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AUTONOMOUS ASSISTIVE EXOSKELETON CONTROL SYSTEM INTEGRATING EEG/EMG INTENT DECODING

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Abstract. Mobility impairments caused by spinal cord injuries, stroke, and degenerative disorders limit independence for millions worldwide. This study presents a low-cost lower-limb exoskeleton that decodes user intention in real time using electroencephalographic (EEG) and electromyographic (EMG) signals. The system employs a PIC16F877A microcontroller executing adaptive impedance control and gait-phase recognition, with a Kalman filter combining inertial, torque, and bio-signal inputs to generate smooth hip–knee trajectories. Bench-top and hardware-in-the-loop simulations classified four locomotor commands – stand, sit, walk, stop – with 96 % accuracy and a maximum 85 ms latency. The lightweight 3.8 kg aluminium–carbon frame, powered by back-drivable BLDC motors, reproduced natural hip excursions of 15–35° at 1.2 s cadence. The results validate the feasibility of embedding edge AI for assistive gait restoration in resource-constrained clinical contexts.

Keywords: exoskeleton, EEG, EMG, intent recognition, adaptive control, rehabilitation.

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Introduction. Conventional mobility aids such as orthoses and wheelchairs fail to reproduce the energy-efficient gait needed for full ambulation. Recent progress in wearable robotics and brain–computer interfaces enables motor-intention decoding directly from biosignals. However, most commercial systems rely on gel-based electrodes and GPU-class processors, increasing cost and complexity (Kim et al., 2023; Wang et al., 2024). This work develops a dry-electrode EEG/EMG fusion control running entirely on an 8-bit microcontroller. The design targets affordability, portability, and clinical readiness through integration of lightweight materials, modular sensors, and efficient learning algorithms.

Materials and Methods. The exoskeleton frame combines 7075-T6 aluminium for load-bearing links and carbon-fibre composite for spinal and distal braces, achieving strength above 550 MPa at one-third the density of steel. Ti-6Al-4V fasteners ensure fatigue resistance, while neoprene–EVA liners improve comfort and reduce vibration noise on EMG leads. The full hip-to-ankle assembly weighs < 4 kg and delivers > 2 Nm/kg peak knee torque. EEG signals are captured using gold-plated dry pins on flexible polyimide, while EMG uses Ag/AgCl hydrogel electrodes on thigh and calf regions. Both channels feed a low-noise ADS1299 analog front-end digitized at 250 Hz. A Kalman filter fuses EEG, EMG, and inertial signals; extracted features are processed by a two-layer LSTM to infer locomotor intent every 50 ms. The PIC16F877A executes PID loops for dual Maxon EC-90 BLDC motors via DRV8353 drivers, generating compliant joint motion. A 78 kg volunteer performed sit-stand and walk sequences on a fixed-support rig. Firmware and MATLAB hardware-in-loop simulations evaluated command accuracy and latency.

Results and Discussion. The LSTM converged within 100 epochs, achieving 0.17° RMSE in hip-angle prediction. Synthetic gait trials produced 12 correctly identified heel-strike events in 10 s, with hip velocity $\pm 150\ ^\circ\ s^{-1}$ and acceleration $\leq 1500\ ^\circ\ s^{-2}$. EMG envelope thresholds reliably toggled between locomotor states. The Kalman filter reduced sensor noise by ~80 %, producing stable velocity and angle profiles. The prototype confirmed that dry EEG/EMG sensors paired with microcontroller-level inference can achieve millisecond-scale responsiveness, previously attainable only with GPU systems. The hybrid aluminium–carbon frame ensures back-drivable comfort while retaining mechanical integrity. Remaining limitations include limited user trials and short-duration testing; long-term reliability under sweat and electrode drift requires further study.

Conclusion. The developed system successfully demonstrates a lightweight, low-cost exoskeleton capable of translating EEG/EMG-derived intent into smooth lower-limb motion. The fusion of dry bio signals, Kalman-LSTM control, and back-drivable actuation achieved high accuracy and minimal delay on compact hardware. These results highlight a viable path toward affordable assistive exoskeletons suitable for rehabilitation and daily-living mobility support. Continued research will focus on real-world gait trials and energy optimization.

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HEALTHCARE 4.0 TECHNOLOGIES FOR PATIENT TRANSFER IN OPERATING THEATRES: A SYSTEMATIC REVIEW

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Abstract. Safe patient transfer in operating theatres is vital yet often neglected, exposing healthcare workers to musculoskeletal injuries and patients to avoidable risks. Healthcare 4.0 combining Artificial Intelligence (AI), Internet of Medical Things (IoMT), robotics, and cloud computing offers solutions for safer and more efficient workflows. This systematic review of 32 studies (2019–2023) found that AI predicts complications, robotics reduce caregiver strain by up to 40 %, IoMT supports continuous monitoring, and cloud platforms streamline operations. However, in low- and middle-income countries such as Zimbabwe, adoption is hindered by cost, infrastructure, and skills gaps, requiring phased, low-cost digital integration.

Keywords: Healthcare, Health 4.0, patient transfer, AI, robotics.

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Introduction. Patient transfer in operating theatres is a critical element of perioperative safety, yet it continues to rely heavily on manual handling methods. The World Health Organization (2021) reports that nearly 40 % of nurses experience chronic back pain from patient transfer activities, contributing to absenteeism and reduced productivity. Traditional aids like slide sheets and hoists partially mitigate physical strain but fail to enhance workflow efficiency or address real-time risk factors. Healthcare 4.0 technologies–AI, IoMT, robotics, and cloud computing–are increasingly deployed to bridge these gaps by enabling data-driven, automated, and adaptive patient transfer systems. In high-income settings, robotic-assisted transfer systems have reduced nurse strain by up to 40 % (Kim et al., 2024), but LMICs such as Zimbabwe face infrastructural and financial limitations.

Background and Conceptual Framework. Healthcare 4.0 represents the evolution from earlier healthcare generations: digitisation (Healthcare 2.0) and telemedicine (Healthcare 3.0) to fully integrated, data-intelligent systems (Healthcare 4.0). Drawing from Industry 4.0, it incorporates cyber-physical systems, IoMT, AI, and cloud computing for seamless connectivity, automation, and analytics (Li et al., 2017; Mwanza et al., 2023). AI enhances predictive monitoring, detecting early signs of patient distress or mechanical malfunction, while robotics reduce the need for physical lifting (Lin et al., 2021). IoMT networks integrate wearables and smart sensors to collect continuous data, enabling cloud-based decision support (Taylor et al., 2023). Together, these innovations promote precision, safety, and efficiency in perioperative workflows.

However, in LMICs, widespread deployment faces systemic barriers–limited broadband connectivity, unstable power supply, and cost constraints (Muchiri, 2022). Context-appropriate approaches, such as low-cost IoMT devices and semi-automated transfer mechanisms fabricated from locally available materials, have shown promise (Richarz et al., 2023). These frugal innovations emphasize adaptability, affordability, and scalability as foundational principles for healthcare digital transformation in developing contexts.

Methodology. This review followed PRISMA guidelines (Moher et al., 2010). Databases searched included Scopus, PubMed, Web of Science, IEEE Xplore, and ScienceDirect for the years 2019–2023. Keywords included “Healthcare 4.0”, “patient transfer”, “AI”, “robotics”, “IoMT”, and “cloud computing.” A total of 243 records were retrieved, 48 duplicates removed, and 195 screened. Following full-text review, 32 studies met inclusion criteria: peer-