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Development of a Low-Cost Smart Medical Bed with mmWave Radar-Based Non-Contact Monitoring and Bilingual Voice Control System

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The growing global elderly population and rising incidence of mobility-limiting injuries have significantly increased the number of bedridden patients requiring long-term care. Caring for these individuals in hospitals and home settings imposes substantial physical and emotional burdens on caregivers, while commercially available smart medical beds remain prohibitively expensive and inaccessible in resource-limited environments. This study presents a low-cost smart medical bed that integrates millimeter-wave (mmWave) radar-based non-contact vital signs monitoring with bilingual (Sinhala and English) voice-activated bed control to enhance patient autonomy and safety.

The system employs a 60 GHz mmWave radar sensor for continuous, non-invasive monitoring of heart rate and respiratory rate, eliminating the need for attached physiological sensors. An ESP32-based voice control unit, connected to a cloud speech recognition service, enables patients to adjust bed positions via Sinhala and English voice commands, while a Raspberry Pi manages radar signal processing, data logging, and communication with a mobile application that displays real-time and historical vital signs. Experimental validation under controlled conditions demonstrated 95% accuracy in heart rate and respiratory rate compared with a medical-grade pulse oximeter at a 1.5 m sensing distance, with minimal body movement. Voice command recognition achieved 95% accuracy for English (38/40 successful commands) and 80% accuracy for Sinhala (32/40 successful commands). The complete system was implemented at a cost below LKR 70,000, offering over 90% cost reduction compared with typical smart medical beds. The proposed solution, therefore, provides a cost-effective, technically robust assistive bed platform suitable for home care and rural healthcare settings, with the potential to reduce caregiver workload and improve continuous monitoring of bedridden patients.

Keywords: mmWave radar sensing, Non-contact vital signs monitoring, Bilingual voice recognition, Smart medical bed, Low-cost healthcare technology