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Intelligent Biosignal Processing Architectures for Remote Health Monitoring and Automated Diagnostic Support

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Abstract

The evolution of smart biosignal processing systems has redefined the landscape of remote health monitoring and diagnostic intelligence, fostering a seamless convergence of biomedical engineering, artificial intelligence, and Internet of Things (IoT) technologies. The continuous acquisition and intelligent interpretation of physiological signals such as ECG, EEG, EMG, and PPG enable real-time assessment of patient health states, supporting proactive medical decision-making beyond traditional clinical environments. The integration of wearable and implantable biosensors, energy-efficient signal acquisition architectures, and edge–cloud hybrid frameworks enhances both scalability and responsiveness, allowing uninterrupted monitoring across diverse healthcare contexts. Advanced computational techniques, including deep learning and federated analytics, empower predictive diagnostics by extracting high-value features from complex, multidimensional biosignals while maintaining stringent privacy and security standards. This chapter provides a comprehensive examination of the theoretical, computational, and architectural foundations of smart biosignal processing systems. It explores signal preprocessing and artifact removal strategies, feature extraction and dimensionality reduction methodologies, and machine learning–driven analytics that transform raw biomedical data into clinically actionable insights. The chapter also emphasizes the significance of interoperability standards, ethical governance, and cybersecurity mechanisms in ensuring data integrity, reliability, and trust in remote diagnostic ecosystems. By bridging engineering innovation with biomedical relevance, the discussion underscores how intelligent biosignal frameworks are shaping the next generation of personalized and precision-driven healthcare systems. The insights presented aim to support the development of adaptive, secure, and ethically aligned diagnostic infrastructures capable of delivering continuous, real-time healthcare monitoring in an increasingly connected digital world.

Keywords: Smart biosignal processing, Remote health monitoring, Artificial intelligence, Wearable biosensors, Edge–cloud architecture, Federated learning

Introduction

The rapid digital transformation of healthcare has led to the emergence of smart biosignal processing systems that integrate sensing technologies, artificial intelligence, and data-driven analytics to revolutionize patient monitoring and diagnostics [1]. These systems enable continuous observation of physiological functions through wearable, implantable, and ambient sensors that capture real-time biological signals such as electrocardiograms (ECG), electroencephalograms (EEG), electromyograms (EMG), and photoplethysmograms (PPG) [2]. The fusion of biomedical signal processing with intelligent computational models allows clinicians to derive meaningful insights from complex physiological patterns, enabling early diagnosis and preventive healthcare [3]. Traditional hospital-centric monitoring models are gradually being replaced by decentralized and intelligent systems capable of supporting patients across homes, workplaces, and remote environments [4]. The goal of this technological shift is to create an adaptive, responsive, and efficient healthcare ecosystem where biosignals serve as a continuous link between patients and medical expertise [5].

The evolution of biosignal processing technologies has been driven by advances in sensor miniaturization, wireless communication, and computational intelligence [6]. High-resolution, low-power biosensors are capable of detecting subtle physiological changes that were once difficult to observe outside of clinical settings [7]. The integration of Internet of Things (IoT) infrastructure enables these sensors to transmit data securely to cloud and edge computing platforms, where artificial intelligence algorithms perform real-time analysis and predictive modeling [8]. This capability allows for timely alerts, remote diagnostics, and personalized healthcare recommendations based on individual physiological profiles [9]. The growing adoption of such systems across cardiology, neurology, and rehabilitation medicine highlights their potential to bridge gaps between medical accessibility and technological innovation, ensuring continuous and data-informed healthcare delivery [10].