Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)

DESIGN AND IMPLEMENTATION OF NON-INVASIVE BLOOD GROUP AND VITAL SIGNS DETECTION SYSTEM IN EMERGENCY SERVICES: CASE STUDY OF RWANDA

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A Dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfilment of the requirements for the Master's Degree in Biomedical Engineering.

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DECLARATION

I, NGENDO Boniface Jovica, declare that this dissertation entitled " **DESIGN AND IMPLEMENTATION OF NON-INVASIVE BLOOD GROUP AND VITAL SIGNS DETECTION SYSTEM IN EMERGENCY SERVICES: CASE STUDY OF RWANDA**" is my original work based on research and prototype and has not been submitted for any other degree or professional qualification.

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Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)

CERTIFICATE

This is to certify that the project entitled "**DESIGN AND IMPLEMENTATION OF NON-INVASIVE BLOOD GROUP AND VITAL SIGNS DETECTION SYSTEM IN EMERGENCY SERVICES: CASE STUDY OF RWANDA**" is a record of original work done by NGENDO Boniface Jovica (Reference number: 222001137), a MSc. Degree student in Biomedical Engineering.

This work has been submitted under the guidance of Dr. BAKUNZIBAKE Pierre and Dr. RUSHINGABIGWI Gerard.

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ABSTRACT

This study presents the design and implementation of a non-invasive blood group and vital signs detection system. The primary objective of this system is to detect blood groups using light intensity detection produced by LEDs. The system utilizes an optoelectronic sensor, specifically the OPT101, to measure the light intensity passing through the finger. Based on the detected light intensity, the system categorizes the blood group types. Additionally, the device incorporates the MAX30100 sensor to detect the user's heartbeat, enabling simultaneous monitoring of vital signs.

The key innovation of this system lies in its non-invasive nature, making it safer and more comfortable for users compared to traditional blood typing methods. Moreover, the system is cost-effective, with an estimated cost of only 68,300 Rwandan Francs. Experimental testing of the device yielded a 70% accuracy rate in blood group detection. However, it was observed that blood groups other than B tended to fall within the range of blood group B, indicating a potential limitation in accuracy.

In light of these findings, future plans for the system include addressing issues related to accuracy improvements. Strategies may involve refining the algorithms used for blood group classification and enhancing the sensitivity of the sensors to differentiate between closely related blood group types. Overall, the developed system holds promise for non-invasive blood group detection and vital signs monitoring, with potential applications in healthcare settings and beyond.

Keywords: Blood group, heartbeat, optical biosensor .

LIST OF ACRONYMS

CCTV: Closed-Circuit Television

CFD: Computational Fluid Dynamics

MRI: Magnetic Resonance Imaging (MRI)

NCBT: National Centre for Blood Transfusion

LED: Light-Emitting Diodes

Rh: Rhesus

RBC: Red Blood Cells

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CHAPTER 1. GENERAL INTRODUCTION

1.1Introduction

Blood group is an important piece of information for healthcare providers. It is used to determine compatibility for blood transfusions, as well as to diagnose and treat certain medical conditions. Traditionally, blood group is determined by a blood draw, which is a minimally invasive procedure that can be uncomfortable for patients.

There is a growing need for a non-invasive blood group detection system. This would be beneficial for patients who are unable or unwilling to undergo a blood draw, as well as for situations where a blood draw is not possible, such as in the field or in an emergency setting. Blood typing is a method used to determine an individual's precise blood type. Variations in human blood types stem from the presence or absence of particular protein molecules known as antigens and antibodies. These antigens are found on the surface of red blood cells, while the antibodies exist in the blood plasma. People possess diverse configurations of these molecules.

Human blood types are determined by the presence or absence of specific proteins, known as antigens, on their red blood cells. An individual's blood type is inherited from their parents and falls into one of the eight primary categories: A (+) positive, A (-) negative, B (+) positive, B (-) negative, AB (+) positive, AB (-) negative, O (+) positive, and O (-) negative [1]-[2]. The traditional process of blood grouping is a manual procedure performed by laboratory technicians. To ascertain a person's blood type, a blood sample is mixed with antibodies for blood types A and B. If the blood cells clump together, it indicates a reaction with one of the antibodies. The subsequent step, referred to as back typing, involves combining the plasma (serum) of the blood, without cells, with blood of known types A and B. Those with type A blood possess anti-B antibodies, type B blood carriers have anti-A antibodies, and type O blood includes both types of antibodies. These two steps enable the determination of an individual's blood type. Rhesus (Rh) typing is conducted using a similar approach. Here are some additional details about the two steps involved in conventional blood grouping:

- **ABO typing**: This examination identifies whether red blood cells bear A, B, or both A and B antigens on their surface. Antigens are proteins generated by the body as a response to encountering foreign substances. Antibodies, on the other hand, are proteins produced by the body to combat antigens.
- **Rh** typing: This test ascertains the presence or absence of the RhD antigen on red blood cell surfaces. Roughly 85% of the population possesses the RhD antigen. Those with it are categorized as Rh positive, while those lacking the RhD antigen are classified as Rh negative.

Blood typing is a crucial medical examination employed to ascertain an individual's blood type, a critical step in guaranteeing that the correct blood type is administered during transfusions.
When blood typing is conducted to determine the presence of the Rh factor on an individual's red blood cells, the outcomes will fall into one of two categories:

- **Rh+ (positive):** Signifies the presence of this cell surface protein.
- **Rh- (negative**): Denotes the absence of this cell surface protein.

The majority of techniques used still rely on the fundamental concept of the interaction between antigens and antibodies, leading to the agglutination or clumping of red blood cells, resulting in a positive outcome. Conversely, the absence of agglutination indicates a negative result. The illustration below illustrates this process.
The current manual blood grouping process has certain disadvantages, including its slow speed and variable accuracy due to reliance on the operator's skills and fatigue levels. Therefore, there is a need to create an automated blood group identification system.
This system has been developed to assist in addressing the shortage of blood group O in Rwanda, as highlighted by the Rwanda Biomedical Center. This call to action was initiated by the Rwanda Biomedical Centre in collaboration with the National Centre for Blood Transfusion (NCBT).
Using his twitter handle, the Division Manager of NCBT, Dr Thomas Muyombo said; "The Nation Centre for Blood Transfusion in RBC is calling upon you to save the lives of patients. Type O blood group is in high demand, so we ask all people with this type to reach out to us and donate". Rwandans have been called to donate blood, with focus on people with Type O blood group which officials say is in high demand at the medical facilities across the country [3].

Blood group O is the universal donor, meaning, a person with this group can donate blood to someone with any group. This system will solve the problem of relying on universal blood donors (O) because it will be easy to identify the blood type quickly in cases of emergencies so that people with blood group A, B and AB can be given similar blood and minimize the lack of universal blood group donor (O).
The heart is a crucial organ responsible for pumping blood throughout the body, situated within the fibrous pericardium. It consists of four chambers - two atria and two ventricles, divided into left and right sides. Four valves, namely mitral, tricuspid, aorta, and pulmonary, regulate the flow of blood, with the first two managing input and the latter two controlling output. The heart's function is governed by the sympathetic and parasympathetic autonomic nerves, which influence the strength of contractions and the heartbeat rate. The heartbeat cycle consists of two phases: systole, the contraction phase, and diastole, the resting phase of the heart.

The vital signs are proof of the body's current physical functioning. They refer to a group of the most important medical signs that indicate the status of the body's vital (life-sustaining) functions. These measurements are taken to help assess the general physical health of a person, give clues to possible diseases, and show progress toward recovery. The normal ranges for a person's vital signs vary with age, weight, gender, and overall health.

Employing the smart system in vital signs measurement and monitoring becomes an important research area in order to resolve some important problems on a conventional monitoring system. These problems include high prices of the conventional devices, difficult to be used by ordinary people, and none mobile. Therefore, several works published recently to solve some of the above problems.

In addition to this, Vital signs measure your body's basic functions. The measurements check your general physical health. They're the first step of any medical exam or evaluation. Vital signs are important because they give a healthcare provider clues about any underlying conditions that affect your health or show your progress toward recovery.

Table 1: Vital signs and normal and abnormal range.

	NORMAL	**ABNORMAL**	
HR	60-100 Beats per minute	<60 bpm (bradycardia)	>100 (tachycardia)
BP	120/80 mmHg	<90/60 (Hypotension)	>130/90 Hypertensive
RR	10-20 Breaths per minute	<10 Hypoventilation	>20 Hyperventilation
O_2	95-100%	<95% (Hypoxemia	
T	97.8-100.4^{0}F	< 97.8 Hypothermia	>100.4 Febrile temperature

1.2 Problem statement

As discussed in the above papers traditional and other methods have many disadvantages such as time consumption, pricking of skin, addition of chemical reagents, inaccuracy in some of the methods and high throughput analysis in determination of blood group, in addition to this some of the existing machines to detect human vital signs can only detect some components of vital signs like blood pressure, heart rate and so on. There is also a big problem in detecting human vital signs together with blood group in emergency cases like in accidents and other emergency cases because the patient needs to be taken to hospital for the blood group to be checked and medical doctors need other medical equipment to check all vital signs, it is not easy for a patient to check his blood group and vital signs at home so this is a problem that hinders point of care delivery, remote diagnosis, telemedicine, and finally this is a barrier to people living far from hospitals, people with chronic diseases which can be monitored remotely.

