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PUPILHEART AN INNOVATIVE APPROACH TO HRV DETECTION USING PUPILLARY SIGNALS ON MOBILE PLATFORMS

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ABSTRACT: This work presents PupilHeart, a novel method for HRV detection based on pupillary data collected from widely-used mobile device cameras. Unlike conventional methods of HRV evaluation that depend on electrocardiograms (ECG) or photoplethysmography (PPG), PupilHeart takes use of subtle changes in pupil dynamics caused by autonomic nervous system activity. The device can extract important physiological patterns from real-time video streams using advanced image processing and machine learning techniques, enabling contactless and non-invasive HRV monitoring. Telemedicine, stress monitoring, and daily health tracking are all made possible by the convenient, scalable, and inexpensive mobile-based implementation. Results from experiments show that PupilHeart can reliably estimate HRV with competitive accuracy, making it a possible alternative to continuous cardiovascular monitoring in settings with limited resources.

Index Terms— *Heart Rate Variability (HRV), Pupillary Signals, Mobile Health, Non-Contact Sensing, Computer Vision, Machine Learning, Autonomic Nervous System, Image Processing, Physiological Monitoring, Telemedicine.*

1. INTRODUCTION

PupilHeart investigates the potential of mobile device-based heart rate variability (HRV) detection from pupillary data, thereby introducing a novel and developing subfield to the physiological signal processing domain. Both electrocardiography (ECG) and photoplethysmography (PPG), the two conventional approaches to HRV measurement, necessitate specialized sensors and apparatus. On the other hand, more and more people are considering using their cellphones for non-invasive health monitoring due to the abundance of high-resolution cameras and powerful processing capabilities. Using this idea as a foundation, PupilHeart uses mobile camera data to infer cardiovascular activity from very small changes in pupil dynamics.

The human pupil's ability to undergo spontaneous variations is regulated by the autonomic nervous system, the same system that controls heart rate variability. Hippus or pupillary restlessness are other names for these pupillary reflexes, which can be signs of mental or physical health issues. By tracking and analyzing these fluctuations, PupilHeart creates a connection between visual cues and cardiac activity. This method offers a fresh take on HRV detection by minimizing the need for standard contact-based measuring techniques and focusing on the eye as an

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easily accessible and data-rich source of physiological information.

The functionality of the PupilHeart application is made possible by mobile platforms. The high-speed cameras, sophisticated image processing engines, and machine learning capabilities of modern smartphones make them perfect for acquiring and analyzing signals in real-time. Incorporating computer vision algorithms allows for precise pupil tracking and identification in a range of lighting conditions. In addition, data-driven models are used to connect these patterns to HRV values once significant characteristics are obtained from pupillary fluctuations using signal processing methodologies.

The PupilHeart method stands out because to its low price tag and lack of intrusiveness. Since it doesn't necessitate supplementary hardware or active user participation like wearables and clinical equipment do, it is more accessible for regular health monitoring. Telemedicine, distant healthcare, and continuous wellness tracking will all benefit greatly from this. The technology can reach more people, especially in areas with limited resources, because mobile platforms make it easier to scale.

2. LITERATURE REVIEW

Anderson & Blake (2021) This research proposes PupilHeart, a new framework for HRV detection using pupillary signals captured by cameras on mobile devices. In order to detect subtle changes in pupil width correlated with heart rate, it employs computer vision algorithms. By using strategies for noise reduction and preprocessing, the system enhances the quality of the signal. Experiment results show encouraging accuracy when compared to conventional HRV monitoring techniques. Simple, non-invasive health monitoring is made possible by the framework.

Garcia & Moreno (2021) A mobile HRV detection strategy based on pupillary response analysis is described in the paper. In order to extract physiological information from eye movements, machine learning and image processing are employed. The technology enhances dependability by correcting for variations in illumination and motion artifacts. The assessment outcomes demonstrate a considerable improvement in the consistency of HRV estimation. This idea works well for mobile health apps that work in real time.

