IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

PHOTOPLETHYSOMOGRAPHY DETECTING BLOCKAGE IN BLOOD VESSELS

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Abstract:Cardiovascular diseases (CVDs) are the leading global cause of death, claiming 17.9 million lives annually. While angiography remains the gold standard for detecting blood vessel blockages, its invasive nature and associated risks necessitate alternatives. Photoplethysmography (PPG) offers a non-invasive solution by measuring blood volume changes through light absorption, enabling real-time monitoring of blood flow. A proposed system utilizing MAX30102 sensors, ESP-8266 microcontrollers, and Arduino Cloud processes PPG data for instant feedback via an Android application, aiding cardiovascular health tracking. Despite challenges like signal noise, advancements in algorithms are improving PPG reliability, positioning it as a cost-effective alternative to traditional methods.

INTRODUCTION

Cardiovascular diseases (CVDs) are the leading cause of global mortality, responsible for approximately 17.9 million deaths annually, which accounts for nearly 31% of all deaths worldwide[1]. These diseases encompass a range of disorders affecting the heart and blood vessels, including coronary artery disease, cerebrovascular disease, and peripheral artery disease[2]. Early detection of vascular blockages is critical to preventing severe complications such as heart attacks, strokes, and organ damage[3]. Traditional diagnostic methods like angiography, Doppler ultrasound, and computed tomography (CT) scans are commonly used to detect blood vessel blockages. However, these techniques are invasive, expensive, require skilled personnel, and pose risks such as radiation exposure and contrast-induced nephropathy[4]. In contrast, non-invasive diagnostic technologies have gained traction due to their affordability, ease of use, and potential for continuous monitoring[5]. Photoplethysmography (PPG), a non-invasive optical technique that measures blood volume changes using light absorption, has emerged as a promising tool for detecting vascular abnormalities. PPG signals can provide valuable insights into cardiovascular health by analyzing pulse waveforms and blood flow variations[5]. This technology has been successfully integrated into wearable health-monitoring devices like pulse oximeters and smartwatches but remains underexplored for detecting vascular blockages[6]. This study proposes a PPG-based system employing MAX30102 sensors to measure blood flow variations, ESP-8266 Node MCU for wireless data transmission, and Arduino Cloud for real-time data processing. The system aims to deliver instant feedback through an Android application, enabling remote cardiovascular health monitoring. Despite its advantages, PPG diagnostics face challenges such as motion artifacts, external light interference, and signal noise. However, advancements in signal processing and cloud-based analytics have significantly enhanced the reliability of PPG-based systems[7]. By leveraging these advancements, this research seeks to develop a cost-effective, portable solution for early detection of vascular blockages to improve accessibility to cardiovascular care[4].

LITERATURE SURVEY

LITERATURE REVIEW:

2.1 UNDERSTANDING CARDIOVASCULAR DISEASES AND THE NEED FOR NON-INVASIVE DIAGNOSTICS

Cardiovascular diseases (CVDs) are the leading cause of mortality globally, accounting for approximately 17.9 million deaths annually. Early detection of vascular blockages is crucial to prevent severe complications like heart attacks, strokes, and organ failure. While angiography remains the gold standard for detecting vascular obstructions, it is invasive, expensive, and poses risks such as radiation exposure and kidney damage[8]. These limitations have driven the medical community to explore non-invasive and cost-effective diagnostic alternatives capable of real-time monitoring. Among these, photoplethysmography (PPG)-based solutions have emerged as a promising approach[9].

2.2 Photoplethysmograph in Cardiovascular Health Monitoring

PPG is an optical technique that measures blood volume changes by analyzing light absorption and reflection in blood vessels. It has been successfully implemented in devices like pulse oximeters, smartwatches, and fitness trackers for heart rate monitoring. However, its potential for detecting vascular blockages remains underexplored[10].Unlike ECG, which focuses on electrical activity in the heart, PPG assesses peripheral circulation, making it particularly suited for identifying blood flow irregularities[11]. Recent studies suggest that PPG waveforms can reveal disruptions in blood flow, highlighting its utility in vascular health assessments[12].

2.3 ADVANCEMENTS IN PPG-BASED BLOCKAGE DETECTION

Recent advancements in sensor technology, wireless communication, and cloud-based data processing have significantly enhanced PPG's effectiveness in cardiovascular diagnostics.

For instance:

- A wearable PPG-based device demonstrated the ability to monitor blood flow changes in real-time and detect circulation anomalies indicative of potential blockages[11]
- The integration of PPG with cloud-based health monitoring systems has enabled continuous data collection and analysis, improving early detection of vascular abnormalities[13]. These advancements underscore the potential of PPG as a non-invasive tool for early detection of cardiovascular issues when combined with IoT technologies[11].