In emergencies or life-threatening situations, patients are generally shifted to hospitals in ambulances. The health conditions of on-board patients can become critical if they are not evaluated and treated in time. Chances of saving lives can increase significantly if patients' vital signs inside an ambulance or on-site triage area are transferred to a hospital in real time. If the ambulances are linked to target hospitals, then the physicians in emergency rooms can monitor on-board patients' vital signs and issue instructions to paramedics to stabilize patients' medical conditions before they reach the assigned hospitals.

In this paper, a non-invasive blood detection method and vital signs monitoring system which is cost-effectively designed to monitor, archive, analyze, and tag the vital signs data and blood group of multiple patients and. The aged people may find it sometimes difficult to consult the doctor for small health checks for which they may have to get strained by traveling and spending money. Sometimes it'll be difficult for paralyzed and bedridden patients, patients with chronic diseases also to visit normal health checks for which they had to travel causing much discomfort to them and it is also expensive. Sometimes the Doctors or Physicians may also find it difficult to visit all their patients due to paucity of time and their busy schedule. With the advent of Smart Medical gadgets these problems can be solved in a remarkable way.

To overcome these limitations, a fast non-invasive method is used to detect both the blood group and also human vital signs using only one device. The result of the project is useful since it does not involve blood samples obtained from pricking of the skin, which could be a limitation for newborn infants. The serious risks of administration of incompatible blood groups could be avoided and the lack of universal donor blood group in Rwanda will be solved since some people will be given blood group A, blood group B, and blood group AB, and vital signs will be taken remotely (point of care) which will also help in emergency cases.

1.3 Objectives

1.3.1 General Objective

The general objective of this study is to design and implement a low cost, point-of-care non-invasive blood group and vital signs detection system that work in blood transfusion emergency cases in Rwanda.

1.3.2 Specific Objectives

- Designing a non-invasive blood detection system.
- Developing algorithms for classification of blood groups based on light intensity.
- Designing vital signs detection system.
- Prototyping and testing the whole system.

1.4 Study Scope

This project builds a point of care device that uses light to measure your heartbeat and oxygen levels without needles. It will use a light sensor and signal processing to track your pulse and blood oxygenation. The final product will be a prototype to test this approach for monitoring blood groups and vital signs.

1.5 Significance of the Study

1. The system could lead to improved emergency care in Rwanda by providing faster and more accurate blood group identification and vital signs monitoring, helping healthcare professionals make quicker and more informed decisions.
2. The implementation of the system could lead to reduced errors in blood transfusions by ensuring accurate blood group identification, which is critical in emergencies.
3. This project offers a painless and non-invasive alternative to traditional blood draws and finger pricks for monitoring vital signs. This can significantly improve patient comfort, especially for those requiring frequent monitoring or with needle anxiety.
4. The non-invasive nature makes this system suitable for home use. This empowers individuals to take a more active role in monitoring their health and potentially reduces hospital readmission rates for chronic conditions.

1.6 Summary

This research project aims to develop and deploy a technology solution for swiftly and accurately determining blood groups and vital signs without invasive procedures, particularly in emergency medical situations. The focus is on enhancing healthcare delivery in Rwanda, with a specific emphasis on improving efficiency and efficacy within emergency services in blood transfusions. Through innovative design and implementation strategies, the project seeks to address critical gaps in medical response by providing healthcare professionals with rapid and reliable diagnostic tools.

CHAPTER 2. RELATED LITERATURE REVIEW

2.1. INTRODUCTION

The blood transfusion has become a crucial service in medicine especially in emergency departments in the hospitals due the patient needs the blood as the result of much blood bleeding during an accident. The transfer of blood requires to know the blood group of donor and recipient. In 1901 the blood groups were discovered by Landsteiner [4] from that time different approaches to transfer blood from one person to another, and to transfer the blood the blood group of two participants must be known to ensure the compatibility due Different blood types contain different antigens on the surface of red blood cells and preventing alloimmunization. Currently now the most blood grouping system includes [5];

i. **ABO Blood Group System:** This method is used to determine the blood groups based on identifying the blood groups based on absence or presence of antigens A and B on the surface of red blood cells. This method also employs the method of determining the presence of antibodies in the plasma against antigens [6].

ii. **Rh Blood Group System:** This method determines the blood group based on the presence or absence of Rh antigen on the surface of red blood cells [7].

iii. **Antigen-Antibody Agglutination Tests:** This involves the mixing of blood with specific antibodies to see the absence or presence of specific antigens [8].

Those methods have all involved the taking the sample blood group from donor and recipient, the sample is taken to laboratory to determine their blood group. Since those methods pass through different steps are time consuming which cause the delay in response in case the patient needs blood urgently while his/her blood group is unknown during the moment. To avoid the long time taken in determining blood groups, the researchers are trying to invent new techniques which employ non-invasive methods to determine blood groups.

2.2. NON-INVASIVE METHODS IN BLOOD GROUP DETERMINATION.

Non-invasive blood group determination refers to the detection of blood groups without taking a patient's blood sample to the hospital. This method is considered fast in terms of obtaining results compared to the invasive techniques. The developed techniques are mainly classified into two major methods

i. **Optical Techniques:** This method uses spectroscopy and imaging to explore the blood groups. Each blood group has specific optical properties compared to another, by using the device that generates light and that light passes through a certain individual, by measuring the detected light the individual blood group can be distinguished [9].

ii. **Machine Learning and Data Analysis:** Also by using certain cameras to capture the blood, by using different programming languages and applying image classification method, each blood group can be distinguished based on taken image [10].

Since this work is related to determining the blood groups by using optical methods, the related works are reviewed to identify the achievement of different researchers on this method and knowing the gaps to be solved in this area so that the methods can be used smoothly in future.

- **Related works on optical techniques to determine blood groups.**

Work by N.Deepa et al developed non-invasive blood detection using Nir sensor; the proposed system uses emitters and NIR to fashion the blood group [11]. The block diagram of the system is shown in Figure 2.1.

The proposed system use photoplethysmogram (PPG) signal machine learning algorithm to process the signal. PPG is captured from fingertip as shown in the Figure 2.1, the Near Infrared is used to produce specific wavelengths a light passes through the fingertip then the resulted signal is detected on detector. Detector estimate blood grouping (Hb), by using the convolutional neural network PPG signal is delivered to generate optimal features (point selection) that corresponding to the specified blood group.

The developed algorithms are loaded in smart phones so that the system is portable to everywhere. The PPG signal is converted into meaningfully voltage that corresponds to each blood group, Therefore the name of the blood group detected is displayed on the mobile smartphone of the user. A piece of work by Jaya et al [12] developed a work named blood group measurement using light emitting diodes. The system is made by Light-emitting diodes, detector, Arduino board and PC display. The optical detector used was OPT101 that has the capacity to detect a light of wavelength range from 300 nm to 1100 nm, and it requires power supply ranges from 2,7V to 36V. To process the data Arduino Boards were used and programmed by programming languages C and C++.

The device is developed and tested on 100 samples to determine the range of voltage of each blood group. The results show that Blood group O has the lowest voltage while blood group AB has highest voltage.

The researchers mentioned that the developed device has advantages of minimizing risks of infections compared to the invasive techniques and reducing time consumption. In the future authors suggest using laser technology in blood group detection.

Iot based non-invasive approach for blood group detection using Led was another work developed by Deepa et al [13]. The device is composed by PIC Microcontroller board, power supply, Led, Light Dependent Resistor (LDR), request button, node microcontroller, Global System for Mobile Communication (GSM), Liquid Crystal Display (LCD) server, mobile application, user software, embedded C.

LED produce light, light passes through the finger, the LDR measures the light intensity of transmitted light from the sensor, Node MCU is used to process data and transmit data to the server through Wi-Fi. In an emergency case the user clicks the request button to alert the nearest blood bank, and with the help of GSM a request message is sent to the donor.

The device is developed and tested and the reference voltage was 5V.

The device have many advantages over conventional methods such as;

- The risk of infection is minimized.
- The patient's blood group is identified within a few seconds.
- Equipment is used anywhere (portable).
- No reagent needed.

The researchers recommend the future researchers to include the vital sign monitoring system like body temperature sensor to avoid the spreading of the diseases while using a device.

A piece of paper by N. Nagar developed a blood group detection and mobile monitoring system [14]. A device determines blood group and also monitors body temperature and pulse-rate of patients by using body temperature sensor, pulse rate sensor. The blood group is determined by analyzing the absorbance of light generated by IR LED in blood sample, optic fiber is used to transmit the light to sample and from sample to the photo detector. To determine blood group a device uses a principle of the presence and absence of the antigens in grouping of blood. The detected light passes through the band pass filter to remove the noise, then the resulting light intensity is measured and converted to voltage. A device was tested on deterrent blood samples.

The authors conclude that the system can be used to analyze the blood group and vital signs in emergency cases which has a great impact in reducing the work of doctors and nurses to a great extent. On other hand, authors mentioned that determining the Rhesus factor can provide a very precise determination of the blood group.

Related works on Machine Learning and Data Analysis techniques to determine blood groups.

Ajitkumar et al developed blood group detection by using image processing techniques [15]. The proposed system is based on image processing techniques such as;

i. Pre-processing techniques
ii. Thresholding
iii. Morphological operations
iv. HSL plane
v. Quantification

To find the specific features of each blood group, each blood group, the blood were mixed by anti-A and anti-B reagents , by using a camera image taken then image has been digitized, and are pre-processed using color plane extraction. During image classification, support vector machines (SVM), k-nearest neighbors (KNN), decision trees and artificial neural networks (ANN), are used to perform the task.

