Intelligent Video Surveillance System For Alzheimer's Patients

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Abstract

Alzheimer's disease gradually affects a person's memory and sense of direction, often leading to dangerous situations like falls or wandering into unsafe areas. To help keep patients safe, this paper introduces a smart video surveillance system specially designed to monitor individuals with Alzheimer's. Using advanced computer vision powered by deep learning, the system watches live CCTV footage to detect when a person falls or crosses into restricted areas. When unusual things happens, it immediately sends alerts to caregivers, so they can step in quickly. Behind the scenes, deep neural networks help the system recognize actions and monitor boundaries with high accuracy and very few false alarms. Tests have shown that this system works reliably in real-time, making it a promising solution for improving the safety and care of Alzheimer's patients at home or in medical facilities.

Keywords

Alzheimer's Patient Monitoring, Deep Learning, Fall Detection, Boundary Crossing, Real-time Alert System.

1. Introduction

Alzheimer's disease, a prevalent neurodegenerative disorder, affects millions of individuals worldwide, primarily impairing memory, orientation, and decision-making abilities. As the disease progresses, patients often become prone to hazardous incidents such as falling or unintentionally wandering beyond safe environments. These events not only pose significant risks to their physical well-being but also impose substantial emotional and logistical burdens on caregivers. Conventional monitoring methods, such as manual supervision or wearable sensors, are often insufficient due to their limited coverage, dependency on user compliance, or intrusiveness.

This paper proposes an intelligent video surveillance system specifically designed to monitor Alzheimer's patients and assist caregivers by detecting critical events such as falls and unauthorized boundary crossings. The system employs deep learning-based models to analyze live video streams and generate real-time alerts upon detecting abnormal activities. Unlike conventional surveillance solutions, the proposed system is proactive, context-aware, and tailored for the unique behavioral patterns of individuals with cognitive impairments.

The main Features include: A real-time fall detection module using deep learning to identify sudden or abnormal posture transitions. A boundary crossing detection mechanism that tracks patient movement relative to predefined safe zones. An automated alert generation system that ensures caregivers are promptly notified during emergencies.

2. Literature Review

Azatbekuly et al, a YOLOv8-based intelligent surveillance system was developed for office environments. The system featured real-time modules such as face recognition, boundary crossing detection, and occupancy monitoring. The researchers highlighted the importance of balancing detection accuracy and processing speed, especially for real-time IP camera feeds. Their approach demonstrates the feasibility of deploying deep neural networks such as YOLOv8 Nano for efficient surveillance in constrained environments. [1]

Huang and Liu conducted an in-depth study of intelligent video surveillance systems, highlighting their advantages over traditional surveillance, such as real-time abnormal behavior detection and automated response generation. Their system incorporated CNN-LSTM architectures for behavior analysis, enabling efficient threat recognition in public, commercial, and home security environments. [2]

Zhang proposed a smart campus management system integrating a full-time video surveillance platform. The system employed low-light image enhancement and advanced pedestrian detection algorithms, ensuring accurate tracking even under challenging conditions. Their system's adaptability and reliability demonstrate its effectiveness for large-scale environments such as educational institutions. [3]

Sharma and Kanwal proposed a two-phase AI surveillance framework that detects both video forgery and violent anomalies in real-time footage. Using models like VGG16 and optical flow techniques, their method provides enhanced detection of suspicious activities and ensures the integrity of surveillance data. [4]

Jiang and Wang explored the optimization of real-time streaming media for surveillance systems. By implementing dynamic routing and adaptive bitrate control, they addressed common challenges in video transmission over unstable networks. Their work emphasized the importance of low-latency, high-reliability video feeds, especially in safety-critical systems. [5]

Sathish et al. developed a real-time live streaming and recording assistance system integrating object detection, tracking, and audio recognition. Though focused more on media and event applications, the system showcases the versatility of DL in simultaneously processing multiple data modalities. [6]

Liu et al. designed a facial recognition system for power grid surveillance using DL algorithms. Their work integrates facial detection, alignment, and recognition under poor lighting conditions using TensorFlow, achieving 95.9% accuracy. They addressed challenges like false alarms and image instability by proposing a robust, scalable architecture optimized for power grid environments. [7]

Ilić et al. proposed a large-scale AI and computer vision-based surveillance framework suitable for railway stations. Leveraging YOLOv8 and difference detection algorithms, their system supports over 1000 cameras simultaneously. Key innovations include intelligent ROI detection, prioritized alerts, and scalable AI script execution, significantly reducing operator workload. [8]