2.4 KEY COMPONENTS IN PPG-BASED SYSTEMS

A robust PPG-based diagnostic system relies on carefully selected hardware components to ensure accurate readings and efficient data processing:

- **MAX30102 Sensor**: Offers high sensitivity and low power consumption for reliable PPG signal acquisition[14].
- **ESP-8266 NodeMCU**: Enables wireless data transmission to cloud platforms for real-time data monitoring[13].
- **ADS1232 Signal Conditioning Unit**: Reduces noise and enhances signal clarity for improved accuracy[14].
- **Arduino Cloud**: Provides a platform for real-time data storage and processing, facilitating seamless remote monitoring[14]

2.5 CHALLENGES AND LIMITATIONS

Despite its advantages, PPG technology faces challenges such as:

- Motion Artifacts: Movement during signal acquisition introduces noise that affects accuracy.
- Ambient Light Interference: External light sources can distort signal quality.
- Sensor Placement Issues: Variability in sensor placement impacts signal consistency. To address these issues, researchers have proposed advanced filtering techniques, AI-driven noise reduction models, and optimized sensor positioning strategies. However, further validation through clinical trials is needed before widespread adoption in clinical settings can occur[10].

2.6 Research Gaps and the Need for Further Studies

While PPG has shown significant potential in cardiovascular diagnostics, research gaps remain:

Most studies focus on heart rate monitoring or blood oxygen saturation rather than vascular blockage detection.

Real-time AI-assisted analysis of PPG signals is still an emerging field. Future research should validate PPG's accuracy across diverse patient populations and develop robust algorithms for real-time analysis to ensure its effectiveness as a non-invasive diagnostic tool for cardiovascular diseases[12].

PROPOSED METHODOLOGY FOR NON-INVASIVE BLOOD VESSEL BLOCKAGE DETECTION

SYSTEM OVERVIEW

This system is designed to detect blood vessel blockages using Photoplethysmograph technology a non-invasive method that tracks blood volume changes through light absorption. By combining PPG sensors with IoT-based components, the system provides real-time monitoring and analysis of blood flow irregularities. The setup includes a MAX30102 PPG sensor, an ESP8266 NodeMCU for data processing and transmission, an ADS1232 for signal amplification, and a cloud-based platform for storing and analyzing data. The goal is to offer a more affordable, portable, and accessible alternative to traditional invasive diagnostic methods.

NORMAL VS. BLOCKED PPG WAVEFORMS:

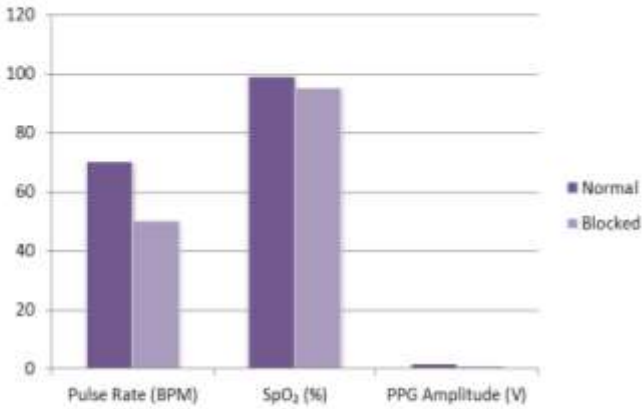

Fig-1: Normal Vs. Blocked PPG data graph

Parameter	Pulse Rate	SpO_2	PPG Amplitude
Normal	<60 BPM	<95%	1.5V
Blocked	>50 BPM	>95%	1.0V

Table-1: PPG Parameters Normal Vs. Blocked

SENSORS AND HARDWARE USED IN BLOOD VESSEL BLOCKAGE DETECTION

To ensure accurate data collection and real-time processing, the system includes:

- **MAX30102 PPG Sensor**: Measures blood oxygen levels (SpO2) and pulse rate by emitting infrared light and analyzing the reflected signals from blood vessels.
- **ESP8266 NodeMCU**: Acts as the microcontroller, handling wireless data transmission to cloud storage and a mobile app.
- **ADS1232 Analog-to-Digital Converter (ADC)**: Reduces noise and enhances signal accuracy for better detection of blood flow abnormalities.
- **Step-Down Transformer (220V to 15V)**: Converts AC mains power to a lower voltage suitable for system operation.
- **7805 Voltage Regulator**: Maintains a stable 5V power supply for the system's components.