The system is tested and shows the advantages of improving accuracy in blood detection, increasing speed (response time) in case of emergency , ensuring objectivity in blood group determination and also these techniques can be used in forensic Applications. It is concluded that the blood detection using image processing techniques offer promising approaches in the blood typing process.

A piece of work by A. Malhotra [16] developed automated blood group determination using image processing techniques with integration of raspberry pi. The system also is based on detecting absence or presence of antigens in the certain blood group by using image-processing techniques. To perform tasks machine learning algorithms are developed including Color plane extraction, Thresholding, Morphological operation, HSL, Quantification. The raspberry pi with installed raspbian operating system was used to process data and display results virtually using VNC server. The blood group classification is based on the features obtained and the image of blood groups after quantification are different.

The system is tested on different blood groups, the Authors conclude that a system has accuracy same as conventional method and has more advantages such as; addressing problems of reagent dilution, blood separation and incubation also it reduces expenses and saves time.

A piece of work P. Hansik et al developed blood group detection using image processing MATLAB [17].

Gray Scale conversion involves converting true color image to gray scale image whose pixel value ranges from 0-255 while Binary conversion converts the digital image in just two values per pixel either 0 or 1. Segmentation refers to extracting the needed features of each blood group, the Group A and B are shown after segmentation.

Canny edges detection involves identifying brightness discontinuities, after this step the algorithm decides the Blood group of the taken image. During the experiments the obtained results show the potential efficiency of the system compared with results obtained from blood group determination conducted in laboratories. The Authors conclude with recommending the future researchers to use the microscopic picture to identify pattern approaches of certain antibodies in each blood cell.

Related Literature on Vital signs monitoring system.

A piece of work Sowmya et al developed IOT Based Health Monitoring System [18]. The system is designed to detect vital signs such as heart rate and body temperature by using a temperature sensor and pulse oximeter and measure the condition of the environment (humidity, temperature and carbon monoxide) by using a carbon monoxide sensor. Node MCU processes the data, d stored on the BLYNK server and displayed on the Blynk App.

The model use Pulse Oximeter of MAX30100 to detect pulse rate, Temperature sensor of DS18B20 to measure body temperature, Humidity-temperature sensor of DHT-11 to measure temperature and humidity of ambient air and carbon monoxide is detected by Carbon monoxide sensor of MQ-7. A device has been tested on a healthy person and results show that it is functioning well, it is concluded that a device can be used to monitor the health of a patient and doctor monitors him/her and advises the patient about their health.

A work by A. Ahmed [19] developed Human Vital Physiological Parameters Monitoring: A Wireless Body Area Technology Based Internet of Things. A device monitor body temperature and heartbeat by using DHT11 temperature sensors and EN 11574 pulse/heartbeat sensor respectively, both sensors are made by embedded microchip that make contact with the human skin while of (HC-06) Bluetooth low energy Tx/Rx module was used to transfer a data from patient to a doctor. An android mobile web application has been developed with a graphical user interface for patients and medical dashboard.

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The system was tested and it was found that it is working effectively compared to the existing developed system, and a good performance in terms of accuracy, sensitivity and response time were provided by a device. The author mentioned that in the future, more features to sense more human physiological data should be considered.

Another vital sign monitoring system has been developed by Jose et al [20]. A device is designed to detect vital signs such as Heart Rate, Body temperature and Oxygen saturation, by using DS18B20 temperature sensor, GY-61 cardiac pulse sensor and MAX30100 oximetry sensor respectively. Arduino MEGA 2560 ATMEGA components, Shield Ethernet for Arduino, Router with LAN ports are used to process and transmit the data to the doctor.

A device was tested in a hospital setting and showed good performance in detection and transmitting the signal. The doctors claim that a device will diminish challenges that arise in monitoring patients physically.

Table 2: Summary of the related works.

TITLE AND AUTHOR	SENSORS	METHOD	SPECIFICATION	DRAWBACK
B.K Bhoomika., K. Muralidhara, "Secured Smart Healthcare Monitoring System Based on IOT,"	Temperature, heartbeat rate, blood pressure	Arduino-mega collects the data from the sensors and sends them to the web server using Wi-Fi.	Managers/doctors can monitor the data through smartphones.	The system can save only part of the data in the webserver
M. G. Ayoub, M. N. Farhan, and M. S. Jarjees, "Streaming in-patient BPM data to the cloud with a real-time monitoring system,"	Temperature (LM35), Pulse oximeter (TCRT1000), Liquid Crystal Display (16x2), GSM modem.	ATMEGA8 microcontroller collects the data from the sensors and sends the data to a Web page	The sent data are encrypted, and it can be accessed anytime by the doctors using a unique URL link.	The system does not have a smartphone application. The cost still not cheap
S M Farhad, Matiur Rahman Minar "Measurement of Vital Signs with Non-invasive and Wireless Sensing Technologies and Health Monitoring"[21] DOI:10.12720/jait.8.3.187-193	IR temperature sensor,	The data collected through the sensor is passed through	Managers/doctors can monitor the data through smartphones.	The low cost spirometer needs a sensible fan to accurately read data. Without the proper fan the hardware

		Arduino and then to the smartphone via Bluetooth.		implementation got stuck at a point. Skin temperature sensor with hygrometer sensor can measure body climate under cloth.
Mahmoud Salem, Ahmed Elkaseer, Islam A. M. El-Maddah, Khaled Y. Youssef, Steffen G. Scholz and Hoda K. Mohamed "Non-Invasive Data Acquisition and IoT Solution for Human Vital Signs Monitoring: Applications, Limitations and Future Prospects"		multi-camera systems		
Haider Ismael Shahadi , Maha Khalid Kadhim , Nawal Mousa Almeyali , Ali Thamir Hadi "Design and Implementation of a Smart, Interactive, and Portable System for Monitoring of Human Vital Signs"[22] DOI: 10.26555/jiteki.v7i1.20209	Body temp. Ambient temp. Heart rate ECG sensors	The system combines the smart modules that are controlled by the ESP32 microcontroller with the cloud database.	The implemented system allows the doctor to monitor his/her patients from any place in the world in real-time. I	The system can work only when there is internet
Gayathri T, Rekha M, , Naizathul Akmha S , K.Nithyakalyani "NON INVASIVE BLOOD GROUP DETECTION USING LIGHT EMITTING DIODE"		Light acts as a source for optical signals which is allowed to pass through the finger and the detector	The process is uncomplicated and convenient to determine ABO blood groups in a short period of time, So it can	The system cannot send data on internet

		detects the varying voltage. As the optical property of blood varies for different antigen present on the RBC, the voltage value obtained also gets varied. Depending upon the output voltage of the detector, blood groups are determined.	be economically used for blood tests during hospitality, emergencies, war fields and infants.	
M. G. Ayoub, M. N. Farhan, and M. S. Jarjees, “Streaming in-patient BPM data to the cloud with a real-time monitoring system,” Telkomnika Journal, vol. 17, no. 6, pp. 3120–3125, 2019. [23]https://doi.org/10.12928/telkomnika.v17i6.13263	Temperature, heartbeat rate, blood pressure.	Arduino-mega collects the data from the sensors and sends them to the web server using Wi-Fi.	Managers/doctors can monitor the data through smartphones.	The system can save only part of the data in the webserver.
A. Singh, B. N. Naik, S. L. Soni, and G. D. Puri, “Real-Time Remote Surveillance of Doffing during COVID-19 Pandemic: Enhancing	SpO2, ECG, heart rate, blood	A technology for remote monitoring utilizing	Patient vital signs can be visualized by smartphone.	This system does not connect to the web server to monitor and

Safety of Health Care Workers," Anesth. Analg, pp. E112–E113, 2020.[24] https://doi.org/10.1213/ANE.0000000000004940	pressure, and camera.	CCTV cameras and smartphones. Also, the data of the sensors are collected and sent to the phone.	So, it alerts and manages patient care without being physically present bedside.	analyzes the history of the patient vital signs
P. Valsalan1, T. Baomar, A. Baabood, "IoT based Health Monitoring System for Elderly People," Journal of critical reviews, Vol 7, Issue 4, pp. 739-740, 2020.[25] https://doi.org/10.31838/jcr.07.04.137	Ultrasonic sonar, pressure pad Pulse, temperature.	Arduino-Uno collects data from all sensors, then sends them to the cloud to save data. The doctor can display the data using the cloud site	The project provides fast data collection. The cost is fair.	Sonar sensor has a slow sensing rate, and it is very sensitive to temperature changes. Also, no smartphone application
A. Singh, B. N. Naik, S. L. Soni, and G. D. Puri, "Real-Time Remote Surveillance of Doffing during COVID-19 Pandemic: Enhancing Safety of Health Care Workers," Anesth. Analog, pp. E112–E113, 2020.[24] https://doi.org/10.1213/ANE.0000000000004940	SpO2, ECG, heart rate, blood pressure, and camera.	A technology for remote monitoring utilizing CCTV cameras and smartphones. Also, the data of the sensors are collected and sent to the phone.	Patient vital signs can be visualized by smartphone. So, it alerts and manages patient care without being physically present bedside.	This system does not connect to the web server to monitor and analyzes the history of the patient vital signs

K. Mohanraj, N. Balaji, and R. Chithrakkannan, “IoT based patient monitoring system using raspberry pi 3 and Lab view,” Pakistan Journal of Biotechnology, vol. 14, pp. 337–343, 2017. [26]https://doi.org/10.1109/ICOMET.2019.8673393	Temperature and humidity (DHT11), pulse, and oximeter.	Raspberry-pi collects data from sensors and display on Lab-View.	Graphical patient’s data is displayed for the doctor.	No web server, no remote access to the patent’s data.

