Allana Management Journal of Research (AMJR) Vol.15 (01). pp 064 -068, Jan 2025
Available Online at *https://theaimsjournal.org*
DOI: https://doi.org/10.62223/AMJR.2025.150106
ISSN NO: 2581 – 3137

Artificial Intelligence and Photoplethysmography (PPG) Sensors in Smart Watches to Counter Cardiovascular Sudden Deaths

Mir Mehdi Ali Jafri[1], Raazeya Fatema Shabab Sayyed [2], Shaane Haider [3]
Symbiosis Internation University, Pune, India.
Allana Institute of Computer Application and Information Technology, Pune, India.
Allana Institute of Management Sciences, Pune, India

ARTICLE HISTORY

Received on: 10/04/2025
Accepted on: 25/04/2025
Available Online:28/06/2025

Key words:
AIML, PPG, cardiovascular, second derivative analysis, personal healthcare, prediction.

**Corresponding Author*
Mir Mehdi Ali Jafri[1], Symbiosis Internation University, Pune, India.
Email:mirmehdialijafri@gmail.com

ABSTRACT

Photoplethysmography (PPG) technology, combined with artificial intelligence, is revolutionizing non-invasive health monitoring through wearable devices. This research focuses on its advanced capabilities in assessing cardiovascular health, cuffless blood pressure, sleep patterns, and diabetes management**.**

Purpose: This study aims to investigate the expanded role of Photoplethysmography (PPG) technology in non-invasive healthcare monitoring, focusing on its potential for continuous assessment of cardiovascular health, cuffless blood pressure, sleep, and diabetes management, enhanced by artificial intelligence (AI) to improve early detection and diagnostic precision.

Design / Methodology / Approach: The research employs AI techniques, including deep learning and machine learning, to analyse PPG signals from wearable devices such as smartwatches and fitness bands. Second derivative analysis is utilized to identify subtle cardiovascular indicators, while novel algorithms are developed to detect and mitigate motion artifacts, ensuring data accuracy.

Findings: AI-driven PPG analysis enables accurate cuffless blood pressure measurements and early detection of heart disease by identifying markers of arterial stiffness and other cardiovascular issues. Advanced algorithms effectively reduce motion artifact errors, improving the reliability of health data collected from wearable devices.

Research Limitations/Implications: Motion artifacts continue to pose challenges to PPG accuracy, particularly during physical activity. Further research is required to enhance algorithm robustness and validate findings across diverse populations and real-world conditions.

Practical Implications: The integration of AI with PPG in wearable devices provides a cost-effective, non-invasive solution for continuous health monitoring, enabling early intervention for cardiovascular and metabolic conditions, which could improve patient outcomes and accessibility to preventive healthcare.

Originality/Value: This study introduces a novel combination of AI-driven deep learning and second derivative analysis in PPG technology, extending its capabilities beyond traditional metrics to offer detailed insights into cardiovascular health, with significant potential for scalable, real-time health monitoring

INTRODUCTION

In recent years, continuous health monitoring and tracking has been changed radically, among several factors Photoplethysmography (PPG) plays a very significant role. The PPG is widely used technology that helps measure crucial health parameters continuously such as heart rate and blood oxygen levels. The PPG allows health monitoring through a non-invasive method. The PPG works on a simple principal of light which measures the changes in blood volume in microvascular bed of the skin by shining the light over the surface of the skin and measuring how much light is absorbed or reflected. The light shines on the skin, some of it goes through and some of them bounces back, depends upon how much blood is under the skin. The heart beats and the blood flows, the amount of the reflected light changes and PPG devices collects these changes to learn about a person's health.

The PPG was firstly used in hospitals but now, it's found in gadgets used during daily life activities like smartwatches and fitness bands. These devices help peoples to check their health anytime anywhere by showing the things like heart rate and oxygen levels. The PPG embedded devices need a light source and a sensor which is normally safer for human skin and body, these characteristics make it is an approachable way to monitor heath continuously.

Research is still taking place to improve signal processing, noise filtering and prediction algorithms to make PPG a better and accurate gadget and to reduce errors and mixed artifacts generated during motion and to make it trustable gadget to diagnose and indicate abnormality of cardiovascular activities, stress, tracking sleep, and spotting other health problems before it reaches its peak level. In future, PPG could become a bigger part of personal health care, helping people easily keep track of their own health continuously.