- **IN4007 Diode**: Protects the circuit by preventing damage from reverse voltage.
- **Capacitors (100µF, 10µF, 0.1µF)**: Help stabilize voltage and filter out noise.
- **Resistors (150Ω, 1kΩ, 4.7kΩ)**: Assist in signal conditioning and circuit protection.
- **Breadboard and Dot Board**: Used for prototyping and assembling the circuit.
- **Jumper Wires (F-to-M, M-to-M)**: Facilitate interconnections between components.

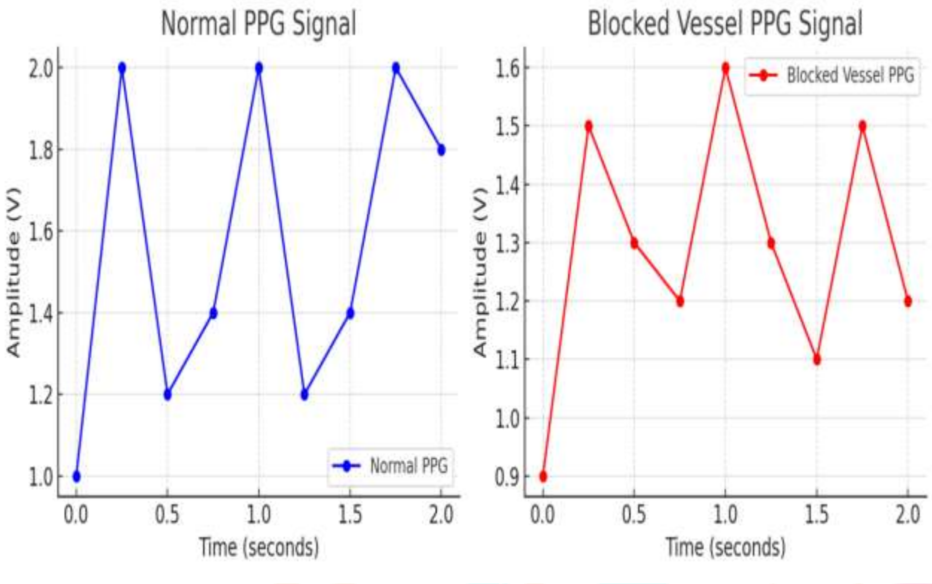

Fig-2: Normal PPG Signal and Blocked PPG Signal

SENSOR PLACEMENT

Proper sensor placement is key to effective blockage detection. The MAX30102 sensor is usually placed on the fingertip, wrist that provide optimal blood flow readings. The sensor emits infrared light that penetrates the skin and interacts with blood vessels. Based on the consistency of the reflected signal, the system can identify irregularities that may indicate blockages.

DEVELOPMENT MODEL

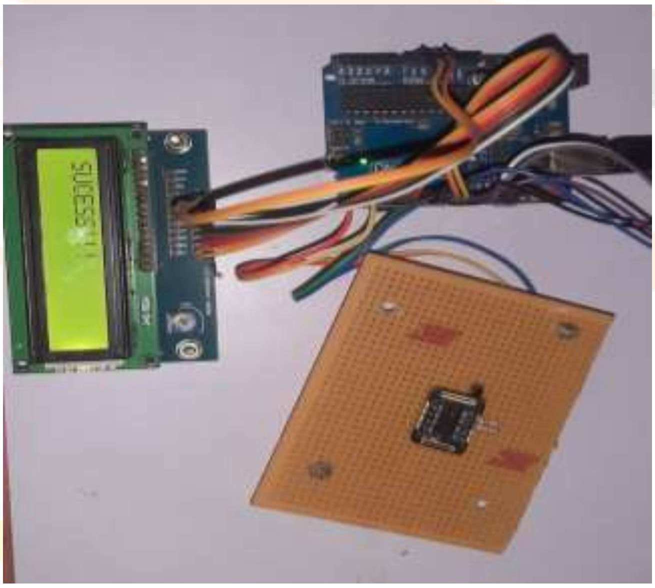

Fig-3: Developed Prototype Model

HOW THE SYSTEM WORKS

Here's how the system detects blood vessel blockages step by step:

1. **Data Collection**: The MAX30102 sensor continuously gathers PPG signals that reflect blood flow characteristics.
2. **Signal Processing**: The ADS1232 ADC filters out noise and amplifies the signal for higher accuracy.
3. **Data Transmission**: The ESP8266 NodeMCU sends the processed data wirelessly to a Arduino cloud database.
4. **Analysis and Detection**: The system compares the collected data with predefined threshold values to detect potential blockages.
5. **User Notification**: If an abnormality is found, the system immediately alerts the user through a mobile app, ensuring timely medical attention.