Issues identified within the comprehensive system for non-invasive blood group detection and monitoring vital signs.

Even though there are a lot of non-invasive blood group detection methods and vital sign monitoring systems, there are a few methods with combined systems that detect both blood group and monitor vitals. In addition, those combined systems have accuracy is small compared to the results obtained from conventional methods. Also the methodology used to design those combined systems have advanced materials like fiber optics, which make them inapplicable in remote areas, and due to such technology of fiber optics make the system too complicated to use and expensive.

Methods to tackle the aforementioned problems.

To address the identified gaps from literature survey, this work aims to design a system with combined both non-invasive blood group detection methods and vital sign monitoring systems, which have the features which are easy to use and which are cost effective, compared to the existing methods.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research Process

This chapter indicates the methodology employed in the research during the designing and implementation of a non-invasive blood group and vital signs detection system tailored specifically for emergency services. The research begins by issuing recognition related to blood transfusion in Rwanda, especially in emergency cases, therefore the challenges are addressed, and to overcome those challenges the non-invasive blood group and vital signs detection system is proposed. To know whether the proposed system is needed and has positive impacts on blood transfusion in Rwanda, a survey is conducted to ensure that the system is needed. Upon designing the non-invasive blood group and vital signs detection system, the previous related works were consulted, and the comprehended understanding of the contents of each blood group was examined to know the specific elements of each blood group so that the device was designed to target those elements. After knowing and knowing the blood group's content, the detection method is chosen which is based on measuring the light intensity detected in the blood group, while that light is generated by light-emitting diode. Figure 3.1, shows the follow chart used to during designing and implementation of a non-invasive blood group and vital signs detection system.

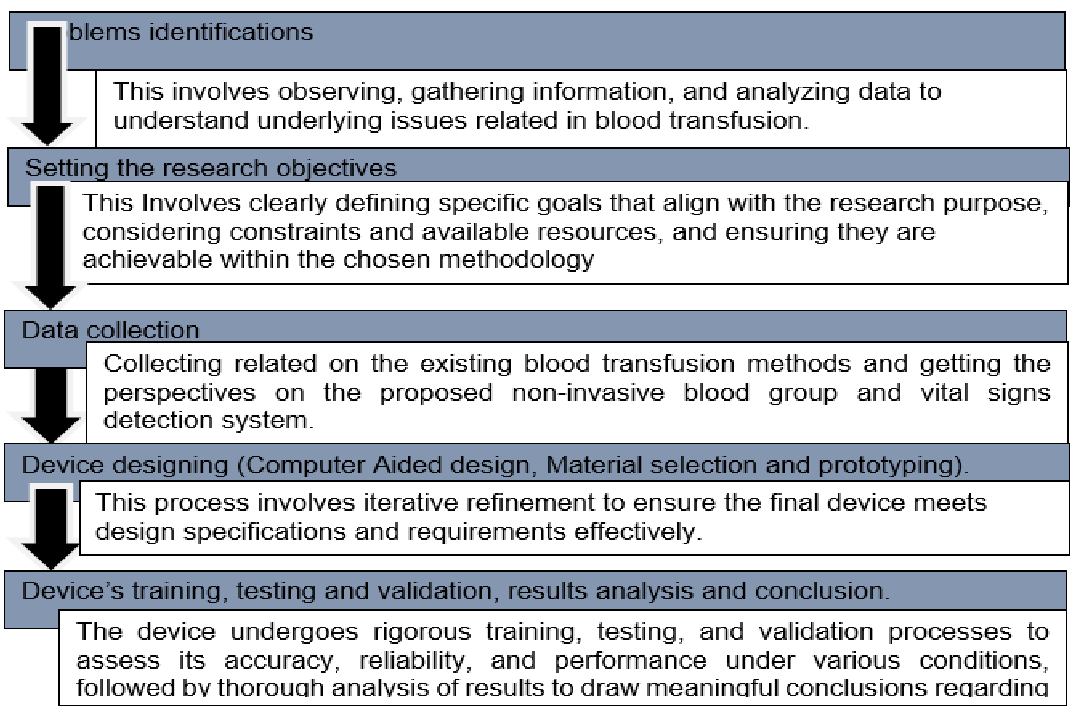

Figure 1: *Research design flow-chart.*

The working principle of the non-invasive blood group and vital signs detection system specifically for emergency services.

Non-invasive blood group and vital signs detection systems specifically for emergency services use the principle of light intensity detection to differentiate the different kinds of blood groups. Firstly, LED is used to generate the light, which is projected at the top of the finger of the patients; however, the photo detector is placed at the bottom of the finger to detect the amount of light that falls on it from the finger. Based on the amount of the light detector, the microprocessor can distinguish if the user has blood group A, B, AB, or O.

Variation of light absorbance in blood groups

Blood groups have different compositions and this leads them to absorb light at different rates, they differ in their antibodies and red blood cells.

a) **Blood Group A:** Blood group A individuals have A antigens on the surface of their red blood cells. These antigens can interact with certain wavelengths of light, leading to absorption and scattering. The specific optical properties of blood group A depend on the concentration and distribution of these antigens.

b) **Blood Group B:** Blood group B individuals have B antigens on their red blood cells. Similar to group A, the presence of B antigens affects how light interacts with the blood. The optical properties of blood group B differ from those of group A due to variations in the structure and distribution of the antigens.

c) **Blood Group AB:** Individuals with blood group AB have both A and B antigens on their red blood cells. This combination of antigens can result in unique optical properties compared to groups A and B alone. The presence of both A and B antigens may lead to increased light absorption and scattering compared to individual blood groups.

d) **Blood Group O:** Blood group O individuals lack A and B antigens on their red blood cells, making their blood type compatible with both A and B blood types during transfusions. The absence of these antigens affects the optical properties of blood group O, potentially resulting in different patterns of light absorption and scattering compared to groups A, B, and AB.

In addition to antigens, other factors such as hemoglobin concentration, oxygen saturation, and the presence of other blood components (e.g., plasma proteins) also influence how blood absorbs and scatters light.

3.2. Research Design Method

The research design methodology for the development of a non-invasive blood group and vital signs detection system for emergency services involves an approach of integrating both qualitative and quantitative methods. The initial step focuses on a literature review to get an update on the design process, identifying key requirements and challenges. Iterative prototyping and testing cycles are used to ensure the system's functionality and usability. Figure 3.2 shows the block diagram of the non-invasive blood group and vital signs detection system.

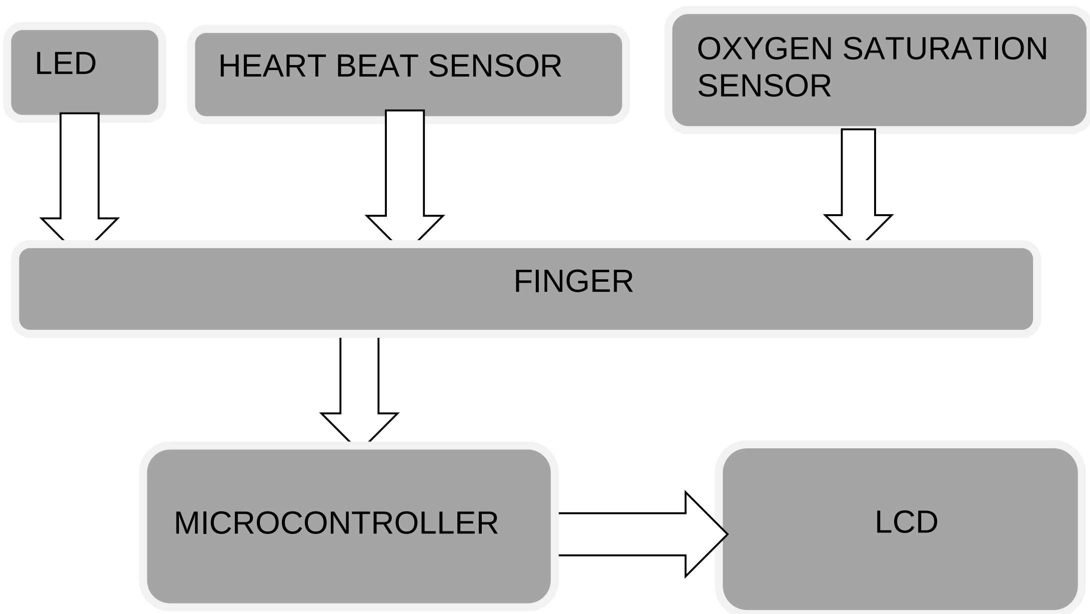

Figure 2: *Block Diagram.*

As shown in Figure 3.3, the system is made by three main systems such as

a) **Data detection system**

Three sensors make a data detection system: photo detector sensor, heart beat sensor and oxygen saturation sensor. The light to be detected is generated by the light emitting diode.

b) **Data processing system**

A data processing system based on the microcontroller is used to process the data and convert them from analog form to digital form.

c) **Results display system**

The patient or health providers observe the results (blood group, heart rate, and oxygen saturation) on the liquid crystal display.

