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Low-Cost Ear-Wearable Physiological Monitoring System for Stroke-Risk Pattern Detection Using CNN-LSTM Anomaly Analysis

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Abstract

Stroke is a leading cause of mortality and long-term neurological disability worldwide, caused by the sudden interruption of blood flow to the brain due to ischemic or hemorrhagic events. Early detection is critical, yet most strokes are diagnosed only after substantial neurological damage has occurred. Subtle physiological changes, including fluctuations in heart rate, oxygen saturation, and peripheral temperature (Sayed and El-Gohary 2019), may appear before overt clinical symptoms, emphasizing the importance of wearable technologies capable of providing non-invasive, real-time measurements. This study presents a low-cost ear-worn multimodal physiological monitoring system integrated with a CNN–LSTM anomaly detection model for continuous analysis of cardiovascular and thermoregulatory dynamics. The proposed system combines photoplethysmography (PPG) and infrared temperature sensing to monitor heart rate (HR), heart rate variability (HRV), blood oxygen saturation (SpO_2), ear temperature, pulse transit time (PTT), pulse arrival time (PAT), and waveform morphology features. An ESP32 microcontroller collects and transmits physiological data via Bluetooth Low Energy, while deep learning models process synchronized multimodal signals using temporal sliding windows. Across 8 participants and 96 repeated trials, the system achieved 97% anomaly detection accuracy, 95% sensitivity, 96% specificity, and an AUC of 0.98. Results demonstrate that ear-based multimodal sensing combined with temporal deep learning provides a strong research-grade foundation for continuous physiological monitoring and analysis of physiological instability associated with cerebrovascular dysfunction. While it doesn't clinically diagnose stroke, the monitored biomarkers are strongly linked to vascular stiffness, autonomic regulation, and cerebrovascular health, supporting its use as an early physiological risk-monitoring platform.

Keywords

Wearable Biosensors; Photoplethysmography; CNN–LSTM; Stroke Risk Monitoring; Physiological Signal Processing

Biography

Pritika Ganguly is a high school researcher focused on wearable physiological monitoring systems, biomedical signal processing, and AI-driven anomaly detection. Her work integrates multimodal biosignal acquisition, embedded systems, and deep learning architectures for continuous physiological monitoring applications. Her research interests include wearable biosensors, biomedical engineering, physiological signal analysis, and machine learning for healthcare technologies.