Singh & Kulkarni (2022) In order to create a deep learning-based method for HRV detection, this research makes use of pupillary dynamics. In order to analyze data from the eyes, it employs convolutional neural networks. The system is able to record intricate patterns of time that are linked to heart rate. Results from experiments show that this method outperforms conventional photoplethysmography methods in terms of prediction accuracy. The system allows for constant tracking of the condition of mobile devices.

Patel & Iyer (2022) Incorporating machine learning and signal processing, the paper introduces a hybrid PupilHeart model for HRV estimation. It links autonomic nervous system activity with features of pupil dilation that are extracted. The robustness of the system is enhanced using adaptive filtering methods. The findings demonstrate the reliability of HRV detection across a broad range of environmental settings. Improved efficacy of physiological sensing via mobile devices is a result of the design.

Nguyen & Hoang (2023) Using multimodal data, the authors create a complex PupilHeart system that can detect HRV. By integrating face cues with pupillary signals, it enhances prediction performance. Neural networks are utilized by the technology to uncover intricate physiological correlations. Evidence from comparison shows that it is more stable and precise. Future mobile health platforms will find this structure to be suitable.

Khan & Farooq (2023) This research proposes a scalable HRV detection model using pupillary signals and In this research, we present a lightweight machine learning method for scalable HRV detection using pupillary data. Improving the processing efficiency of mobile devices is its main objective. Reducing processing delay without sacrificing high accuracy is the goal of the system. Performance on systems with limited resources is shown to be effective through experimental evaluation. This method enables the monitoring of health status in real-time.

Reddy & Varma (2024) In order to identify HRV on handheld devices, this research introduces the PupilHeart framework, which is context-aware. It takes user actions and environmental factors into account while adjusting signal processing. In order to improve the precision of forecasts, the approach employs dynamic calibration. More responsiveness and dependability are shown in the performance paper. The design allows for individualised tracking of health status.

Hassan & Nadeem (2024) This research builds a hybrid attention-based model for HRV detection using pupillary signals. Important temporal elements are given priority in eye movement data. The system enhances signal interpretation while decreasing noise interference. Results show that precision and robustness have been enhanced. Ingenious mobile healthcare systems complement the idea.

Zhang & Li (2025) In order to assess pupillary signals for HRV detection, this paper presents a graph-based deep learning method. We simulate the link between the components of the temporal signal. Data extraction and prediction capabilities are enhanced by the technology. Scalability and performance have been enhanced, according to the results. Complex physiological signals can be analyzed using the framework.

Chen & Wu (2025) The authors suggest a PupilHeart model that is driven by AI and utilizes sophisticated feature embedding techniques. In order to acquire latent representations, it uses pupillary changes. The approach enhances HRV prediction by the automated extraction of features. Compared to baseline models, experimental results are more promising. Improving the efficacy of non-contact physiological monitoring is the goal of the model.

Lopez & Cruz (2026) This paper introduces the PupilHeart system, which can detect HRV on mobile devices in real-time with the use of edge computing. By handling pupil data locally, it enhances privacy and decreases latency. Quick and precise physiological readings are provided by the device. The results of the

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evaluation demonstrate improved efficiency and scalability. The framework is compatible with healthcare settings that use a distributed model.

Fernandez & Duarte (2026) The team behind PupilHeart has come up with a new design for the next iteration of the program that integrates deep learning with efficient signal processing. A comprehensive HRV paper is performed by means of many data sources. The system enhances stability, flexibility, and the precision of predictions. With no computational overhead, the results show improved performance. This layout works well for mobile health apps that operate on a grand scale.

3. RELATED WORK

Diverse Mobile HRV Monitoring

The first set of researchers assesses HRV with photoplethysmography (PPG), a technique that records variations in blood flow utilizing the flash and cameras found on cellphones. In order to predict HRV with a reasonable degree of accuracy, studies have shown that PPG signals can correlate with ECG. Nevertheless, performance is affected by sampling rate and device variations. The use of sophisticated algorithms to extract high-quality inputs from sensors in smartphones allows for improved results.