3.2.1 Material selection

While selecting the material to be used in prototyping a non-invasive blood group and vital signs detection system the following criteria are considered to ensure the cost-effectiveness of the device and safety of the users.

- **Biocompatibility**: The sensors used are biocompatible to ensure they are safe for use with human subjects, minimizing the risk of adverse reactions or complications.
- **Durability**: The selected materials are durable and resilient enough to withstand repeated use in clinical settings without degradation or damage.
- **Sensitivity**: Sensors exhibit the necessary sensitivity to accurately detect and measure blood group markers and vital signs, ensuring reliable performance.
- **Ease of Sterilization**: The materials used are easily sterilizable to maintain hygienic conditions and prevent the spread of infections in clinical environments.
- **Cost-effectiveness**: Consideration of cost-effectiveness is important to ensure the chosen materials are economically viable for mass production and deployment in healthcare settings.

By considering these criteria during designing a non-invasive blood group and vital signs detection system, the specific characteristics of each material are discussed in the next section.

i. **Light emitting diode**

Light emitting diode is a semiconductor that emits light when light passes through it, a device uses white light emitting diode which is also powered by the microcontroller.

Figure 3: *Light-Emitting Diodes*

Figure 3.3 shows the White-LED that is used to generate light that penetrates in human-finger, however the transmitted light detected by the photo detector, White LEDs, which emit light across the entire visible spectrum whose wavelength of , can be used for broad-spectrum analysis and to cover a wide range of wavelengths.

ii.**Photo-detector**

Photo detector is used to detect and measure the light intensity collected from the finger. During designing a non-invasive blood group and vital signs detection system OPT101 Light Analog Light Intensity Sensor Module Single Chip Photoelectric Diode 14KHz CJMCU-101 CO is used.

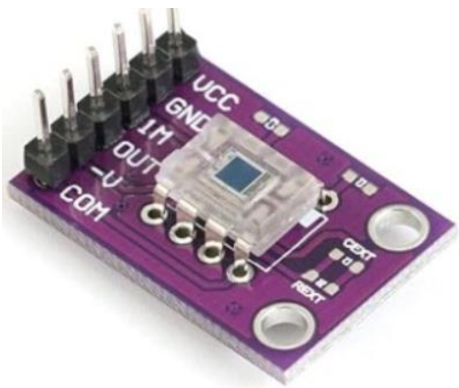

Figure 4:OPT101 Light Analogy Intensity Sensor

Figure 4.4 shows the OPT101, it is a luminance photo sensor that integrates a photodiode and a specially optimized op amp. The transparent package allows the photodiode to have a larger sensing surface with higher sensitivity and a wide spectral response range (infrared to visible light 300 nm-1000 nm).

- Output voltage ratio: 0.45V/uW
- Analog voltage output range: Vs — 1.15
- Bandwidth: 14KHz
- Static power consumption: 120uA

Pin Functions of OPT101 Light Analog Light Intensity Sensor Module Single.

- **VCC:** power supply positive pin
- **-V:** negative supply
- **-IN:** the inverting input of the internal op amp and the negative of the internal photodiode.

- **1M:** Internal 1M feedback resistor input
- **OUT:** Amplifier output
- **COM**: Internal photodiode positive, generally connected to GND

SPECIFICATIONS

- Supply Voltage: 2.7~36V
- Photodiode light irradiation area: 5.2mm
- Photocurrent: 0.45A/W (λ = 650nm)
- Output voltage ratio: 0.45V/uW
- Analog voltage output range: Vs ー 1.15
- Bandwidth: 14 KHz
- Static power consumption: 120uA

iii.**Heart rate and oxygen saturation sensor**

Heart beat and oxygen saturation sensor is integrated in the system no monitor the vital same of the vital signs of the patient such as heartbeat rates and oxygen saturation, in case those values exceed or below the threshold value patient can be fed by oxygen and defibrillation service can be given to her/him. To capture those vital signs by non-invasive blood group and vital signs detection system MAX30100 Pulse Oximeter Heart Rate Sensor Development Board for Arduino SEN34 ,R25 is used, as illustrated in Figure 5.5.

Figure 5:*MAX30100*

Heart Rate Click carries Maxim's MAX30100 integrated pulse oximetry and heart-rate sensor.

Specification:

- 3.3V power supply.
- Optical sensor: IR and red LED combined with photodetector
- Measures absorbance of pulsing blood
- I2C interface plus INT pin

iv. Microcontroller

To process the data vital signs by non-invasive blood group and vital signs detection system uses Node MCU ESP8266 WIFI Internet Development Board BRD51, R11.

Figure 6: Node MCU

Features of NodeMcu ESP8266 WIFI Internet Development Board BRD51, R11.

- Open-source, Interactive, Programmable, Low cost, Simple, Smart, WI-FI enabled.
- Arduino-like hardware IO
- Advanced API for hardware IO, which can dramatically reduce the redundant work for configuring and manipulating hardware.
- Code like arduino, but interactively in Lua script.
- Nodejs style network API
- Greatly speed up your IOT application developing process.
- Wi-Fi MCU ESP8266 integrated and easy to prototyping development kit.

v.Liquid crystal display

To display the results liquid crystal display is used with Inter-Integrated Circuit (I2C). I2Cgets the data from NodeMcu ESP8266 WIFI Internet Development Board BRD51, R11, then transfers them and displays them on a liquid crystal display. Figure 3.7 shows both liquid crystal display and Inter-Integrated Circuit.

Figure 7: *Liquid Crystal Display*

3.2.2 COMPUTER AIDED DESIGN

Proteus software is used to design the virtual circuit before making a temporary circuit and permanent circuit of a non-invasive blood group and vital signs detection system.

- **Interfacing MAX30100 with NodeMcu**

As illustrated in Figure 3.3, the output of the Max30100 is connected to SCL and SDA of the NodeMcu.

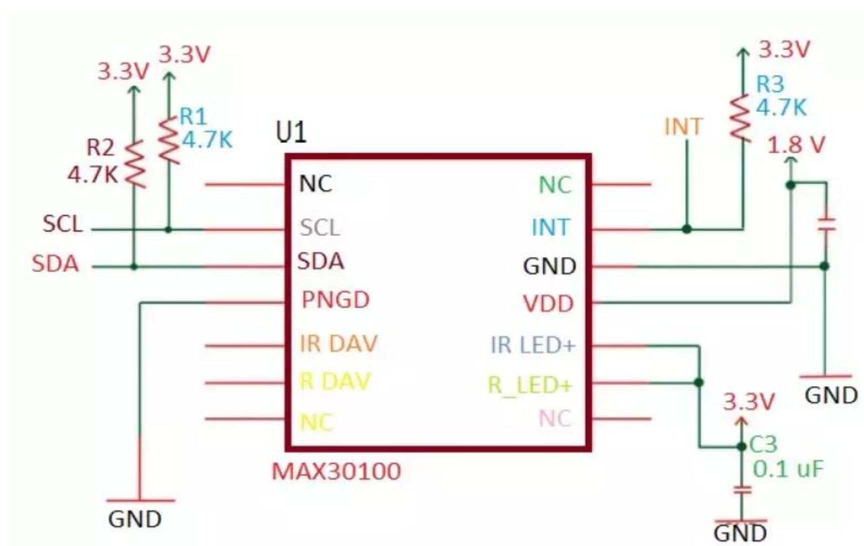

Figure 8: *Interfacing Max30100 with Arduino.*

- **Interfacing NodeMcu and OPT101 Light Analog Light Intensity Sensor Module Single.**

Photo-detector is supplied by 3.3V from NodeMcu's power pin, therefore the output of the sensor is detected from the 1M pin and OUT pins of the OPT101 Light Analog Light Intensity Sensor.

The analogy pin (A0) of NodeMcu's power is used to read the analogy value from the sensor. As illustrated in Figure 3.9 the pin configuration is shown.

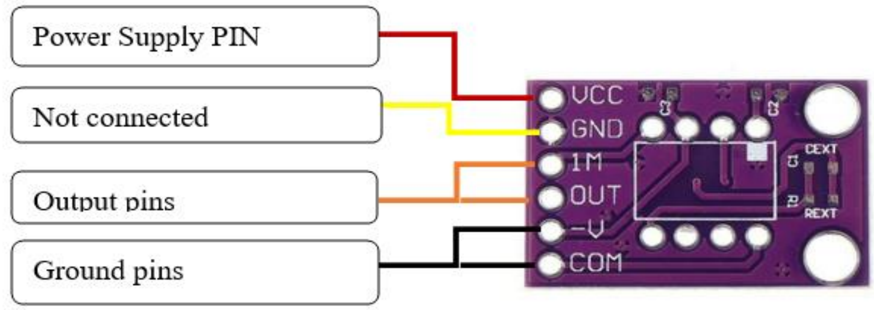

Figure 9: Interfacing OPT101 light sensor.

3.2.3 PROTOTYPING OF NON-INVASIVE BLOOD GROUP AND VITAL SIGNS DETECTION SYSTEM

This phase is about creating a functional prototype of the proposed system, which uses non-invasive techniques to determine blood groups and monitor vital signs. The section demonstrates the development process of the device and training device procedures.

I. **Bread boarding**

Bread boarding involves making the temporary circuit of a non-invasive blood group and vital signs detection system circuit on breadboard. The components used to build the temporary circuit are listed in Table 3.1.