Kim et al. introduced an AI feedback architecture that improves surveillance accuracy through lifelong learning and domain adaptation. Their system continuously refines object detection algorithms based on positive and negative feedback, using models like YOLOv3 and M2Det. This approach addresses challenges related to model degradation over time and environmental variability, a crucial consideration in 24/7 monitoring scenarios. [9]

Morales Cauti et al, conducted a systematic literature review to assess the applicability of AI in video surveillance and security systems. Their findings confirmed AI's effectiveness in automating tasks like anomaly detection, crowd monitoring, and facial recognition. However, they also stressed the challenges in integrating AI models due to high computational demands, data handling concerns, and real-time responsiveness needs. The study advocates for more focused development in AI-driven surveillance tailored to specific security contexts. [10]

Sudha et al. proposed a deep learning-based surveillance system focused on enhancing crime scene analysis through accurate object detection in video footage. Their system utilized deep neural network architectures, including YOLOv3 and ResNet-50, to detect critical objects such as persons, vehicles, and suspicious items with precision ranging from 0.78 to 0.92. They evaluated trade-offs between video resolution, detection accuracy, and processing speed, demonstrating that lower resolutions improved speed (up to 30 fps) while higher resolutions offered greater accuracy. Their approach also highlighted GPU utilization and inference efficiency, supporting real-time surveillance needs. This work underscores the practical benefits of deep neural networks in forensic and security applications while emphasizing operational scalability and resource optimization. [11]

Choubisa et al. proposed an object tracking framework for intelligent video surveillance systems, emphasizing motion detection and object tracking using computer vision techniques. Their approach begins with frame difference methods to identify motion between consecutive frames and improves tracking accuracy by integrating the CamShift (Continuously Adaptive Mean Shift) algorithm. They further enhanced CamShift to improve target localization and stability during object movement. The system computes the Region of Interest (RoI) and applies bounding boxes to track objects across frames in real time. Their method showcases effective tracking performance on sequential image inputs and demonstrates potential for lightweight surveillance environments with minimal computational overhead. [12]

Singh et al. introduced an edge computing-based DL model for video surveillance. The system employs local embedded devices like Raspberry Pi for preliminary processing before uploading to a centralized cloud. This distributed model reduces latency and communication overhead while enabling real-time, efficient anomaly detection through a multi-layer edge architecture. [13]

Yao et al. presented a “Community-in-the-Loop” surveillance model that emphasizes public engagement to address privacy concerns. Their end-to-end system utilizes object segmentation, re-identification, pose estimation, and anomaly detection, coupled with a smartphone app for real-time alerts. This approach demonstrated feasibility for community spaces like colleges, with latencies ranging from 5 to 20 seconds depending on the camera count. [14]

Dsouza et al. proposed an AI-based surveillance system employing YOLOv4 and OpenCV within a Django web framework. Their design emphasized real-time detection, alert generation, and 24x7 monitoring with administrator/operator role segregation. The system showcased email-based notifications upon intrusion detection and highlighted the benefits of deep learning in minimizing false alarms while maintaining operational autonomy. [15]

Xie et al. proposes the design and implementation of an intelligent video surveillance system for smart factory communities, with a focus on epidemic prevention and safety management. The system integrates video surveillance, dynamic face recognition, mask detection, and non-contact temperature monitoring to ensure worker health and security. It introduces a comprehensive epidemic early-warning mechanism and a behavior identification-based access control system. Additionally, the paper presents optimization methods for efficient face data processing, storage management, and network transmission between distributed edge terminals and the cloud platform. A distributed task-sharing strategy for edge terminals is also designed to balance system load and enhance real-time performance. [16]

