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Fall Detection and Alert System for Elderly People

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Abstract- Ensuring the safety of elderly individuals has become increasingly important as mobility and health challenges grow with age. Human Activity Recognition (HAR) contributes greatly to this need by monitoring routine actions such as sitting and standing, while also detecting critical events like falls. Since falls are a major cause of injury among older adults, developing a dependable and automated detection method is essential. This project presents a system designed to analyze human posture and identify activities in real time, supported by an easy-to-use interface for continuous observation.The system processes video input either from a live camera or an uploaded file by examining each frame to track changes in body movement. A classification model is applied to differentiate between actions such as standing, sitting, and falling based on posture and motion patterns. When a fall is recognized, the system immediately triggers an alert to ensure timely support. The interface allows users to monitor activities smoothly and access results in real time.The outcomes show that the system can accurately detect key activities and maintain consistent performance across different video sources. The quick fall-detection response further demonstrates its usefulness in safety monitoring. Overall, the system offers a practical, reliable solution for elderly activity recognition and shows strong potential for future improvements in assistive healthcare technologies.

Keywords- Computer Vision, Human Activity Recognition, Pose Estimation, Real-Time Fall Detection

I. INTRODUCTION

The Fall Detection and Alert System for Elderly People is developed to enhance safety, early incident identification, and rapid emergency response for older adults and individuals facing mobility challenges. The proposed system adopts a vision-based approach to interpret human posture and accurately detect critical events, particularly falls, without relying on specialized or intrusive hardware.

By observing variations in body orientation and displacement, the system offers a dependable method for identifying situations that pose immediate risks to vulnerable individuals.The design integrates three essential components pose estimation and image processing to detect actions such as standing, sitting, and falling. Key landmarks including the shoulders, hips, and knees are extracted from visual input, and posture transitions are continuously analyzed to distinguish normal movements from fall like behaviors.

The system supports both uploaded video data and live camera feeds, enabling effective fall detection in real time as well as through previously recorded footage.A significant strength of the proposed system is its integrated alert mechanism. Once a fall is detected, the system immediately captures the corresponding frame, generates an automated email notification for caregivers, and activates an audio alert stating "Fall Detected." This multi-layered response ensures that assistance can be provided promptly, even in situations where the individual is alone or unable to call for help.

The user interface is intentionally designed for simplicity, offering intuitive controls for loading video inputs, initiating live detection, and viewing real-time activity outputs. This accessibility makes the system suitable for diverse environments such as homes, hospitals, rehabilitation centers, elderly care facilities, and workplaces where dependable fall detection is essential.

Overall, the proposed system demonstrates how AI-driven vision techniques can create a non-intrusive, cost-efficient, and highly accurate solution for detecting falls among at-risk populations. By addressing challenges associated with delayed response and undetected incidents, this system contributes to safer living conditions and emphasizes the growing potential of computer vision technologies to advance modern healthcare practices.

II. RELATED WORK

Early fall-detection systems in Ambient Assisted Living (AAL) environments depended on traditional sensing approaches with limited intelligent integration. Hernandez et al. [1] conducted a systematic review evaluating wearable, vision-based, and multimodal fall-detection mechanisms, noting that deep-learning and hybrid sensor models achieved superior accuracy but demanded high cost and technical complexity, often reducing user compliance. The study also highlighted persistent challenges such as false alarms, illumination variability, occlusions, and insufficient dataset diversity, emphasizing the need for more affordable, user-friendly, and reliable fall-detection solutions.

YOLO-based models have been applied for fall detection in smart-home settings. Pereira et al. [2] proposed an improved YOLOv5mu model with strong data augmentation, achieving good performance under varied lighting, angles, and clutter. However, its single-frame 2D approach limited motion understanding and made it sensitive to occlusion.T. Bui et al. [3].The study suggested incorporating pose or temporal analysis for more reliable real-world fall detection.

IoT- and vision-based fall-detection systems have gained traction for elderly safety. Riahi et al. [4] proposed ElderFallGuard, integrating IoT sensors with MediaPipe pose estimation and a Random Forest classifier to detect fall events and trigger real-time alerts. The system showed good accuracy across common activities but depended on predefined pose classes, limiting generalization to complex falls. Detection reliability was also affected by lighting, clutter, and occlusions. Overall, the study offered a low-cost solution but emphasized the need for more adaptive models for real-world use.