Table 3: Main components and accessories used during bread boarding

	Components
Main components	NodeMCU
	OPT 101
	MAX30100
	LED
Accessories	Breadboard
	Jumper wires

By using the listed components in Table above, the temporary circuit is constructed and is shown in Figure 3.10.

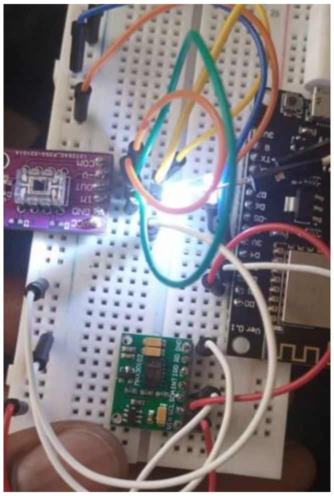

Figure 10: *Temporary Circuit.*

The temporary circuit is constructed and is being tested and data is monitored on the serial monitor of Arduino IDE. To test temporary circuit LEDs were turned ON and all light were projected on the OPT 101 sensor. When all light from LED projected on the sensor at 90^0 maximum analogy value of 1023 is detected, by gradually decreasing light angle the analogy value also decreases, when there is not any light the analogy value of 0 is detected. It concluded that OPT101 Light Analog Light Intensity Sensor is able to detect any small change in light intensity and is able to be used in blood group detection. On the other hand, MAX30100 is able to measure heartbeat and oxygen saturation.

II. **Soldering**

After testing a circuit on temporary set-up, a permanent circuit is constructed; the components and materials used are listed in Table 3.3.

Table 4: Main components and accessories used during Soldering.

	Materials
Main components	NodeMCU
	OPT 101
	MAX30100
	LED
	LCD
	I2C
Accessories	Printed Circuit board
	Jumper wires
	Cartoons
Equipment	Soldering gun
	Soldering wires

With using the shown materials in table above, the permanent circuit is constructed by considering the following criteria:

a. The blood group is detected by inserting the finger on a specified place of the device, a device is designed in the way that finger is placed between LED and OPT 101 Light Analog Light Intensity Sensor.

b. To ensure the good accuracy of the detected signal a device is designed in such a way that the light angle from the LED is not changing, it remains the same for all measurements.

c. To avoid the external light to interfere with the light generated by LED, the OPT 101 Light Analog Light Intensity Sensor is covered so that no external light is detected.

Internal component of the non-invasive blood group and vital signs detection system.

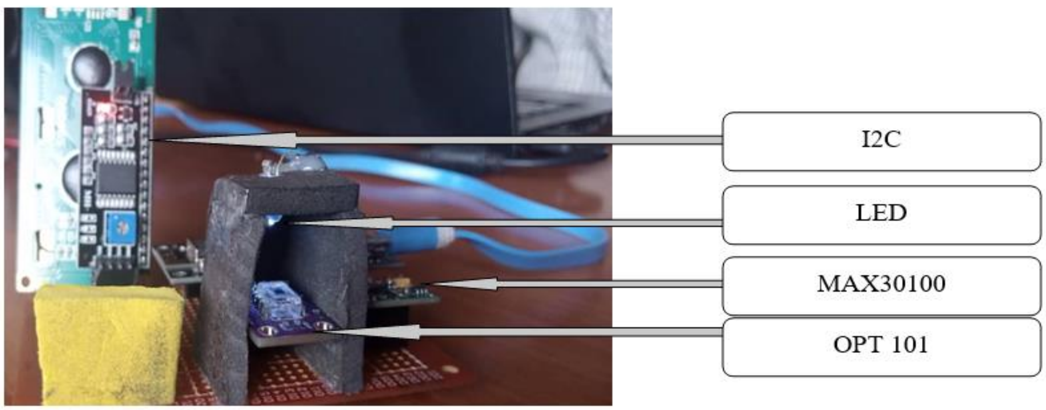

Figure 11: *Internal Components of the Device.*

External component of the non-invasive blood group and vital signs detection system.

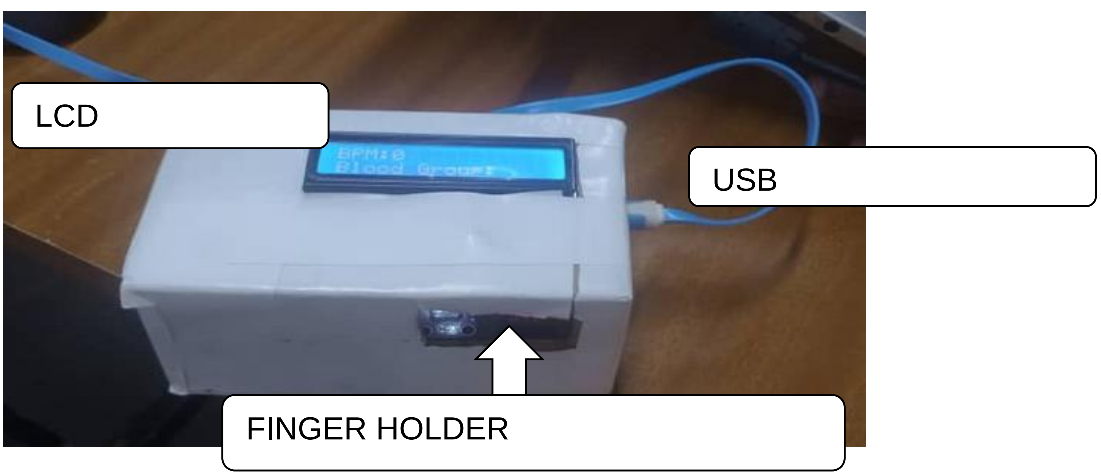

Figure 12: *External component of the non-invasive blood group and vital signs detection system.*

III. MODEL PERSONALIZATION

For better functioning of non-invasive blood group and vital signs detection system, a software system is embedded in microcontroller, then microcontroller process the data based on the software program, to identify the blood group of the user microcontroller have the specific ranges of analogy value of each blood group. To know the range of analogy value of each blood the sample of 10 individuals with the same blood is measured by a device, the results are recorded and analyzed, therefore those ranges are inserted in a software program.

- **Collected data on blood group analogy value**

Table 5: Collected Data

Participant	A	B	AB	O
1	160	137	125	114
2	171	140	130	116
3	178	158	138	117
4	180	148	133	119
5	160	137	125	114
6	171	140	130	116
7	178	158	138	117
8	180	148	133	119
9	178	158	138	117
10	180	148	133	119
11	160	137	125	114
12	171	140	130	116
13	178	158	138	117
14	180	148	133	119
15	180	148	133	119
16	160	137	125	114
17	171	140	130	116
18	178	158	138	117
19	180	148	133	119
20	171	140	130	116
21	178	158	138	117
22	180	148	133	119

- **Data analysis**

Data were analyzed in Microsoft Excel are the results are summarized in Table 3.4.

Table 6: Data Analysis.

	Blood group A	Blood group B	Blood group AB	Blood group O
MEAN	172	145	131	116
MAX	180	158	138	119
MIN	160	137	125	114

Based on the obtained results the device is trained to display blood group A when the analogy value ranges between 160 and 180, and blood group B when the analogy value ranges between 137 and 158. A device also displays blood group AB when the analogy value ranges between 125 and 138, and blood group O when the analogy value ranges between 114 and 119.

- **Software development**

The developed software program is designed so that the user puts the finger first on the OPT 101 Light Analog Light Intensity Sensor to detect blood groups and then the finger is placed on the MAX30100 to detect vital signs (heart rate and oxygen saturation). The algorithms to classify the blood group based on light intensity, the program is developed based on the collected data summarized in Table 3.4.

DEVICE TESTING

To test the functionality of a device and its accuracy, it is tested on the individuals who know their blood group, the accuracy of the device, and the obtained results are compared with their group. Sample of 20 individuals is taken with six people of group A, five with group B, five whose blood group AB and four people whose blood group O. The results are summarized in Table 4.1.

Cost estimation of non-invasive blood group and vital signs detection system.

One of the main objectives of this research is to design cost-effectiveness non-invasive blood group and vital signs detection system, the cost estimation of device is shown in the Table 3.5

Table 7: Cost Estimation

SN	Components	Quantity(ies)	Price per unit	Total
	NodeMCU	1	11000	11000
	OPT 101	1	15000	15000
	MAX30100	1	8000	8000
	LED	1	300	300
	LCD	1	11000	11000
	I2C	1	4000	4000
	Jumper wires	25	2000	2000
	Cartoons	1	2000	2000
	Soldering gun	1	10000	10000
	Soldering wires	1	4000	4000
	USB to Micro USB Cable wire 1M for NodeMCU	1	1000	1000
GRAND TOTAL				**Rwf 68300**

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 DATA ILLUSTRATIONS

i. **Blood group detection**

This section summarizes the obtained results after testing the device and discussion about them.

The obtained results after testing the devices are listed in Table 4.1.

