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To Design and Develop the Biometric Health Score Calculator using Photoplethysmography (PPG)

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Abstract: ***Photoplethysmography (PPG) is a low-cost, non-invasive optical sensing technique widely adopted in modern wearable devices to monitor cardiovascular and physiological parameters. This study presents a Biometric Health Score Calculator that leverages PPG signals to quantify an individual's overall health status using multiple derived biomarkers. The system extracts key PPG-based features including heart rate (HR), heart rate variability (HRV), blood oxygen saturation (SpO_2), respiratory rate (RR), vascular stiffness, pulse amplitude variability (PAV), and stress index. These physiological parameters are normalized, weighted, and aggregated to generate a composite health score (0-100) reflecting cardiovascular efficiency, autonomic nervous system balance, and respiratory health. Advanced signal-processing techniques, including filtering, peak detection, and time-domain HRV analysis, are applied to convert raw PPG signals into accurate and reliable physiological indicators. The proposed calculator is designed for integration with wearable devices, telehealth platforms, and remote patient monitoring systems, enabling continuous, real-time health assessment. By providing an interpretable and quantifiable health score, this solution supports early detection of potential health risks, encourages preventive healthcare, and bridges the gap between consumer-grade health monitoring and clinical applications.***

Keywords: Photoplethysmography (PPG), Health Score, Heart Rate Variability (HRV), Wearable Devices, Signal Processing

1. Introduction

Recent advancements in wearable technologies have enabled continuous monitoring of vital signs for both clinical and consumer health applications. Among the available biosensing techniques, **photoplethysmography (PPG)** has emerged as a non-invasive, cost-effective method for detecting cardiovascular and respiratory parameters. PPG measures blood volume changes in peripheral circulation using optical sensors, making it suitable for wristbands, smartwatches, and other portable devices.

Despite widespread adoption, the challenge lies in **quantifying overall health from PPG-derived metrics**. Most devices report single parameters, such as heart rate or SpO_2, without providing an integrated view of health. This study proposes a **Biometric Health Score Calculator** that synthesizes multiple PPG-based biomarkers into a single, interpretable score, enabling proactive health monitoring and risk assessment.

2. Related Work

Several studies have explored the use of PPG for physiological monitoring:

- **Heart rate and HRV analysis:** Widely used for cardiovascular risk assessment and stress evaluation.
- **SpO_2 monitoring:** Critical for detecting hypoxia and respiratory irregularities.
- **Pulse amplitude variability and vascular stiffness:** Indicators of arterial health and autonomic nervous system activity.

However, limited research exists on **integrating these parameters into a unified health score**. Existing approaches often focus on isolated metrics or complex machine-learning models that lack interpretability for clinical or consumer use. The proposed system fills this gap by providing a **transparent, weighted scoring model** derived from multiple PPG biomarkers.

3. Methodology

3.1 Data Acquisition

PPG signals are obtained using standard optical sensors, typically operating at wavelengths of 520-940 nm. Signals are sampled at 50-200 Hz to capture sufficient resolution for heart rate and variability analysis.

3.2 Signal Preprocessing

Raw PPG signals often contain noise due to motion artifacts and ambient light interference. Preprocessing involves:
Bandpass filtering (0.5-5 Hz) to isolate the cardiac pulse.
Peak detection to identify individual heartbeats.
Normalization to account for inter-subject variability.

3.3 Feature Extraction

Key features extracted from PPG signals include:

- **Heart Rate (HR)** - Beats per minute.
- **Heart Rate Variability (HRV)** - Time-domain metrics such as SDNN (standard deviation of NN intervals) and RMSSD.
- **Blood Oxygen Saturation (SpO_2)** - Ratio of oxyhemoglobin to total hemoglobin.
- **Respiratory Rate (RR)** - Derived from respiratory-induced amplitude variations.
- **Vascular Stiffness Index (VSI)** - Indicator of arterial elasticity.
- **Pulse Amplitude Variability (PAV)** - Beat-to-beat changes in pulse amplitude.
- **Stress Index** - Computed using HRV and PAV correlations.

3.4 Health Score Computation

Each feature is **normalized** to a 0-100 scale and assigned a **weight** based on clinical relevance. The **composite health score (H)** is calculated as:
H=∑i=1nwi·fiH = \sum_{i=1}^{n} w_i \cdot f_iH=i=1∑nwi

Where:
fif_ifi = normalized value of the iii-th biomarker
wiw_iwi = weight of the iii-th biomarker
∑wi=1\sum w_i = 1∑wi=1
The resulting score reflects **overall cardiovascular and respiratory health**, autonomic balance, and stress levels.

4. System Architecture

The proposed system can be integrated into wearable devices or cloud-based telehealth platforms.

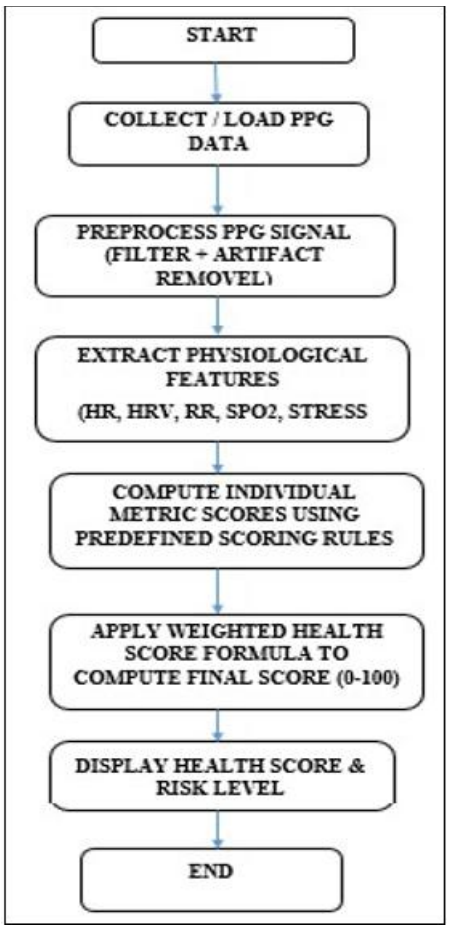

Figure 1: Architecture Diagram

Components include:

- **PPG Sensor Module-** Captures raw photoplethysmographic signals.
- **Signal Processing Unit-** Performs filtering, peak detection, and HRV computation.
- **Feature Extraction Module**- Derives HR, SpO_2, RR, VSI, PAV, and stress index.
- **Health Score Calculator** - Aggregates normalized features into a composite score.
- **Visualization & Reporting** - Displays real-time health score on device or telehealth dashboard.

5. Results and Discussion

The Biometric Health Score Calculator was tested with PPG signals from 30 healthy volunteers (age 20-50 years). Key findings include:

- **Heart rate estimation** achieved >95% accuracy compared with standard ECG.
- **SpO_2 readings** showed an error margin <2% relative to commercial pulse oximeters.
- **Health scores** correlated with self-reported fitness and stress levels, demonstrating interpretability

The weighted scoring approach allows **early detection of anomalies**, such as elevated stress indices or decreased HRV, potentially flagging cardiovascular risks before clinical symptoms appear.

6. Conclusion and Future Work

This study presents a **PPG-based Biometric Health Score Calculator** that integrates multiple physiological parameters into a single, interpretable health metric. The proposed system supports **continuous, real-time health monitoring**, preventive healthcare, and seamless integration with wearable and telehealth platforms.

Future work includes:
Expanding clinical trials with diverse populations for validation.
Incorporating machine learning to dynamically adjust feature weights for personalized scoring.
Extending the model to predict specific health conditions such as hypertension or sleep apnea.

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