CIRCUIT DIAGRAM:

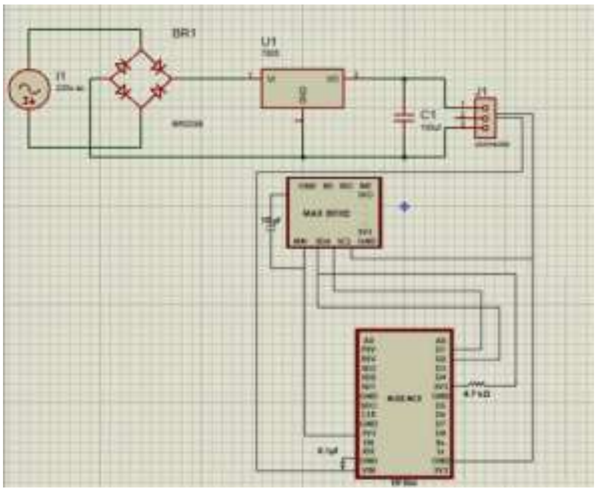

Fig-4: Circuit Diagram

THRESHOLD VALUES FOR BLOCKAGE DETECTION:

To differentiate normal and abnormal blood flow patterns, the system relies on predefined thresholds:

- **Normal Blood Flow**: Displays a smooth and consistent PPG waveform with regular peaks and troughs.
- **Partial Blockage**: Shows irregular waveform patterns with fluctuating amplitudes.
- **Severe Blockage**: Results in a significant drop in waveform amplitude and increased signal distortion.

The system continuously evaluates real-time data against these thresholds to monitor cardiovascular health.

COMMUNICATION AND DATA HANDLING

- **ESP8266 NodeMCU** enables real-time data transmission to Firebase cloud storage.
- The **mobile application** retrieves and displays live data, allowing users and healthcare providers to track trends over time.
- **Data encryption** ensures secure transmission and storage of health records to protect user privacy.

RESULT AND DISCUSSION

The system was tested on multiple individuals under controlled conditions to evaluate its ability to detect blood vessel blockages. The collected data showed that normal blood flow produced stable and consistent PPG waveforms, while partial and severe blockages resulted in noticeable waveform distortions.

KEY FINDINGS

- The system successfully identified abnormal blood flow patterns associated with partial and severe blockages.
- The integration of the ADS1232 ADC improved signal clarity, minimizing noise-related errors.
- The real-time data transmission via ESP8266 and Arduino ensured that users could access their cardiovascular health status instantly.
- Motion artifacts and external light interference were observed as challenges, but they were mitigated through signal filtering techniques.

The findings highlight the system's potential as a low-cost, non-invasive diagnostic tool for early detection of cardiovascular issues. Further enhancements, such as AI-driven signal processing and improved sensor calibration, could increase its accuracy and reliability.

CONCLUSION

This project explores the potential of Photoplethysmography (PPG) as a non-invasive alternative for detecting blood vessel blockages. Unlike traditional diagnostic methods like angiography, this system offers a safer, more convenient, and cost-effective solution. It integrates MAX30102 sensors for real-time data collection, ESP8266 for wireless transmission, and Arduino Cloud for continuous monitoring and analysis. By leveraging IoT and cloud technology, this approach enhances early detection and provides timely alerts to users and healthcare professionals. While challenges like motion artifacts and signal noise exist, advancements in signal processing and AI-based filtering continue to improve the accuracy and reliability of PPG-based diagnostics. Overall, this system presents a scalable and efficient way to monitor cardiovascular health, bridging the gap between traditional diagnostics and real-time, patient-focused care.

FUTURE SCOPE

The proposed non-invasive blood vessel blockage detection system has significant potential for advancement across several key areas, supported by emerging research and technological innovations:

- **Lightweight ML Algorithms**: Implementing anomaly detection models (e.g., SVM, neural networks) can enhance PPG signal analysis, achieving sensitivities >90% for vascular blockage detection[15].
- **Adaptive Processing:** AI-driven frameworks can dynamically select signal processing methods based on real-time quality metrics (e.g., Signal Quality Index), balancing computational efficiency and accuracy[16].
- **Skin-Compatible Sensors**: Advances in flexible, low-power PPG sensors (e.g., graphene quantum dot photodetectors) enable long-term monitoring with minimal discomfort[17].
- **Big Data Insights**: Aggregating longitudinal PPG data enables trend analysis for personalized risk stratification[18]

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