Table 8: Test Results

	Individuals	
SN	**Blood group**	**Measured blood group**
1	A	A
2	A	A
3	B	AB
4	A	B
5	AB	AB
6	O	O
7	B	B
8	AB	B
9	O	O
10	B	B
11	A	A
12	AB	AB
13	O	O
14	B	B
15	A	A
16	AB	B
17	O	O
18	B	B
19	A	A
20	AB	B
21	B	B
22	A	A
23	AB	AB
24	O	O

25	B	B
26	A	A
27	AB	B
30	O	O
31	B	B
32	A	A
33	AB	B
34	AB	B
35	O	O
36	B	B

The taken sample is 20 persons, 30% have blood group A, 25% have blood group B, 25% have blood group AB and 20% have blood group O. Each person, his/her group is tested by using a device and the obtained results are listed in Table 4.1, column 3. As shown in Table 4.1, the same of the obtained results are mismatching with the known blood groups.

ii. **Vital signs monitoring**

The device was also tested in detection of vital signs such as heartbeat, the results obtained on five healthy people are summarized listed in Table 4.2.

Table 9: Vital Sign monitoring.

SN	Heart beat (beat per minute)	Heartbeat measured by pulse oximeter
1	69	71
2	73	75
3	65	66
4	71	72
5	74	73
6	80	78
7	82	80
8	73	74
9	69	71
10	73	75
11	65	66
12	71	72
13	74	73
14	80	78

15	82	80
16	73	74
17	71	72
18	74	73
19	80	78
20	82	80
21	73	74
22	65	66
23	71	72
24	74	73
25	80	78
26	82	80
27	73	74
28	71	72
29	74	73
30	71	72

4.2 RESULTS ANALYSIS

i. **Blood group detection**

The raw data are analyzed with Microsoft Excel and the processed results are shown in Figure 4.1.

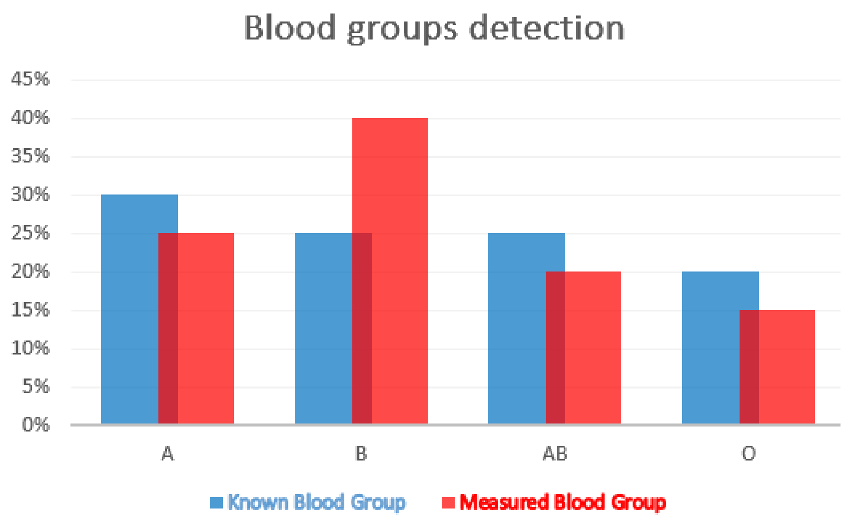

Figure 13: Results presentation on blood detection.

Figure above shows the comparison between the known blood group and measured blood group, red color indicates measured group while blue color indicates the Known blood group.

ii. **Heart Beat Monitoring**

The Figure 4.2 shows the graph of the results measured by a developed device and a pulse oximeter, the red color indicates the measured data by pulse oximeter while the blue color indicates the results measured by a developed device.

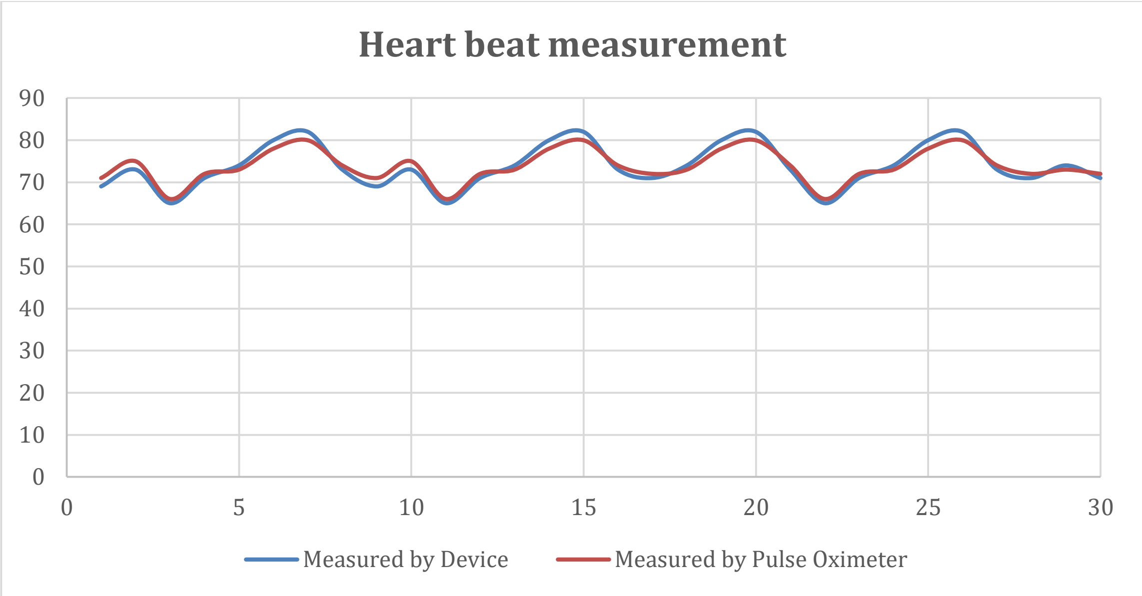

Figure 14: Results Presentation on Vital Sign Monitoring.

4.3 RESULTS DISCUSSION

i. **Blood group detection**

Non-invasive blood group and vital signs detection systems are developed and tested in a real world environment during testing the functionality of the device in blood group detection, among 20 persons with the known group, 14 persons were tested positive. This means that the overall accuracy of the device is 70%, the specific accuracy among the blood group is listed in Table 4.3.

Table 10: Device Accuracy.

SN	BLOOD GROUP	ACCURACY
1	A	83%
2	B	63%
3	AB	80%
4	O	75%
OVERALL ACCURACY		**70%**

As shown in Figure 4.1, blood group B the measured number of blood group B is higher than the known number, this is due to the range of light intensity that corresponds to Blood group B is very close to the Blood group AB, this causes the same of the AB person to be tested B. Therefore the further improvement is needed to increase the device accuracy.

ii. **Vital signs detection**

The device is used to detect the heartbeat of eight participants, the results are compared with the results obtained by using the pulse oximeter. The results show no significance difference between the data taken by Non-invasive blood group and vital signs detection system and pulse oximeter.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The project is a prototype of blood group and vital signs detection using Light emitting Diodes. The system can determine a patient's blood type quickly and easily without the need for a blood sample, which eliminates the pain and discomfort of being pricked with a needle and which will minimize the lack of universal blood group (O) in Rwanda. This is especially useful in emergency situations, blood transfusions, and vital signs detection as it can greatly reduce the time it takes to determine a patient's blood type, getting vital signs and administering the correct blood. The system is also small and affordable, making it a practical option for a variety of settings.

In addition, the heartbeat rate is one of the vital parameters in every human's body, which by knowing it can detect heart disease and prevent more serious problems. Therefore, we present a heartbeat rate measuring device based on infrared light in this paper which can be measured at any time when needed. The main elements of this device include a low-cost microcontroller, which is the overall function of the device. The advantages of this device are low cost, easy to use, high speed, high precision and easy transportation.

The accuracy of the system is affected by a few factors, including external light, the size of the data set, and the sensitivity of the sensors. To improve the accuracy of the system, the data set can be increased to include thousands of samples per blood type. The sensitivity of the sensor can also be increased to improve the accuracy of the blood group detection by using a high sensitive sensor. Additionally, the system can be used in a dark room to minimize the effects of external light.

Overall, this non-invasive blood group and vital sign detection system is a promising new technology that has the potential to improve the efficiency and accuracy of blood transfusions. The system is safe, affordable, and easy to use, making it a practical option for a variety of settings

5.2 Recommendations

The proposed device can be used with high sensitivity sensors and prevent light from interfering with light from LED. The device can also be used with GSM 900A modem which transmits the messages to the person in charge of blood bank to prepare the needed blood on time without relying on only blood group O.

REFERENCES

[1] A. Shrestha, “Determination of Blood Group: ABO and Rh Systems,” 2023.

[2] A. Professor, “Non Invasive Blood Group Detection,” vol. 6, no. 5, p. 139, 2019, [Online]. Available: www.jetir.org

[3] “Rwandans with blood group Type O urged to donate - The New Times.” https://www.newtimes.co.rw/article/189248/News/rwandans-with-blood-group-type-o-urged-to-donate (accessed Jun. 05, 2023).

[4] B. S. Coller, “Blood at 70: Its roots in the history of hematology and its birth,” *Blood*, vol. 126, no. 24, pp. 2548–2560, 2015, doi: 10.1182/blood-2015-09-659581.

[5] M. Franchini and C. Bonfanti, “Evolutionary aspects of ABO blood group in humans,” *Clin. Chim. Acta*, vol. 444, pp. 66–71, 2015, doi: 10.1016/j.cca.2015.02.016.

[6] R. Mitra, N. Mishra, and G. P. Rath, “Blood groups systems,” *Indian J. Anaesth.*, vol. 58, no. 5, pp. 524–528, 2014, doi: 10.4103/0019-5049.144645.