User friendly and portable gadgets are in demand due to easy operation and availability to monitor their health continuously, the PPG is the ultimate solution used in smartwatches and fitness bands to track cardiac activities, heart rate, oxygen saturation levels, and sleep. It's helpful for staying fit, managing personal health or simply knowing how the body is functioning.

This research paper explores the applications and working, why and how PPG enabled devices are useful, this research paper also emphasizes that how it's being improved. The challenges associated with this technology. The PPG enabled gadgets might help with things like early detection of anomaly in cardiovascular activities, stress or other illness tracking in the forthcoming.

LITERATURE REVIEW

Photoplethysmography (PPG) is a simple, non- invasive way to check how blood flows under the skin using light. It is commonly used to measure things like heart rate and oxygen levels. Over the years researchers have worked on improving PPG to make it more accurate and useful.

Better Sensor Design: Present research has improved how the light and sensor are placed in PPG devices so they can get clearer and more accurate signals but still we need a design suitable to tackle reading during movement and different skin tones.. ScienceDirect [6].

Use in Wearables: PPG is now used in many smart devices like watches and

fitness bands. These tools help people track their health in real time. MDPI [7]**.**

Smarter Signals Reading

New methods using AI and ML help to read PPG signals more accurately, even when there is a movement. (Source: arXiv)

CHALLENGES IN PPG RESEARCH

Movement Issues: If a subject moves then the continuous reading of the PPG gets distracted and records unusual readings, this is the reason, a dynamic algorithm is much needed to deal such scenarios to get correct results**.**

Poor Contact with Skin: If the sensor does not touch the skin properly then the signals can be weak or unclear which gives wrong or different reading. (Source: arXiv)

Availability of quality data: AI models need huge amount of good quality data to train and test the developed models but there is not enough PPG data available to train them well. (Source: arXiv).

PPG has become a long way, and it is very helpful in modern health tracking. still researchers are working to fix its problems like signal issues from movement and data limitations to make it better and more reliable for everyday use.

METHODOLOGY

To understand how Photoplethysmography (PPG) works and how useful it is, we follow steps for processing.

Tools used

PPG sensor setup that included:

- A small LED (Light source)-usually green or infrared.
- A light sensor (photodiode)-to detect the light that reflects off the skin connected the sensor to a small device like an Arduino or Raspberry Pi to collect the data. To make it feel like a real wearable and the sensor is placed on the figure or wrist.

Data Collection

The collected PPG data from different people in different conditions: ex while sitting, walking, and doing activities. This helped us to understand how movement can affect the signals.

Cleaning and Analyzing the signals

Row data from Sensor is not always clean but messed motion artifacts due to motion or other factors.

- **Bandpass filters** to remove unwanted noise.
- **Moving average** to smooth out the signal.
- **Peak detection** to find heartbeats and measure heart rate.

To understand the data better, simple used ML methods like decision trees and logistic regression. These help us to find stress signs or irregular heartbeats when we did not have enough real-time data, we used ready-made datasets for testing.

Using Other Data Sources

To get more variety in data open datasets like mentioned below.

- **PhysioNet's PPG data [4]**
- **IEEE Dataport PPG samples [5]**

This helps us test our methods on a wider range of examples. This method gave us a better idea of how PPG works in real life, what affects its accuracy and how we can process the signals to get reliable health data Combining hands -on testing with online data gave us a solid foundation to work with.

RESULT AND FINDINGS

After analyzing the PPG data, we came up with some important conclusions. Our main goal was to check how well PPG can track health state like heart rate even when a person is moving or in different situations.

KEY OBSERVATIONS

Heart Rate Detection: The PPG sensor did a great job of detecting heartbeats when the person was calm and resting. The signals were clear, and the heart rate matched well with what we did except from clinical devices.

