

Edge-Native Privacy-Preserving Fall Detection System Using Optimized Skeleton-Based Pose Estimation on NVIDIA Jetson

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Abstract

The rapid growth of the global aging population has escalated the need for reliable, proactive healthcare monitoring. Falls represent a leading cause of fatal and non-fatal injuries among older adults, necessitating systems capable of immediate detection and alert. However, traditional vision-based monitoring systems raise severe privacy concerns and heavily rely on cloud computing, introducing critical latency, bandwidth constraints, and security vulnerabilities. To address these challenges, this paper proposes an edge-native, privacy-preserving fall detection framework deployed on the NVIDIA Jetson platform.

Our approach utilizes a lightweight skeleton-based human pose estimation model (leveraging YOLOv8-Pose) to extract spatiotemporal joint coordinates. By processing structural motion data rather than raw RGB video streams, the system inherently protects user anonymity. To meet the stringent computational limits of edge devices and achieve real-time inference, the model is optimized using TensorRT quantization techniques. Furthermore, the proposed framework incorporates an advanced spatiotemporal logic designed to handle real-world complexities, specifically addressing the research gap of partial occlusions in cluttered indoor environments.

Experimental evaluations on standard public datasets demonstrate that the proposed system achieves high detection accuracy and robustness while maintaining a processing speed suitable for real-time applications with minimal power consumption. Ultimately, this human-centric IoT solution bridges the gap between advanced artificial intelligence and practical healthcare applications, providing a secure, scalable, and life-saving technology that supports independent living for the elderly.

Keyword: Fall Detection, Edge Computing, Privacy-Preserving, Human Pose Estimation, NVIDIA Jetson, TensorRT, Skeleton-based Action Recognition.