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IoT and ML Frameworks for Stroke Detection and Real-Time Patient Monitoring

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Abstract

Stroke was one of the leading causes of mortality and long-term disability worldwide, emphasizing the need for early detection and continuous patient monitoring. Recent advancements in Internet of Things (IoT) technologies and Machine Learning (ML) frameworks have enabled the development of intelligent, real-time monitoring systems capable of detecting subtle physiological and behavioral changes indicative of stroke events. This chapter presents a comprehensive overview of IoT-enabled wearable devices, non-invasive sensors, and multimodal data acquisition techniques for continuous monitoring of cardiovascular, neurological, and motion-related parameters. Emphasis was placed on ML-based predictive models, including deep learning and ensemble approaches, which analyze complex time-series data to provide accurate stroke risk assessment and timely alerts. The integration of edge and cloud computing architectures ensures low-latency analytics, scalability, and reliable performance, while explainable AI methods facilitate clinical interpretability and trust. Security, privacy, and regulatory considerations are addressed to safeguard sensitive health data in connected healthcare ecosystems. The chapter concludes by highlighting research gaps, challenges, and future directions for developing scalable, robust, and patient-centric stroke monitoring systems.

Keywords: Stroke Detection, Internet of Things (IoT), Machine Learning, Real-Time Monitoring, Explainable AI, Wearable Sensors

Introduction

Stroke remains one of the leading causes of mortality and long-term disability worldwide, with an escalating prevalence due to aging populations and the rise of comorbidities such as hypertension, diabetes, and cardiovascular disorders [1]. Early detection and continuous monitoring are critical for improving patient outcomes, reducing neurological impairments, and enabling timely clinical interventions [2]. Traditional diagnostic methods, including magnetic resonance imaging (MRI), computed tomography (CT), and periodic clinical assessments, are limited by their episodic nature, cost, and accessibility [3]. These approaches often fail to detect transient physiological changes that precede stroke events, leaving high-risk patients vulnerable to delayed treatment. Consequently, there was an urgent need for intelligent, real-time monitoring systems capable of continuous surveillance in hospital, home, and remote settings [4]. Recent technological advances in the Internet of Things (IoT) and Machine Learning (ML) offer a promising solution, enabling seamless acquisition, analysis, and interpretation of multimodal physiological and behavioral data for proactive stroke management [5].

IoT-enabled wearable devices and ambient monitoring sensors form the cornerstone of contemporary patient monitoring frameworks [6]. These devices capture high-resolution data streams, including electrocardiogram (ECG) signals, electroencephalogram (EEG) activity, blood pressure, oxygen saturation, and motion-related parameters such as gait and posture [7]. The integration of multiple heterogeneous sensors allows the detection of subtle deviations in physiological patterns that may indicate imminent stroke risk [8]. Wearable sensors, coupled with wireless communication protocols such as Bluetooth, Zigbee, or low-power wide-area networks (LPWAN), facilitate continuous, non-invasive monitoring without restricting patient mobility [9]. Data acquisition strategies focus on high-fidelity signal capture, precise synchronization across devices, and minimization of artifacts caused by motion or environmental interference. Preprocessing pipelines, including noise filtering, baseline correction, feature extraction, and dimensionality reduction, ensure that the collected data was suitable for real-time analysis, enhancing predictive accuracy and system reliability [10].

Machine Learning algorithms play a pivotal role in transforming raw physiological and behavioral signals into actionable clinical insights [11]. Supervised, unsupervised, and deep learning models are employed to identify complex temporal and spatial patterns indicative of stroke risk [12]. Deep neural networks, including convolutional and recurrent architectures, excel in modeling high-dimensional and sequential data, whereas ensemble and hybrid approaches enhance robustness and minimize false positives [13]. Feature selection and importance ranking further optimize model performance while reducing computational load for real-time deployment [14]. Explainable Artificial Intelligence (XAI) methods provide transparency, allowing clinicians to interpret model predictions, understand contributing risk factors, and make informed decisions. The integration of predictive analytics with continuous monitoring enables timely alerts, supports personalized interventions, and shifts the paradigm from reactive to proactive stroke management [15].