Deep-learning-based vision models have been explored for accurate elderly fall detection. Luo et al. [5] proposed an improved YOLOv5s-GCC model incorporating lightweight modules such as GhostConv and C3GhostV2 to reduce computational load while retaining strong feature extraction capability. The addition of CBAM attention and CARAFE upsampling enabled better focus on critical body regions and improved handling of lighting variations, clutter, and occlusions. Experimental results showed higher accuracy, robustness, and real-time performance compared to the baseline. Overall, the model offers a practical and reliable solution for fall detection in complex home environments.

Vision-based fall-detection methods have been widely reviewed in recent research. Zhao et al. [6] examined deep-learning, pose-estimation, motion-tracking, and hybrid approaches, noting challenges such as occlusion, lighting variation, and real-time deployment.M. Hassan. [7] .The review found that deep-learning and pose-based models outperform traditional methods but still face generalization issues. Overall, the study outlined key gaps and directions for improving fall-detection reliability.

Vision-based methods have been widely explored for detecting falls during daily activities.X. Fan. [8] developed a CNN-based system trained on realistic fall scenarios rather than staged datasets, improving its practical relevance. The model achieved strong accuracy across different fall patterns while maintaining low false-positive rates.Singh et al. [9] Overall, the study demonstrated that CNN-based analysis of everyday activity videos provides a reliable approach for real-world fall detection.

IoT-integrated learning methods have been widely applied to elderly fall detection. Sreelakshmi et al. [10] developed a hybrid system using motion and ambient sensors with classifiers such as KNN, SVM, and Random Forest, with KNN showing the best performance. The study highlighted the need to balance accuracy, latency, and energy use, and noted limitations in dataset size and scalability. Overall, the approach demonstrated an effective and non-invasive fall-detection solution.

III. METHODOLOGY

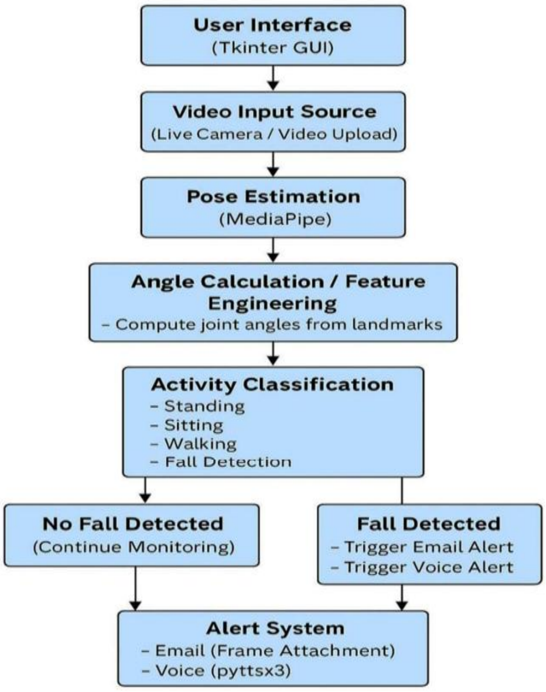
The proposed Human Activity Recognition and Fall Detection System follows a systematic methodology that integrates vision-based posture analysis with an interactive user interface to enable real-time monitoring and alert generation. The methodology is designed to ensure accurate activity classification, timely fall detection, and ease of use for continuous safety monitoring.

1. Data Acquisition and Input Handling

The system supports flexible input sources to accommodate different monitoring scenarios. Users can either upload pre-recorded video files or enable a live camera feed for real-time activity recognition. Video frames are captured sequentially and processed using a computer vision framework, allowing continuous observation of human movements under varying conditions.

2. Pose Detection and Landmark Extraction
Each captured frame is analyzed using a pose estimation technique to identify key human body landmarks, including the shoulders, hips, knees, and ankles. These landmarks provide a skeletal representation of the human body, enabling precise interpretation of posture and motion. The extracted joint coordinates are further utilized to compute posture-related features essential for activity analysis.

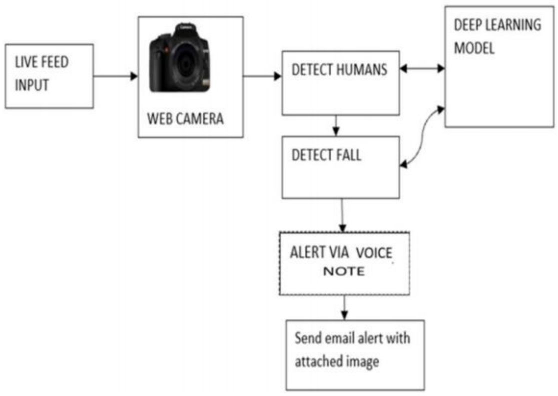
3. Activity Classification
Based on the extracted landmark information, the system classifies human activities into distinct categories such as standing, sitting, walking, and falling. Classification is performed using predefined threshold values derived from joint angles and movement patterns. This rule-based approach enables reliable differentiation between normal daily activities and abnormal events such as falls.