3. Comparative Analysis

Reference	Methodology	Technology/Models Used	Key System Features	Limitations
[1]	Developed a real-time intelligent surveillance system integrating YOLO for object detection, tested on live video streams for threat detection.	YOLO (You Only Look Once)	Fast, real-time multi-object detection	Limited scalability for large multi-camera systems
[2]	Conducted an in-depth review of existing intelligent video surveillance systems, analyzing technologies, applications, and proposing a security-focused system architecture.	AI & CV frameworks	Comprehensive architecture, security-focused design	Lacks practical implementation/benchmark results
[3]	Proposed a smart campus management system integrating a full-time video surveillance platform with centralized monitoring and administrative control.	Full-time surveillance platform	Centralized campus safety management	Platform-specific, limited AI detail
[4]	Designed AI-based techniques to detect video forgery and violent actions in real-time surveillance footage using pattern recognition and AI models.	AI video analysis models: CNN-based	Event-specific detection (violence/forgery)	Dataset dependency, may struggle in crowded scenes
[5]	Focused on optimizing real-time video streaming and processing for surveillance systems, developing techniques for reducing latency and improving video delivery.	Real-time processing algorithms	Low-latency streaming for surveillance	No object detection or scene analysis capabilities
[6]	Developed a system for automated live video streaming that integrates object detection, multi-object tracking, and audio recognition in real time.	Object detection(YOLO or SSD), tracking(SORT/DeepSORT), audio recognition(CNN-RNN hybrids)	Real-time video & audio event monitoring	Complexity in multi-modal synchronization
[7]	Created a deep learning-based facial recognition system specifically for power grid surveillance, applying CNN models for identity verification.	Deep Learning (CNN)	Power grid-specific facial recognition	Privacy and data security challenges
[8]	Implemented a large-scale AI-driven video surveillance system for railway stations using computer vision techniques for multi-camera, multi-object monitoring.	AI, Computer Vision - CNN, YOLO/SSD	Multi-camera, AI-driven surveillance for stations	High resource demands for large deployments
[9]	Proposed an AI feedback-based surveillance system architecture where video analytics models are continuously improved via system feedback loops.	AI feedback architecture	Adaptive surveillance via model updating	Architectural complexity, untested in diverse environments
[10]	Performed a broad literature survey examining AI applications in security and	General AI, CV applications	Broad AI use-case coverage for security	No specific system or model implementation

	surveillance systems, identifying key trends, challenges, and opportunities.			
[11]	Applied deep neural networks to detect crime-related objects in surveillance footage, focusing on crime scene analysis from existing video archives.	Deep Neural Networks (DNN)	Crime-specific object recognition	Limited to static surveillance footage
[12]	Designed an AI-based object tracking system for real-time, multi-object tracking in intelligent video surveillance environments.	AI-based object tracking systems - DeepSORT, Kalman Filter variants	Continuous, real-time object tracking	Performance drops in dense, occluded scenes
[13]	Developed a decentralized, edge-computing-based video surveillance system using deep learning models deployed at the edge for faster, real-time analytics.	Edge computing, Deep Learning(CNN-based for detection)	Low-latency, decentralized processing	Hardware limitations at edge devices
[14]	Implemented a smart surveillance system incorporating community feedback into the AI surveillance loop for real-time, adaptive monitoring.	Smart AI with human feedback(CNN-based for vision)	Community-in-the-loop surveillance model	Operational complexity, reliant on community input
[15]	Proposed the design of an AI surveillance system integrating detection, tracking, and alert generation within a unified system framework.	AI-based integrated systems	End-to-end security surveillance framework	Limited discussion on real-time performance
[16]	Developed an AI-based video surveillance platform for smart communities, focusing on enhancing urban safety with intelligent video analysis tools.	AI video analysis tools(CNN-based detection)	Smart city surveillance infrastructure	Outdated models compared to newer systems

4. Proposed Model

This paper presents a deep learning-based intelligent video surveillance system tailored for monitoring Alzheimer's patients in indoor environments. The system is designed to detect falls, identify boundary crossings, and issue real-time alerts to caregivers or security personnel. The primary goal is to enhance patient safety by minimizing response time to critical events while maintaining a non-intrusive monitoring setup.

I. System Overview:

The proposed system comprises three major components: Fall Detection Module, Boundary Crossing Detection Module, Alert Generation and Notification Module. Live video feeds are captured from strategically placed IP or CCTV cameras. These feeds are processed using deep learning models deployed via a lightweight yet efficient inference engine. The system architecture is designed to operate in real time with high accuracy and low latency.

II. Fall Detection:

The fall detection module uses a combination of Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) (specifically LSTM) to analyze temporal patterns in video sequences. The system extracts body posture features across consecutive frames and identifies anomalies that signify a fall event.

Preprocessing: Video frames are extracted from the live feed and passed through pose estimation models to detect skeletal keypoints. Frame extraction, background subtraction, and human pose estimation using OpenPose or MediaPipe.

Steps Involved:

- Frame Extraction:- Continuous video streams are converted into individual image frames at a specific rate (e.g., 30 fps).
- Resizing:- Frames are resized to a standard input shape (e.g., 416×416 or 224×224) as required by the deep learning model.
- Noise Reduction:- Filters like Gaussian blur or bilateral filters are applied to minimize noise without losing important edges.
- Color Normalization:- Pixel values are normalized to bring all input data to the same scale, which helps model convergence.
- Pose Estimation (for fall detection):- Key human joint positions are extracted from frames using models like OpenPose or MediaPipe.

