Non-Invasive Measurement of Blood Parameter

Hemavathi B[1], Fazilath M [1], Dr.Bobby N.D [2], Satish Kumar P [3]

[1]Assistant Professor, Faculty of Engineering, St. Peter's Institute of Higher Education and Research, Chennai, Tamil Nadu, India
[2]Professor, Faculty of Engineering, St. Peter's Institute of Higher Education and Research, Chennai, Tamil Nadu, India
[3]Assistant Professor, Faculty of Engineering, St. Peter's Institute of Higher Education and Research, Chennai, Tamil Nadu, India

Abstract

Non-Invasive blood Parameter measurement has gained significant attention due to its potential to revolutionize healthcare by providing real-time monitoring without the need for painful and inconvenient blood draws. This paper presents a novel approach for non-invasive measurement of key blood parameters such as Heamoglobin (Hb), Red Blood cells (RBC), White blood cells (WBC) and Platelets. The proposed method leverages optophotometry to extract relevant physiological data; which is then analyzed using successive approximation for accurate estimation. The system is designed to be user friendly, Portable and suitable for continuous monitoring for physiological data in healthcare. Preliminary results demonstrate promising accuracy compared to traditional invasive methods, highlighting of this potential of this technology in medical diagnostics

Keywords: Haemoglobin, Red Blood Cells, White Blood Cells, platelets, Optophotometry, Successive Approximation.

Introduction:

Accurate measurement of blood parameters is essential for diagnosing, monitoring and managing various medical conditions such as diabetes, anaemia, and cardiovascular diseases. Parameters like haemoglobin levels, WBC, RBC, platelets play a vital role in patient care, guiding therapeutic interventions and improving health outcomes.

Conventional methods of blood parameter measurement, such as venipuncture or finger stick tests are invasive, causing discomfort and posing risks of infection. Also, this method will require trained personnel and frequent repetitions, making them inconvenient for continuous monitoring.

In recent years, non-invasive techniques have emerged as promising alternatives, leveraging advancements in optical sensing, spectroscopy, and wearable technologies. This method seeks to improve patient compliance and accessibility while offering real-time, painless services.However, many existing methods face challenges in achieving sufficient accuracy and reliability, particularly in dynamic clinical settings.

This paper aims to develop a non-invasive method for measuring blood parameters using optophotometry combined with machine learning algorithms. A prototype device has been designed to enable real timemonitoring and offering a user-friendly solution for patients and healthcare providers. The proposed approach has the potential to revolutionize blood parameter monitoring, reducing the dependency on invasive procedures and facilitating early detection and management of health conditions.

This paper explores the current state of non-invasive blood parameter devices, detailing their working principles, technological advancements, clinical applications, and challenges. Furthermore, we discuss the accuracy reliability, and regulatory considerations that will influence their widespread adoption in healthcare.

Literature Review:

Komhive dostal proposed a system for detection of hemoglobin non-invasive method. In this optical or system is too wavelength of light to the measurement w hoed en radiation of red and near infrared light emitted by light emitting diodes in the range of 600mm to 1400mm.The opt101 operates from 2.7v to 36v supplies and quiescent current only 120 MA.

Sinwankaur and mohammad saad alam et al. proposed a method for non-invasive blood cell count of flowing blood cells using surface charge of blood cells Using imaging techniques calculations are done after acquiring data from the detector, the software based on the data. Finally, they concluded that measuring zeta potential of the various blood components on real time.

Edward jay wang et al, proposed a system for the detection of non-invasive blood screening of haemoglobin using smartphone cameras. This method evaluates hema app on 31 patients ranging from 6-77yrs of age yielding a 0.82 rank order correlation with the gold standard blood test. IR light at 970nm and 880nm are used to capture the different absorption between the various forms of haemoglobin. The sensitivity and precision of hema app is 85.7% and 76.5%.

Masimo corporation et at.,build the non-invasive solution for Hb measurement based on the idea of pulse oximeter they used the 500-1300nm wavelength of light and get the significant accuracy. Finally, they concluded with measurement of total hemoglobin correlation coefficient -0.88.in accurate in dyshemoglodin, very low level Hb.

Orsense corporation et al., proposed a system on use of ten emitters and detectors, measure light absorption with the wavelength of 600-950nm.it gives better performance than rainbow technology Have limited data with unstable patient and clinical setup.

James W. Winkelman, MD (2000) et al.. proposed detection of WBC's can be accomplished by using a UV light source and a UV receiver for the spectral reflectance of nucleic acids The WBC count is determined by computing the ratio of WBC's with respect to RBC's in a sufficient number of images and multiplying it by the computed RBC count. The same analytic approach, taking into account the dimensions of the WBC's vs the platelets, will provide a platelet count. Alternative approaches to WBC and platelet enumeration are under consideration that specifically use the OPS imaging technology in the Hemoscan.