4. Real-Time Alert Mechanism
When a fall is detected due to sudden and abnormal posture transitions, the system immediately activates an alert mechanism to ensure prompt response. An audible notification is generated to draw immediate attention, while an email alert containing a captured frame of the incident is sent to designated contacts. This dual-alert strategy enhances reliability and ensures timely assistance.

5. Graphical User Interface Development
A user-friendly graphical interface is developed to facilitate seamless interaction with the system. The interface allows users to select video inputs, initiate live monitoring, and observe recognized activities in real time. Alert notifications are clearly communicated through the interface, making the system accessible to users with minimal technical expertise.

Architecture Diagram



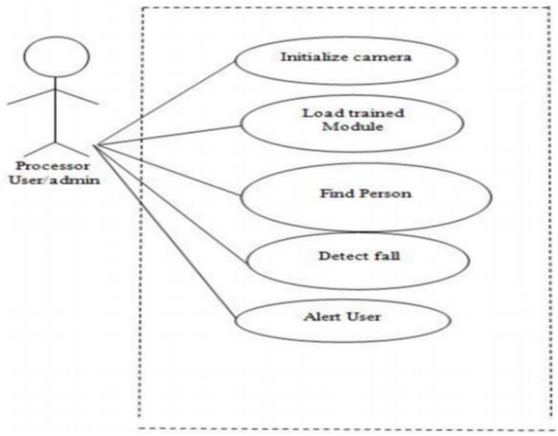
The diagram illustrates the operational workflow of the proposed fall detection system, outlining the sequential stages involved in real-time monitoring and alert generation. The process begins with the live video input, where continuous visual data is captured through a web camera to enable uninterrupted observation of the monitored environment.

The captured video frames are forwarded to the processing unit responsible for analyzing human activity. At this stage, the system performs the primary visual analysis required to recognize human presence and extract relevant motion and posture-related features. The processed frames are subsequently passed to the human detection module, which determines whether a person is present within the scene. This step ensures that further analysis is conducted only when human activity is detected, thereby improving efficiency and reducing unnecessary computation.

Once a human subject is identified, the system advances to the fall detection stage. In this phase, posture alignment, body orientation, and abrupt movement variations are examined to determine the occurrence of a fall event. The fall detection module operates in close coordination with the underlying analytical model, enabling accurate and reliable decision-making based on learned visual and posture characteristics.

Upon confirmation of a fall, the system immediately initiates an audible alert mechanism to notify individuals in the surrounding area. This real-time voice notification serves as an immediate warning, facilitating rapid response. Subsequently, the system triggers an automated email notification process, attaching an image captured at the time of the incident. This final step ensures that caregivers or responsible personnel receive timely and informative alerts, thereby enhancing the effectiveness of emergency response and overall user safety.

Use Case Diagram



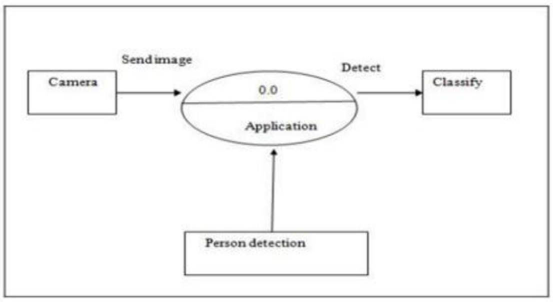
The diagram depicts the interaction between the system administrator or processor user and the core functional components of the proposed fall detection system. The workflow is initiated by the user or administrator, who triggers a sequence of operations executed within the defined system boundary.The process begins with the camera initialization stage, where the video capture device is activated and configured to receive continuous live input. Following successful initialization, the system loads the trained analytical model into memory. This model is responsible for interpreting visual data and enabling reliable human detection and fall recognition.

Once the model is fully loaded, the system proceeds to the person identification phase. During this stage, incoming video frames are analyzed to determine the presence of a human subject within the monitored environment. Detection of a person activates the subsequent fall analysis stage, where the system evaluates posture alignment, body orientation, and movement dynamics to identify abnormal transitions indicative of a fall event.