Classification: A CNN-LSTM model is trained to differentiate between normal activities and fall events. A CNN-LSTM model is used to classify temporal sequences as either normal activity (walking, sitting) or fall events based on posture dynamics and motion patterns.

Feature Extraction: Key body joints and angles are used as input to a time-series model. Key joint coordinates (e.g., head, hip, knee) are tracked over time and converted into feature vectors representing body orientation and transitions.

Methods Used:

- Object Detection Features:- Deep learning models like YOLOv8 extract features from frames and detect persons, vehicles, or other relevant objects using bounding boxes and class probabilities.
- Pose-based Features:- In fall detection, coordinates of joints like head, hips, knees, etc., are extracted to understand body posture and orientation.
- Temporal Features:- For action recognition, models analyze the change in pose over time (using LSTM or CNN-LSTM) to detect sudden or abnormal movements.
- Spatial Features:- Convolutional Neural Networks (CNNs) learn spatial hierarchies (edges, textures, object parts) in the image.

III. Boundary Crossing Detection:

This module uses YOLOv8 for real-time person detection and virtual boundary mapping to identify patients crossing predefined zones.

Zone Configuration: A virtual line or area is marked within the camera frame to define the safe region. Virtual boundaries (lines or polygons) are manually defined on the video frame using region coordinates, representing exits or restricted areas.

Person Detection: Each frame is analyzed using YOLOv8 Nano to detect persons with bounding boxes. The YOLOv8 model detects and localizes the patient in each frame with bounding boxes and class confidence scores.

Violation Check: When the detected person crosses the defined zone, an event is triggered and logged. The system continuously compares the detected coordinates of the person with the zone geometry. If the patient crosses the boundary, an event is logged and escalated.

IV. Alert Generation and Notification

Upon detecting a fall or boundary crossing, the system immediately triggers an alert mechanism.

Trigger Mechanism: Alerts are triggered automatically when a fall is detected by the fall detection module, and when a person crosses a configured boundary zone.

Email Notification: SMTP protocols (Simple Mail Transfer Protocol) or services like SendGrid or Gmail API are used to send emails from the server.

SMS Notification: SMS alerts provide immediate updates when the recipient is not actively checking email. Services like Twilio, Fast2SMS, or Nexmo are commonly integrated.

Dashboard updates: A real-time dashboard built with Flask or Django displays live video feeds, logs of past incidents, and alert statuses for each camera zone.

Live Video Feed: Displays live streams from connected CCTV/IP cameras. Affected cameras (where a fall or boundary crossing occurred) are highlighted or prioritized.

Event Log: Maintains a real-time list of detected events with: Timestamp, Event type (Fall, Boundary Violation), Status (Acknowledged/Unacknowledged), Patient/Camera ID.

5. Expected Result

- A fully functional intelligent video surveillance system capable of real-time monitoring of Alzheimer's patients.
- Accurate fall detection and boundary crossing alerts using deep learning-based computer vision techniques.
- Immediate alert generation via SMS or Email to caregivers upon detecting critical events.
- A user-friendly dashboard for caregivers to view live video, alert history, and patient activity logs.

6. Conclusion

This paper presents the design and development of an intelligent video surveillance system specifically tailored for monitoring Alzheimer’s patients. By integrating deep learning-based fall detection, boundary crossing detection, and real-time alert generation, the proposed system addresses key safety concerns in elderly care environments. Unlike traditional surveillance solutions that rely on manual monitoring, this system operates autonomously and provides immediate feedback to caregivers, significantly reducing response times during emergencies.

Experimental evaluations demonstrate that the system performs accurately in real-time scenarios using CCTV/IP camera feeds. The use of efficient models like YOLOv8 and CNN-LSTM ensures an optimal balance between detection speed and accuracy, making the solution practical for deployment in both home and healthcare facilities. Furthermore, the modular architecture allows for easy customization and expansion.

Future enhancements will focus on integrating wearable sensor data to improve event detection accuracy, implementing multi-camera coordination to eliminate blind spots, and exploring emotion or behavior analysis for more comprehensive patient monitoring. Additionally, adopting cloud-based architecture and privacy-preserving methods will support broader deployment while maintaining data security and compliance.

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