Moria Shimoni et al., proposed the Use of unable light source allows the determination of metabolic gas concentration within the container without etal on use. In this method, the light from the light source is transmitted through the gaseous part of storage bag is measured by means of an IR detector. The concentration of CO_2gas inside the platelet bag is determined by equilibrium conditions between the release rate and the rate of diffusion of the metabolic gases through the bag walls.

Masimo pronto and smartphone-based apps utilize spectrophotometry and auto flash reflection detection for hemoglobin estimation. Continuous Non-invasive Arterial Pressure (CNAP)devices measure real time blood pressure without invasive methods. Challenges that we face in Accuracy & reliability issues: variability in readings due to skin tone, ambient light and motion artifacts. Calibration & standardization is need for consistent protocols across devices and populations. Non-invasive blood parameter devices offer a promising alternative to traditional blood tests, improving patient compliance and accessibility. However, ongoing research and development are needed to enhance accuracy, expand capabilities, and ensure clinical adoption.

Proposed Methodology:

The proposed methodology for non-invasive measurement of WBC, platelet, haemoglobin, and RBC counts integrates advanced optical sensing techniques with machine learning algorithms. This prototype is equipped with multi-wavelength LED's, photodetectors, and optical filters is designed to collect optical signals from capillary-rich sites such as the fingertip. Light-tissue interaction data is processed to extract features indicative of blood cell concentrations and haemoglobin levels. specific method NIRS (near infrared spectroscopy) is employed to analyze absorption of blood components, machine learning models trained on paired invasive and non-invasive datasets, are used to estimate blood parameters with high accuracy. Validation is performed against clinical standards, and iterative testing ensures device optimization. Ethical considerations are addressed through informed consent and data security measures.

Device Design and Hardware Setup:

The system employs advanced optical techniques and machine learning algorithms to estimate WBC, platelet, haemoglobin, and RBC counts. It is designed to analyze light interactions with blood cells and haemoglobin using non-invasive optical method.

Haemoglobin: Haemoglobin (Hb) is a protein in red blood cells (RBC's) responsible for transporting oxygen from the lungs to the rest of the body and carrying carbon dioxide back to the lungs for exhalation. It is a critical component for maintaining the body's oxygen supply.it contributes to maintain blood pH by binding and releasing hydrogen ions.

Men: 13.8 to 17.2 grams per decilitre (g/dL).

Women: 12.1 to 15.1 g/dL.

Children: 11 to 16 g/dL.

Pregnant women: 11 to 14 g/dL.

Hemoglobin is usually measured in grams per decilitre(g/dL) of blood. Near infrared spectroscopy (NIRS) identifies Hemoglobin absorption peaks.

IR identifies Hemoglobin absorption peaks, ratio of oxygenated to deoxygenated haemoglobin is also assessed for accurate quantification.

Platelets: Platelets also known as thrombocytes, are small, disc-shaped cell fragments in the blood that are essential for normal blood clotting. They are produced in the bone marrow from large cells called megakaryocytes and circulate in the bloodstream, playing a critical role in stopping bleeding and repairing damaged blood vessels.

A healthy platelet counts ranges from 150,000 to 450,000 platelets per microliter of blood. Counts below this range (thrombocytopenia) can lead to excessive bleeding.

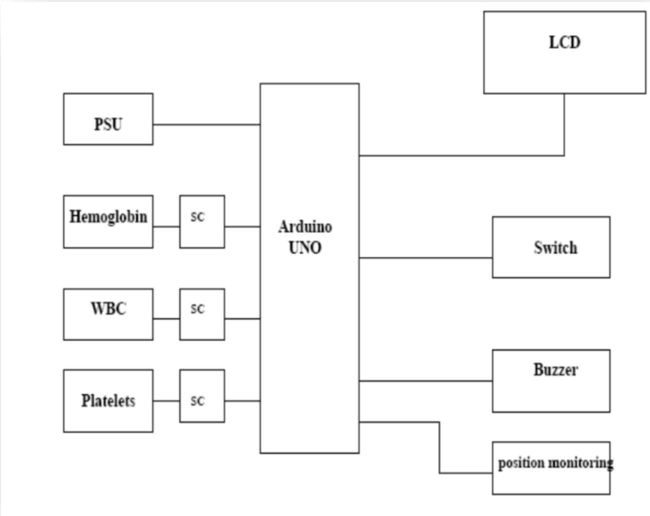
Counts above this range (thrombocytosis) can increase the risk of abnormal clotting. Platelets aggregate at the site of a blood vessel injury, forming a temporary platelet plug.

They release substance that help in blood clotting, such as clotting factors and signalling molecules that recruit more platelets to the injury site.