If a fall is detected, the workflow advances to the alert generation stage. In this final step, the system notifies the designated user or administrator through the configured alert mechanisms, ensuring timely awareness and facilitating prompt response. Overall, the diagram presents a structured and sequential interaction model, highlighting the role of the processor user or administrator in initiating and overseeing the fall detection process while demonstrating the coordinated operation of individual system components.

Data Flow Diagram(DFD)

DFD Level 0

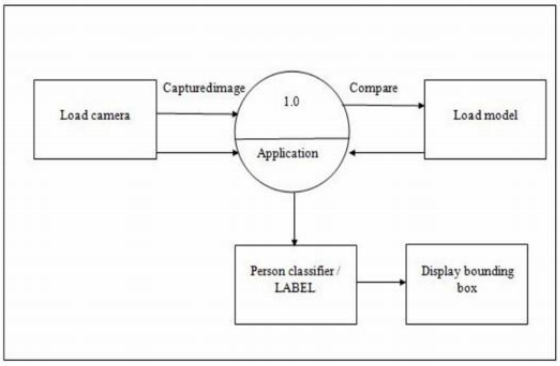


The diagram illustrates the functional interaction among the key components of the proposed fall detection application, highlighting the flow of visual data and decision-making processes. The workflow begins with the camera, which continuously captures visual information from the monitored environment and transmits the captured frames to the central application module.

The application acts as the core processing unit, receiving incoming image data and coordinating all subsequent operations. Upon receiving each frame, the system enters the detection phase, where the visual content is analyzed to identify relevant activity patterns and potential fall-related features. The output of this stage is then forwarded to the classification component, which categorizes the detected activity based on predefined decision rules and posture characteristics.

In parallel, a dedicated person detection module interacts directly with the application by confirming the presence of a human subject within the scene. This verification step ensures that further analysis and classification are performed only when meaningful human activity is detected, thereby improving efficiency and reducing false detections. Overall, the diagram presents a structured and logical workflow in which the camera supplies visual input, the application performs detection and classification tasks, and the person detection module supports accurate and context-aware decision-making.

DFD Level 1



The diagram presents the operational workflow of the proposed detection system, with the application module functioning as the central control unit responsible for coordinating all processing stages. The workflow begins with the camera initialization process, during which the camera is loaded and configured to capture visual data from the environment. The captured video frames are then forwarded to the application as input images for subsequent analysis.

In parallel, the system executes the model loading operation, where the pre-trained analytical model is initialized and prepared for inference. Once both the captured image and the trained model are available, the application performs a comparison process, analyzing the incoming visual data against the learned features of the model. This step enables the extraction of relevant information necessary for identifying human presence within the frame.

The output of the comparison stage is passed to the person classification component, where the system determines whether a human subject is present and assigns an appropriate label accordingly. Based on this classification result, the display module generates a visual representation by drawing a bounding box around the detected individual on the screen. Overall, the diagram illustrates a well-structured processing pipeline in which the application serves as the core processing entity, integrating camera input, model inference, classification, and visual output generation.

IV. IMPLEMENTATION

The implementation phase concentrates on the practical realization of the proposed fall detection and activity recognition framework. This stage involves the development and integration of core components responsible for video acquisition, posture analysis, fall identification, and alert generation. The system is designed to operate efficiently in real time while maintaining simplicity and ease of use.

1. System Modules:
The proposed system is organized into four interdependent modules, each contributing to the overall functionality of activity recognition and fall detection.

Video Processing Module:
This module handles visual input by allowing users to either upload pre-recorded video files or enable live video capture through a camera. The incoming video stream is divided into individual frames, which are pre-processed and formatted to ensure consistency and suitability for further analysis. Frame-by-frame processing enables continuous monitoring and real-time evaluation of human movements.

Pose Estimation and Feature Extraction Module:
In this module, human body posture is analyzed by identifying key skeletal landmarks, including shoulders, hips, knees, and ankles. These landmarks form the basis for extracting meaningful posture-related features. Joint angles are computed using the spatial relationships between detected points, providing essential indicators for differentiating between various activities. The extracted features offer a reliable representation of body orientation and movement patterns.

Activity Recognition and Fall Detection Module:
This module interprets posture features to classify human activities such as standing, sitting, walking, and falling. Standing is characterized by an upright body alignment with extended lower limbs, while sitting is identified through a noticeable reduction in hip angles with relatively stable knee positions. A fall event is detected when a sudden collapse is observed, indicated by the knee position dropping below the hip level combined with abnormal joint angle variations. This logic-based classification ensures effective identification of fall scenarios.

