no specialized training, making haemoglobin monitoring accessible to individuals and healthcare providers alike.

- Pair the device with Our User-Friendly Mobile Application to display real-time results, track historical data, and provide insights for better health management.

- Provide a cost-effective alternative to traditional blood tests, especially beneficial for individuals in rural or underserved regions lacking access to regular diagnostic services.

- Address limitations in the sensor, such as sensitivity to motion artifacts and ambient light, to improve measurement reliability.

- Design an intuitive interface for the device and mobile app to make haemoglobin monitoring simple and accessible for non-specialists.

- Encourage proactive health monitoring by enabling individuals to check haemoglobin levels at home or in areas with limited healthcare infrastructure.

- Conduct thorough testing and clinical validation of the device to ensure its accuracy, reliability, and acceptance in real-world applications.

Methodology:

- Data Collection:

  Device Setup: Use the sensor, a Pulse Oximeter Module, to capture Photoplethysmography (PPG) signals. The sensor emits infrared and red light into the skin, and measures the reflected light intensity from blood vessels.

  Signal Capture: Place the sensor on a finger, where blood flow is prominent, to record the variations in light absorption caused by blood flow dynamics. These variations are directly related to pulse rate and oxygen saturation, and indirectly linked to haemoglobin concentration. So, we chose to measure at the fingertip.

- Signal Processing:

  Noise Filtering: Apply digital signal processing techniques (e.g., bandpass filters) to remove noise caused by motion artifacts, ambient light, or hardware interference.

  Feature Extraction: Extract key metrics such as pulse rate, SpO2, and amplitude variations in the PPG waveform. These features are crucial for further analysis and haemoglobin estimation.

- Haemoglobin Estimation:

  Algorithm Development: We are using random forest machine learning algorithm and statistical algorithms trained on clinical datasets. Which are physically collected by us from clinical labs. These models map the relationship between PPG-derived parameters and haemoglobin levels.

Calibration: Calibrate the system by comparing results with traditional blood-based haemoglobin tests, ensuring the device provides accurate and clinically relevant estimates.

- Data Transmission:

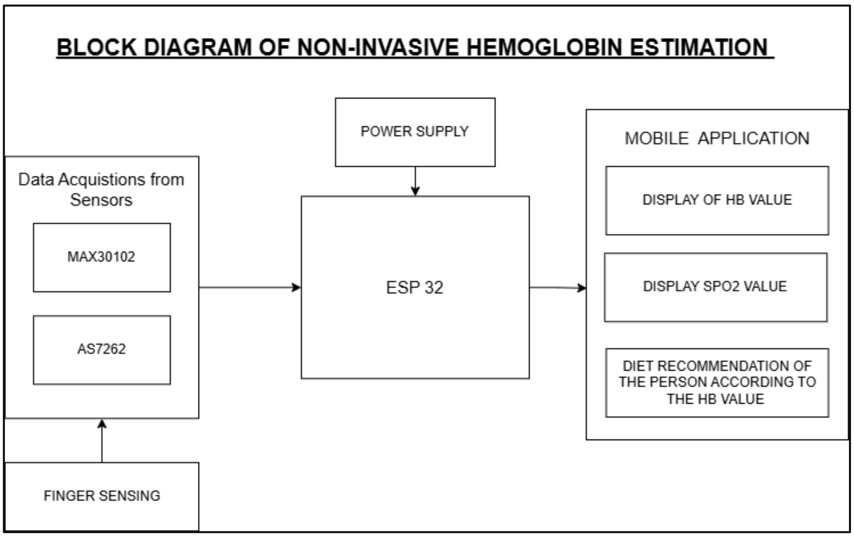
Bluetooth Integration: Incorporate a Bluetooth module (ESP-32) in the device for wireless data transmission. The processed PPG signals and calculated haemoglobin levels are sent to a paired smartphone or computer in real-time.

- Data Display:

Mobile Application Interface: We develop a user-friendly mobile application using Flutter to display haemoglobin levels, heart rate, and SpO2 in an intuitive format in real time.

- Data Analysis and Storage:

Cloud Integration: Implementing cloud storage to log data securely. This enables further analysis, such as trend prediction, and allows healthcare providers or users to access the data remotely.



- Testing and Deployment:

System Validation: Perform rigorous testing under various conditions and demographics to ensure accuracy, reliability, and consistency of the device.

Clinical Trials: We are testing the device on a diverse group of individuals and validate the results against laboratory-grade haemoglobin measurements.

Deployment: Finalize the design for scalability, manufacture prototypes, and release the device for real-world applications, focusing on affordability and ease of use.

Result and Conclusion:

The proposed non-invasive haemoglobin monitoring system has proven to be an effective and accurate alternative to conventional blood-based haemoglobin testing methods. Through comprehensive testing and evaluation, the device demonstrated strong consistency in haemoglobin level readings when compared to standard clinical blood tests, thereby validating its reliability and precision. One of the most significant outcomes of this innovation is the complete elimination of invasive procedures. By using optical sensors and advanced machine learning algorithms, the device enables painless haemoglobin measurement without the need for needle pricks or blood samples. This substantially improves patient comfort, especially for children, the elderly, and individuals with chronic conditions who require frequent monitoring.

In terms of accessibility, the compact and portable design of the device allows for widespread use beyond hospital and clinical environments. It can be easily deployed in rural areas, resource-limited regions, and even in individual households, enabling real-time haemoglobin monitoring without the need for sophisticated infrastructure or trained medical personnel. This empowers individuals to take control of their health and supports community-level health initiatives, particularly in underdeveloped and remote locations.

From a cost perspective, the device offers a long-term economical solution for haemoglobin monitoring. It eliminates the recurring expenses associated with consumables like syringes, needles, and laboratory tests, making regular testing affordable and sustainable. This is especially beneficial for patients suffering from conditions such as anaemia, chronic kidney disease, or cancer, where regular haemoglobin tracking is essential for disease management and treatment planning.

Furthermore, the device holds considerable public health potential. By enabling early detection of haemoglobin-related disorders such as anaemia and polycythaemia, it facilitates timely medical intervention, which is critical in preventing complications and improving patient outcomes. On a larger scale, such early interventions can reduce hospital admissions and lower the overall burden on healthcare systems

In conclusion, the non-invasive haemoglobin monitoring device addresses several limitations of current haemoglobin testing methods by offering a reliable, painless, accessible, and cost-effective solution. It has the potential to transform haemoglobin monitoring practices across various healthcare settings, making routine testing easier and more efficient, and ultimately contributing to better health outcomes and enhanced quality of life for patients worldwide.

Future Scope:

- **Integration with Wearables:** Future versions of the device can be embedded into smartwatches or fitness bands, enabling continuous haemoglobin monitoring alongside heart rate, oxygen saturation, and other vital signs.
- **Cloud-Based Health Monitoring:** By integrating cloud storage and analytics, patient data can be stored securely, enabling remote monitoring by healthcare providers and early intervention through alerts and trend analysis.
- **Multi-Parameter Health Monitoring:** The device can be enhanced to monitor additional parameters such as blood glucose, blood pressure, and hydration levels, offering a more comprehensive health monitoring solution.
- **Integration with Electronic Health Records (EHR):** Seamless integration with hospital EHR systems can facilitate automatic updates to a patient’s medical records, improving data accuracy and clinical decision-making.
- **Clinical Validation and FDA Approval:** Future work includes rigorous clinical trials and obtaining regulatory approvals to position the device as a medically certified tool for use in hospitals and diagnostic centres.
- **Global Health Applications:** The device can be adapted for use in global health initiatives, helping monitor and combat anaemia in developing countries, especially among children and pregnant women.