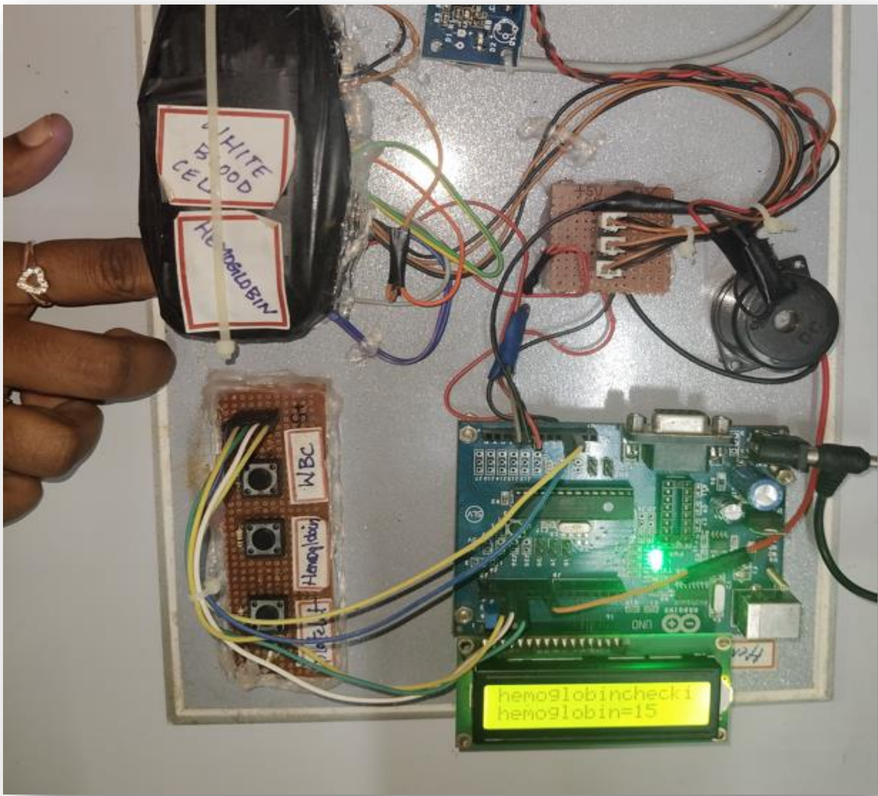
Platelets release growth factors that stimulate tissue repair.

White Blood Cells: WBC stands for white blood cells also known as leukocytes which are a vital component of the immune system. They help the body fight infections, respond to allergens and protect against foreign invaders like bacteria, viruses, and fungi. Scattering patterns are analysed, as WBC's and platelets differ in size and structure compared to RBC's. Advanced signal processing is used to isolate signals corresponding to WBC's and platelets based on their unique scattering properties. protect against infection, remove damaged cells and debris, coordinate immune responses, or chemotherapy. 4,000 to 11,000 WBC's per microliter of blood is considered normal for adults. Counts outside this range can indicate various conditions: Leukocytosis (high WBC count): often caused by infections, inflammation, stress, or leukemia. Leukopenia (low WBC count): may result from bone marrow disorders, autoimmune disease, infections, or chemotherapy.

Non-Inasive Blood Testing Sensor



Block Diagram



Prototype of the product

Result & Conclusion:

The performance of the proposed system was evaluated based on data collected from patients, comparing the system output with standard invasive methods. The results indicate that the device successfully estimates WBC, platelet, hemoglobin, and RBC counts with high accuracy. This device eliminates the need for invasive blood sampling, improving patient comfort, enables real-time monitoring, beneficial for managing conditions such as anemia ad infections. It also reduces dependency on clinical laboratories, making healthcare more accessible, particularly in remote areas. This prototype allows continuous blood monitoring, reducing the need for frequent invasive tests.

Limitations and Future Scope:

Device calibration is required for different skin tones and physiological variations. Larger-scale clinical trials are needed to validate performance across diverse populations. Integration with wearable health monitoring systems could further enhance usability and adoption.