[7] T. Nayeri, M. Moosazadeh, A. D. Asl, F. Ghaffarifar, S. Sarvi, and A. Daryani, “Toxoplasma infection and Rhesus blood group system: A systematic review and meta-analysis,” *PLoS One*, vol. 18, no. 7 July, 2023, doi: 10.1371/journal.pone.0287992.

[8] L. E. Richter, A. Carlos, and D. M. Beber, “https://doi.org/10.1111/voxs.12590.

[9] A. Sdobnov, G. Piavchenko, A. Bykov, and I. Meglinski, “Advances in Dynamic Light Scattering Imaging of Blood Flow,” *Laser Photonics Rev.*, vol. 18, no. 2, 2024, doi: 10.1002/lpor.202300494.

[10] H. Song and Z. Wang, “Automatic Classification of White Blood Cells Using a Semi-Supervised Convolutional Neural Network,” *IEEE Access*, vol. 12, pp. 44972–44983, 2024, doi: 10.1109/ACCESS.2024.3380896.

[11] U. Jhansi, M. Devi, M. Devaki, S. Bhusal, and V. A. Konda, “International Journal of Research Publication and Reviews Anemia Detection using Machine Learning,” vol. 4, no. 4, pp. 1996–2011, 2023.

[12] J. Rubi*, G. Srividhya, A. Keerthana, and R. J. Hemalatha, “Blood Group Measurement using Light Emitting Diode,” *Int. J. Recent Technol. Eng.*, vol. 8, no. 4, pp. 11339–11342, 2019, doi: 10.35940/ijrte.d5408.118419.

[13] K. Bhuvaneswari, M. Visithra, and S. K. Deepa, “IoT based non-invasive approach for blood group detection using LED,” *Int. J. Eng. Res. Technol.*, vol. 9, no. 10, pp. 77–80, 2021, [Online]. Available: https://www.ijert.org/research/iot-based-non-invasive-approach-for-blood-

group-detection-using-led-IJERTCONV9IS10020.pdf

[14] A. Shah, A. Singh, and S. Akotiya, “Blood Group Detection and Mobile Monitoring System,” pp. 20–24, 2015.

[15] H. ATICI, H. E. KOÇER, and S. KADER, “Determination of Blood Group by Image Processing Using Digital Images,” *Bilecik Şeyh Edebali Üniversitesi Fen Bilim. Derg.*, vol. 7, no. 2, pp. 649–659, 2020, doi: 10.35193/bseufbd.646847.

[16] A. Malhotra, N. Chethana, D. . Nagapranitha, S. Anand, and S. B, “Automated Blood Group Determination using Image Processing Techniques with Integration of Raspberry Pi,” *J. Emerg. Technol. Innov. Res.*, vol. 8, no. 6, pp. 954–965, 2021.

[17] P. H. Sagar, “Blood Group Detection using Image Processing MATLAB,” *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 9, no. VI, pp. 5006–5013, 2021, doi: 10.22214/ijraset.2021.36059.

[18] B. Arnav, A. Aarthi, A. Shivam, A. Shivakumar, and A. A. Shankar, “IoT Based Health Monitoring System,” *AIP Conf. Proc.*, vol. 2742, no. 1, 2024, doi: 10.1063/5.0200490.

[19] A. Ahmed, A. A. Lukman, A. James, O. O. Mikail, B. U. Umar, and E. Samuel, “Human Vital Physiological Parameters Monitoring: A Wireless Body Area Technology Based Internet of Things,” *J. Teknol. dan Sist. Komput.*, vol. 6, no. 3, pp. 115–121, 2018, doi: 10.14710/jtsiskom.6.3.2018.115-121.

[20] A. González-Lorence, J. G. Ayala-Landeros, A. J. Amaya-Pérez, and G. G. Sánchez-Orduña, “Monitoring system of vital signs at distance and in real time through IoT Technology,” *J. Technol. Prototypes*, vol. 5, no. 16, pp. 21–32, 2019, doi: 10.35429/jtp.2019.16.5.21.32.

[21] S. M. Farhad, M. R. Minar, and S. Majumder, “Measurement of Vital Signs with Non-invasive and Wireless Sensing Technologies and Health Monitoring,” *J. Adv. Inf. Technol.*, pp. 187–193, 2017, doi: 10.12720/jait.8.3.187-193.

[22] H. I. Shahadi, M. K. Kadhim, N. M. Almeyali, and A. T. Hadi, “Design and Implementation of a Smart, Interactive and Portable System for Monitoring of Human Vital Signs,” *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 7, no. 1, p. 30, 2021, doi: 10.26555/jiteki.v7i1.20209.

[23] M. G. Ayoub, M. N. Farhan, and M. S. Jarjees, “Streaming in-patient BPM data to the cloud with a real-time monitoring system,” *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 6, pp. 3120–3125, 2019, doi: 10.12928/TELKOMNIKA.v17i6.13263.

[24] A. Singh, B. N. Naik, S. L. Soni, and G. D. Puri, “Real-Time Remote Surveillance of Doffing During COVID-19 Pandemic: Enhancing Safety of Health Care Workers,” *Anesth. Analg.*, vol. 131, no. 2, pp. E112–E113, 2020, doi: 10.1213/ANE.0000000000004940.

[25] P. Valsalan, T. A. B. Baomar, and A. H. O. Baabood, “IoT based health monitoring

system," *J. Crit. Rev.*, vol. 7, no. 4, pp. 739–743, 2020, doi: 10.31838/jcr.07.04.137.

[26] I. Khan *et al.*, "Healthcare monitoring system and transforming monitored data into real time clinical feedback based on IoT using raspberry Pi," *2019 2nd Int. Conf. Comput. Math. Eng. Technol. iCoMET 2019*, 2019, doi: 10.1109/ICOMET.2019.8673393.

APPENDIX

1. Utilized codes

```
#include <Wire.h>
#include "MAX30105.h"
#include <LiquidCrystal_I2C.h>

#include "heartRate.h"

MAX30105 particleSensor;

const byte RATE_SIZE = 4; // Increase this for more averaging. 4 is good.
byte rates[RATE_SIZE]; // Array of heart rates
byte rateSpot = 0;
long lastBeat = 0; // Time at which the last beat occurred

float beatsPerMinute;
int beatAvg;

const int OPT101_PIN = A0; // Analog pin connected to the OPT101 sensor

// Initialize the LCD with the I2C address 0x27 (change according to your LCD)
LiquidCrystal_I2C lcd(0x27, 16, 2);

void setup()
{
  // Initialize LCD
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("BLOOD GROUP");
  lcd.setCursor(0, 1);
  lcd.print("DETECTION");
  delay(8000);
```

```
  Serial.begin(115200);
  Serial.println("Initializing…");

  // Initialize sensor
  if (!particleSensor.begin(Wire, I2C_SPEED_FAST)) // Use default I2C port, 400kHz speed
  {
    Serial.println("MAX30105 was not found. Please check wiring/power. ");
    while (1);
  }
  Serial.println("Place your index finger on the sensor with steady pressure.");

  particleSensor.setup(); // Configure sensor with default settings
  particleSensor.setPulseAmplitudeRed(0x0A); // Turn Red LED to low to indicate sensor is
running
  particleSensor.setPulseAmplitudeGreen(0); // Turn off Green LED
}

void loop()
{
  long irValue = particleSensor.getIR();
  int lightIntensity = analogRead(OPT101_PIN); // Read light intensity from OPT101 sensor
  lightIntensity = map(lightIntensity, 0, 1024, 100, 1024);

  if (checkForBeat(irValue) == true)
  {
    // We sensed a beat!
    long delta = millis() - lastBeat;
    lastBeat = millis();

    beatsPerMinute = 60 / (delta / 1000.0);

    if (beatsPerMinute < 255 && beatsPerMinute > 20)
    {
```

```
    rates[rateSpot++] = (byte)beatsPerMinute; // Store this reading in the array
    rateSpot %= RATE_SIZE; // Wrap variable

    // Take average of readings
    beatAvg = 0;
    for (byte x = 0; x < RATE_SIZE; x++)
      beatAvg += rates[x];
    beatAvg /= RATE_SIZE;
  }
}

Serial.print("IR=");
Serial.print(irValue);
Serial.print(", BPM=");
Serial.print(beatsPerMinute);
Serial.print(", Avg BPM=");
Serial.print(beatAvg);

Serial.print(", Light Intensity=");
Serial.print(lightIntensity);

// Check if no finger detected
if (irValue < 50000)
{
  beatAvg = 0; // Set average BPM to 0
}

// Determine blood group based on light intensity
char bloodGroup = ' '; // Initialize blood group character

if (lightIntensity >= 137 && lightIntensity <= 158)
  bloodGroup = 'B';
else if (lightIntensity >= 125 && lightIntensity < 137)
  bloodGroup = 'AB';
```

```
  else if (lightIntensity >= 114 && lightIntensity <= 119)
    bloodGroup = 'O';
  else if (lightIntensity >= 160 && lightIntensity <= 180)
    bloodGroup = 'A';

  // Print to LCD every 2 seconds (adjust as needed)
  static unsigned long lastLCDUpdate = 0;
  if (millis() - lastLCDUpdate >= 2000) {
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("                ");
    lcd.setCursor(0, 0);
    lcd.print("BPM:");
    lcd.print(beatAvg);
    lcd.setCursor(0, 1);
     lcd.print("Blood Group:");
    lcd.print(bloodGroup);

    lastLCDUpdate = millis();
  }

  Serial.println();
}
```