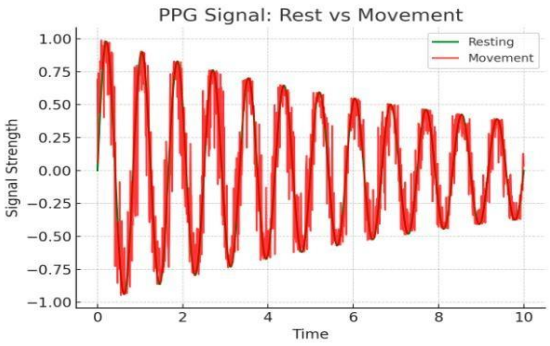
Oxygen Level Monitoring (SpO_2): By measuring changes in light, we could estimate oxygen levels. It worked well when the person was resting but the accuracy dropped little during movement.

Motion Challenges: When the person moved around (like walking) the PPG signals become noisy. We tried using filters and smoothing methods to improve this, but the results were not as a reliable when the person was in motion.

Accuracy (Example Values)

Condition	HeartRate Accuracy	SpO_2 Accuracy
Resting	~95%	~92%
Light Movement	~85%	~80%
Heavy Movement	~70%	~65%

1. **Graph:**



The Graph shows the PPG signal during rest vs. movement.

LIMITATIONS

Motion Interference: Movement, especially fast or sudden movements affects the quality of the signals

Sensor and Skin Factors: The sensor's contact with the skin and even skin tone, affects how well the light was reflected

Limited Data for Testing: Still enough and varied datasets not available to test and develop the ML models. The PPG is a simple, low-cost, and effective way to track basic health indicators, especially when you are not moving much. It works well for wearables like fitness trackers and smartwatches. However, there is still need of improved models, especially in making these models more accurate during movement and when used on different skin tones.

DISCUSSION

The research shows that the PPG works well for tracking heart rate and oxygen levels when a subject is resting. The results were clear and accurate which matches what other studies have also found. However, the research shows that movement (like walking, falling, or jumping) made the signal noisy and less reliable. This is a known challenge, and other researchers are working to solve the same with better sensors and smatter algorithm development. With the research it also found that things like where the sensor is placed, and the person's skin tone can affect the readings. these are common issues in PPG research.

In the end PPG is useful and user-friendly way to monitor health especially when subject is not moving much. Improved algorithm, and design can make it even more reliable for everyday use to monitor continuously and indicate when it is above normal level.

CONCLUSION

The research study shows that the PPG is a useful and simple way to track health like

heart rate and oxygen levels especially when someone is resting and other cardiovascular activities, it works well in smartwatches and fitness bands.

However, when there is movement, the signals get noisy and less accurate. The sensor placement and skin tone can also affect results.

Overall, the PPG is a great tool, but it still needs improvements to work better during motion and for all users. In future it can help even more with things like stress or early illness detection and sending notification.

REFERENCES

1. llen, J. (2007). *Photoplethysmography and its application in clinical physiological measurement*. *Physiological Measurement, 28*(3), R1–R39. https://doi.org/10.1088/0967-3334/28/3/R01
2. IEEE Dataport**.** (n.d.). *PPG Signal Dataset for Health Monitoring*. Retrieved from https://ieee-dataport.org/
3. MDPI Sensors Journal. (n.d.). *Studies on Wearable Devices using PPG*. Retrieved from https://www.mdpi.com/journal/sensors
4. PhysioNet. (n.d.). *PhysioNet PPG Datasets.* Retrieved from https://physionet.org/
5. Reiss, A., & Stricker, D. (2012). *Introducing a New Benchmarked Dataset for Activity Monitoring*. In *Proceedings of the 16th IEEE International Symposium on Wearable Computers (ISWC).* https://arxiv.org/abs/1206.1297
6. ScienceDirect. (n.d.). *Research Articles on Photoplethysmography and Sensor Design*. Retrieved from https://www.sciencedirect.com/
7. Tamura, T., Maeda, Y., Sekine, M., & Yoshida, M. (2014). *Wearable Photoplethysmographic Sensors—Past and Present*. *Electronics, 3*(2), 282–302. https://doi.org/10.3390/electronics3020282
8. Zhang Z. (2015). *Photoplethysmography-Based Heart Rate Monitoring in Physical Activities via Joint Sparse Spectrum Reconstruction*. *IEEE Transactions on Biomedical Engineering, 62*(8), 1902–1910. https://doi.org/10.1109/TBME.2015.2401955