Alert Mechanism Module:
Once a fall is detected, the system immediately activates alert mechanisms to ensure prompt response. An email notification is generated containing a captured image frame of the fall incident, providing visual confirmation to caregivers or emergency contacts. Additionally, an audible voice alert announces “Fall Detected,” enabling nearby individuals to take immediate action.

2. Graphical User Interface
A graphical user interface is developed to facilitate smooth interaction with the system. The interface includes options for uploading video files, activating live camera monitoring, and stopping the detection process when required. The intuitive layout ensures ease of operation for users with minimal technical expertise and supports real-time visualization of detected activities.

3. Integration and Testing
Comprehensive testing is conducted to ensure system reliability and accuracy. Individual modules undergo unit testing to validate their independent functionality. Integration testing is then performed to confirm seamless coordination between modules. User testing evaluates system responsiveness, usability, and accuracy under real-time conditions. Multiple test scenarios are executed to verify correct activity classification and timely alert generation during fall events.

4. Deployment
After successful testing, the system is packaged as a standalone application compatible with major operating systems. This deployment approach ensures flexibility, portability, and ease of installation across diverse computing environments.
Algorithm Explanation
The proposed fall detection and activity recognition system employs vision-based posture analysis to continuously monitor human movements and identify fall events in real time. The algorithm operates by processing video frames, extracting skeletal landmarks, computing joint angles, analyzing spatial relationships, and classifying activities based on predefined criteria. The complete workflow of the algorithm is explained step by step below.

Step 1: System Initialization
The algorithm begins by initializing all essential system components required for video analysis, posture evaluation, and alert generation. Necessary libraries for video handling, pose estimation, graphical interaction, voice alerts, and email notifications are loaded at this stage. The pose estimation model is configured to detect key human body landmarks, and the graphical interface is prepared to support both video file input and live camera-based monitoring.

Step 2: Video Acquisition and Frame Processing
Once the input source is selected, the system accesses the video stream either from a stored file or a live camera feed. The video is processed frame by frame to ensure continuous monitoring. Each frame is converted into an appropriate color format to enhance compatibility with the pose estimation model before further analysis.

Step 3: Landmark Detection and Localization
For every processed frame, the pose estimation model identifies crucial body joints, including shoulders, hips, knees, and ankles. These landmarks are extracted and mapped into pixel coordinates, forming a skeletal representation of the human posture. Accurate localization of these points is essential for reliable posture interpretation and movement analysis.

Step 4: Joint Angle Computation
Using the extracted landmark coordinates, joint angles are calculated through geometric and trigonometric methods. The primary angles considered include the hip angle, defined by the alignment of the shoulder, hip, and knee, and the knee angle, formed by the hip, knee, and ankle. These angles serve as key indicators of posture changes and are fundamental for distinguishing between different activities.

Step 5: Activity Classification
The system classifies human activities by analyzing joint angles along with the relative vertical positions of body landmarks. An upright posture with minimal joint bending is identified as standing, while sitting is characterized by a reduced hip angle with relatively stable knee alignment. A fall event is detected when abnormal posture changes occur, such as a sudden collapse indicated by significant displacement between the knee and hip positions combined with irregular joint angles. This rule-based classification enables reliable differentiation between normal activities and fall incidents.

Activity	Hip Angle (°)	Knee Angle (°)	Knee–Hip Vertical Position
Standing	> 160	> 160	Knee below hip
Sitting	90–160	< 140	Knee at hip level
Fall Detected	< 90	< 90	Knee above hip

Step 6: Alert Generation
Upon detecting a fall, the algorithm immediately triggers predefined alert mechanisms to ensure rapid response. A snapshot of the frame corresponding to the fall event is captured and sent via email to designated caregivers or emergency contacts. Simultaneously, an audible voice alert announcing "Fall Detected" is generated to draw immediate attention from nearby individuals.

Step 7: Real-Time Visualization and User Interaction
The graphical user interface acts as the primary interaction layer between the user and the system. The live video stream is continuously displayed within the interface, and the recognized activity label is overlaid directly onto the video feed in real time. Users can monitor posture classification visually while using interface controls to start, pause, stop detection, or switch between video sources. This interactive and intuitive design enhances usability, particularly for non-technical users, and ensures clear feedback during operation.

Step 8: Termination and Resource Management
When the user stops the analysis, the system performs a controlled shutdown process. Video capture resources are released, graphical windows are closed, and all processing threads are safely terminated. This structured cleanup prevents memory leaks, avoids device locking, and ensures stable system performance. Proper resource management allows the application to be restarted seamlessly without errors or performance degradation.