References:

1. Ma K. F., et al. , "Laser Doppler flowmetry combined with spectroscopy to determine peripheral tissue perfusion and oxygen saturation: a pilot study in healthy volunteers and patients with peripheral arterial disease," J. Pers. Med. 12(6), 853 (2022). 10.3390/jpm12060853.
2. Dinsdale G., et al. , "State-of-the-art technologies provide new insights linking skin and blood vessel abnormalities in SSc-related disorders," Microvasc. Res. 130(April), 104006 (2020). 10.1016/j.mvr.2020.104006.
3. Nouvong A., et al. , "Evaluation of diabetic foot ulcer healing with hyperspectral imaging of oxyhemoglobin and deoxyhemoglobin," Diabetes Care 32(11), 2056–2061 (2009). 10.2337/dc08-2246.
4. Robertson C. S., et al. , "Clinical evaluation of a portable near-infrared device for detection of traumatic intracranial anathemas,"J. Neurotrauma 27(9), 1597–1604 (2010). 10.1089/neu.2010.1340.
5. Tietz N. W., Fiereck E. A., "The spectrophotometric measurement of carboxyhemoglobin," Ann. Clin. Lab. Sci. 3(1), 1388–1393 (1973).
6. Dervieux E., Bodinier Q., Uhring W., "Measuring hemoglobin spectra: searching for carbamino-hemoglobin," J. Biomed. Opt. 25(10), 105001 (2020). 10.1117/1.JBO.25.10.105001.
7. David S. R., et al. , "The blood blues: a review on methemoglobinemia," J. Pharmacol. Pharmacother. 9(1), 1–5 (2018). 10.4103/jpp.JPP_79_17
8. Thom C. S., et al. , "Hemoglobin variants: biochemical properties and clinical correlates," Cold Spring Harb. Perspect. Med. 3(3), a011858 (2013). 10.1101/cshperspect.a011858.
9. Arakaki L. S. L., Burns D. H., Kushmerick M. J., "Accurate myoglobin oxygen saturation by optical spectroscopy measured in blood-perfused rat muscle," Appl. Spectrosc. 61(9), 978–985 (2007). 10.1366/000370207781745928 .
10. Prahl S. A., "Tabulated molar extinction coefficient for hemoglobin in water," (1998).
11. Siggaard-Andersen O., Nørgaard-Pedersen B., Rem J., "Hemoglobin pigments spectrophotometric determination of oxy-, carboxy-, met-, and sulfhemoglobin in capillary blood," Clin. Chim. Acta 42(1), 85–100 (1972). 10.1016/0009-8981(72)90380-4.

12. Zijlstra W. G., Buursma A., Meeuwsen-van der Roest W. P., "Absorption spectra of human fetal and adult oxyhemoglobin, de-oxyhemoglobin, carboxyhemoglobin, and methemoglobin," Clin. Chem. 37(9), 1633–1638 (1991). 10.1093/clinchem/37.9.1633.
13. Kinnunen M., et al. , "Effect of the size and shape of a red blood cell on elastic light scattering properties at the single-cell level," Biomed. Opt. Express 2(7), 1803 (2011). 10.1364/BOE.2.001803.
14. Gienger J., et al. , "Refractive index of human red blood cells between 290 nm and 1100 nm determined by optical extinction measurements," Sci. Rep. 9, 4623 (2019). 10.1038/s41598-019-38767-5.
15. Liu R., et al. , "Theoretical model for optical oximetry at the capillary level: exploring hemoglobin oxygen saturation through backscattering of single red blood cells," J. Biomed. Opt. 22(2), 025002 (2017). 10.1117/1.JBO.22.2.025002.
16. Bosschaart N., et al. , "A literature review and novel theoretical approach on the optical properties of whole blood," Lasers Med. Sci. 29(2), 453–479 (2014). 10.1007/s10103-013-1446-7.
17. Meinke M., et al. , "Optical properties of platelets and blood plasma and their influence on the optical behavior of whole blood in the visible to near infrared wavelength range," J. Biomed. Opt. 12(1), 014024 (2007). 10.1117/1.2435177.
18. Meinke M., et al. , "Empirical model functions to calculate hematocrit-dependent optical properties of human blood," Appl. Opt. 46(10), 1742–1753 (2007). 10.1364/AO.46.001742.
19. Friebel M., et al. , "Influence of oxygen saturation on the optical scattering properties of human red blood cells in the spectral range 250 to 2000 nm," J. Biomed. Opt. 14(3), 034001 (2009). 10.1117/1.3127200.
20. Saito T., Yamaguchi H., "Optical imaging of hemoglobin oxygen saturation using a small number of spectral images for endoscopic imaging," J. Biomed. Opt. 20(12), 126011 (2015). 10.1117/1.JBO.20.12.126011.
21. Jacques S. L., "Optical properties of biological tissues: a review," Phys. Med. Biol. 58(11), R37–R61 (2013). 10.1088/0031-9155/58/11/R37.
22. Murray A. K., et al. , "Noninvasive imaging techniques in the assessment of scleroderma spectrum disorders," Arthritis Care Res. 61(8), 1103–1111 (2009). 10.1002/art.24645.
23. McKay G. N., Mohan N., Durr N. J., "Imaging human blood cells in vivo with obliqueback-illumination capillaroscopy," Biomed. Opt. Express 11(5), 2373 (2020). 10.1364/BOE.389088.