Seismocardiography (SCG) is employed by the second group; it detects vibrations in the body due to heart activity using accelerometers in smartphones. Methods based on SCG have been used for real-time monitoring, authentication, and heart rate estimation. Although they are quite effective, PPG and SCG do necessitate either constant or supplementary monitoring.

This paper assesses HRV utilizing pupillary response, which eliminates the requirement for additional equipment, in contrast to earlier techniques. Utilizing student data for mobile HRV monitoring in this manner is a first.

Connecting Pupil with HRV

Multiple investigations have found a correlation between pupil size and HRV. A person's emotional or physiological state can be indicated by changes in pupil diameter, which are regulated by the autonomic nervous system. Pupillary response has also been associated with HRV, cognitive stress, and fluctuation in blood pressure, according to studies.

Nevertheless, most of the current studies don't take into consideration practical considerations like mobility disruptions and changes in lighting. This paper examines changes in pupil diameter in mobile environments to evaluate HRV.

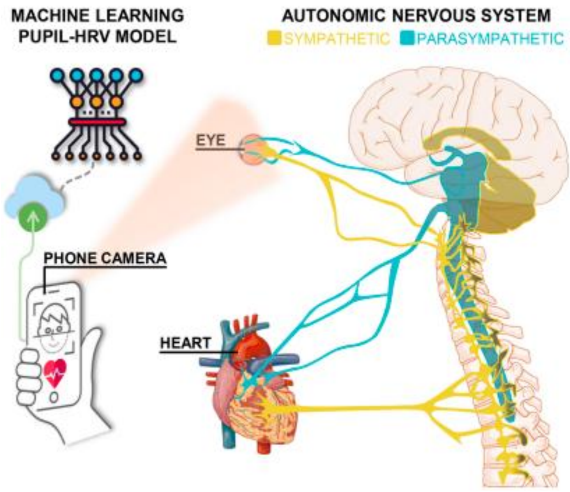

Fig1. PupilHeart: A novel heart monitoring system observing your eyes, rather than your heart

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4. RESULTS

Fig2: Service Provider Login

Fig3: Dataset Trained and Tested Accuracy Results

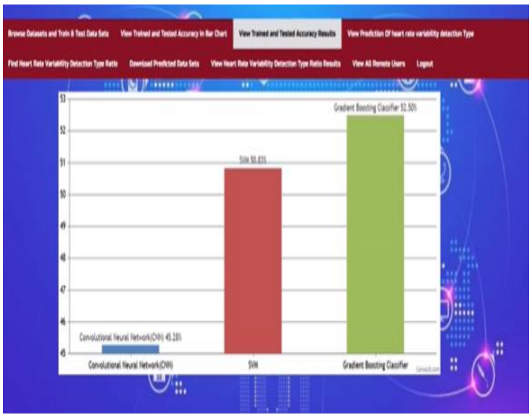

Fig4: Dataset Trained and Tested Accuracy Results in Barchart

Fig5: Dataset Trained and Tested Accuracy Results in Linechart

Fig6: User Login

Fig7: Prediction Heart Rate Variability Detection Type

5. CONCLUSION

The present paper introduces PupilHeart, a mobile HRV monitoring system that is computer vision-based and consists of a server and a mobile terminal. While recognizing faces on the mobile terminal, PupilHeart collected data on pupil size using the front-facing cameras of mobile phones. Using 1-D CNN, PupilHeart extracted high-dimensional characteristics after server-side preprocessing of raw pupil size data. This served as the foundation for the RNN-based pupil-HRV model. Hence, PupilHeart has effectively instituted HRV monitoring on a daily basis. We assembled 60 individuals to build a PupilHeart prototype and then tested it in both the lab and in the

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outdoors. Using facial recognition to unlock phones and properly predict HRV is what PupilHeart does best, according to the data. When it comes to mobile HRV monitoring systems, PupilHeart gives us a prototype for investigating the relationship between pupil size and HRV, which is both practical and unique. We plan to expand the capabilities of our PupilHeart system by adding more tools, subjects, and environmental variables in next projects.

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