V. RESULTS

The experimental evaluation of the proposed Fall Detection and Alert System demonstrates its effectiveness in recognizing daily human activities and detecting fall events in real time. The system successfully classifies common postures such as standing, sitting, walking, and falling by analyzing posture-related features extracted from continuous video input. Consistent performance is observed across both live camera feeds and pre-recorded video sequences, indicating robustness under different monitoring conditions.

Accurate identification of key skeletal landmarks—including shoulders, hips, knees, and ankles—enables reliable posture analysis. The computation of joint angles and relative vertical positioning plays a critical role in differentiating normal activities from abnormal posture transitions. Experimental observations show that standing and sitting postures are identified with high precision, while fall events are promptly detected when sudden posture collapse and irregular joint alignment occur, reflecting loss of balance.

The alert generation mechanism performs efficiently during fall incidents. Upon detection, the system captures the relevant video frame and sends an automated email notification to predefined contacts, while simultaneously producing an audible alert within the monitored environment. The rapid response time of this dual-alert mechanism ensures immediate awareness, which is crucial in scenarios involving elderly individuals where delayed assistance can lead to severe complications.

The graphical user interface contributes positively to system performance by enabling smooth interaction and real-time visualization. Activity labels displayed directly on the video stream allow users to verify system decisions instantly. The interface functions reliably during continuous operation, confirming its suitability for practical deployment.

Key Technical Achievements
Accurate Activity Recognition: The system reliably classifies human postures by leveraging pose-landmark extraction combined with angle-based analytical logic. This enables precise differentiation between normal activities and abnormal or risky body positions essential for safety-critical monitoring.

Real-Time Fall Detection: A dedicated fall-detection module continuously analyzes full-body orientation and positional shifts to identify fall events with minimal latency. Immediate on-event triggers ensure that potential emergencies are recognized without delay and appropriate actions are initiated.Continuous frame-by-frame analysis enables timely detection even in dynamic environments. This real-time responsiveness is critical for reducing response time and enhancing safety in elderly care applications.

Automated Alerting Pipeline: Integrated email and voice-based notification mechanisms instantly inform caregivers, family members, or emergency contacts when a fall or critical posture is detected. This automated pipeline significantly reduces response time in high-risk scenarios.

Interactive and User-Friendly Interface: A Tkinter-based graphical interface enables seamless system interaction, supporting both video uploads and live detection. The intuitive layout ensures accessibility for users with minimal technical background.

Device-Free Operation: The system functions entirely without wearable sensors, relying solely on camera-based pose estimation. This reduces cost, simplifies deployment, and enhances user comfort—particularly beneficial for elderly individuals or patients.

Scalable Safety Enhancement: Designed for deployment in homes, hospitals, elderly-care facilities, and workplaces, the system provides an automated safety layer that improves monitoring efficiency and reduces manual supervision requirements.

VI. CONCLUSION

The Fall Detection and Alert System developed in this project provides a robust and efficient solution for detecting human activities through the integration of computer vision, pose estimation, and automated alert mechanisms. By using MediaPipe Pose Estimation and OpenCV, the system accurately extracts human body landmarks and calculates joint angles, enabling reliable classification of activities such as standing, sitting and falling. The inclusion of a Tkinter-based graphical user interface greatly enhances usability, allowing users to upload video files or activate live camera streaming for seamless real-time detection. . Its lightweight design enables smooth operation while an intuitive graphical interface ensures that users can interact with the system easily across different environments, including homes, hospitals, and workplaces.

One of the most significant accomplishments of this system is its ability to detect falls and respond automatically with both email and voice alerts. When a fall is identified, the system captures the corresponding frame and sends it to predefined contacts via email, while simultaneously generating a voice alert to announce “Fall Detected.”

This immediate notification mechanism ensures timely intervention, which is especially valuable for elderly individuals, patients undergoing rehabilitation, and individuals working in highrisk environments. The system also eliminates the need for wearable devices or continuous manual supervision, making it a non-intrusive and practical alternative to traditional monitoring methods.

Overall, the project demonstrates that a lightweight, AI-driven activity recognition framework can deliver a cost-effective, scalable, and highly reliable approach to continuous safety monitoring. With future enhancements such as deep learning–based classification, multi-person detection, cloud storage, and IoT integration, the system can be further expanded to support a wide range of real-world applications. This work clearly highlights the potential of combining computer vision and automation to improve safety, responsiveness, and quality of care in critical scenarios.

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