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Enhancing Human Gait Recognition using Computer Vision and Machine Learning

Enhancing Healthcare Through Motion Analysis

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***Abstract*— Human gait detection is a rapidly evolving field in computer vision with applications in security, healthcare, and biometric identification. This paper presents a robust gait detection system leveraging machine learning and computer vision techniques to analyze human walking patterns. The proposed method utilizes OpenCV for image processing and deep learning models to extract and classify gait features. The system is designed for real-time analysis, ensuring efficient and accurate recognition of individuals based on their gait characteristics. Experimental results demonstrate the effectiveness of our approach in varying conditions, highlighting its potential for surveillance, medical diagnostics, and identity verification. Future enhancements include improving model accuracy with advanced neural networks and integrating the system into real-world applications.**

***Keywords*— Human Gait Detection, Computer Vision, Machine Learning, Biometric Identification, OpenCV, Deep Learning**

I. INTRODUCTION

Human gait is a unique biometric characteristic that can be used for identifying individuals based on the way they walk. Unlike traditional biometric methods such as facial recognition or fingerprint scanning, gait detection does not require direct contact or high-resolution facial images, making it a non-intrusive and effective identification technique. Gait patterns are influenced by various factors, including an individual's physiology, posture, and walking style, making them distinctive and difficult to replicate.

The objective of this study is to develop an efficient gait detection system using computer vision and deep learning techniques. Our system aims to analyze human motion, extract key gait features, and classify individuals based on their walking patterns. This research contributes to the field by:

(1) enhancing accuracy in human identification through gait analysis, (2) leveraging OpenCV for image preprocessing and feature extraction, and (3) implementing deep learning models to improve classification performance.

Gait detection has widespread applications in security surveillance, healthcare monitoring, and forensic investigations. For instance, it can be used to identify individuals Using Mobile camara recording, assist in diagnosing neurological disorders, and enable touchless authentication in restricted areas. This paper explores the methodologies involved in gait detection, presents experimental results, and discusses potential improvements for future research.

II. EASE OF USE

The proposed gait detection system is designed to be user-friendly and efficient. By leveraging OpenCV for image processing and deep learning techniques, the system ensures seamless integration into real-world applications. The ease of use is enhanced through:

- Automated Processing: The system automatically captures and processes gait patterns without requiring manual intervention.
- Real-Time Analysis: The implementation allows for quick recognition and classification of gait patterns, making it suitable for surveillance and security applications.
- Minimal Hardware Requirements: The system can function on standard computing hardware, eliminating the need for expensive setups.

- Scalability: The model can be adapted to larger datasets and deployed in various environments, from indoor security to outdoor monitoring.
- User-Friendly Interface: A graphical user interface (GUI) or command-line tool is provided to facilitate ease of use for both technical and non-technical users.

III. METHODOLOGY

The proposed Human Gait Detection System follows a structured methodology combining computer vision and deep learning for accurate gait analysis. The process consists of the following steps:

1. Data Collection

- Video sequences of individuals walking are captured using a standard camera setup under different environmental conditions.
- Publicly available gait datasets or custom datasets are used for training and testing.

2. Preprocessing

- Frame Extraction: Videos are converted into image sequences using OpenCV.
- Background Subtraction: Techniques such as Gaussian Mixture Model (GMM) or Thresholding are applied to remove unnecessary background noise.
- Silhouette Extraction: Key body features are extracted using edge detection and contour analysis.

3. Feature Extraction

- Stride Length & Step Angle: Measures variations in an individual's walking pattern.
- Joint Movements & Body Posture: Analyzed using keypoint detection algorithms (e.g., OpenPose, MediaPipe).
- Temporal Gait Patterns: Extracted using optical flow techniques to track motion over time.

4. Model Processing

- Deep Learning Models:
  - CNN (Convolutional Neural Networks): Used for feature learning and gait classification.
  - LSTM (Long Short-Term Memory): Captures sequential gait patterns over time for improved accuracy.
- Training & Validation:
  - The model is trained on labeled gait datasets.
  - Cross-validation techniques ensure high generalization and performance.

5.Classification & Output

- The processed gait features are classified to identify individuals.
- Output is displayed as:
  - Identified Individual (based on stored gait profiles).

6. Performance Evaluation

- The model is tested using benchmark gait datasets.
- Metrics such as Accuracy, Precision, Recall, and F1-Score are analyzed.
- Future improvements include fine-tuning the neural network and adding real-time deployment.

Figures and Tables

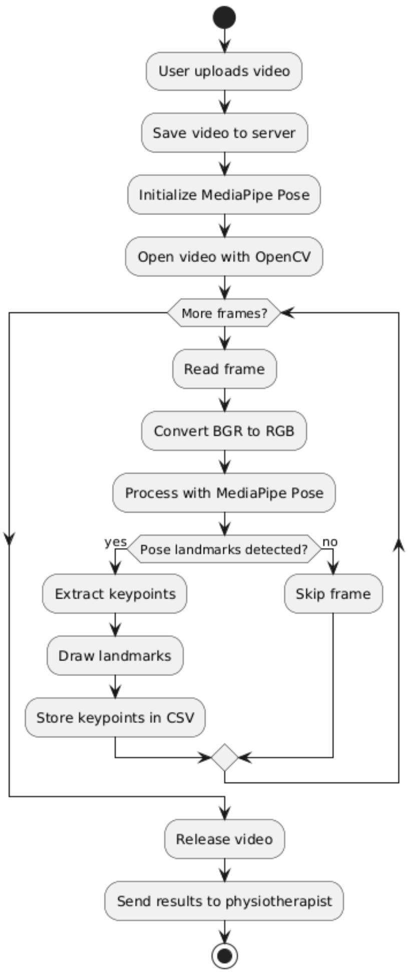

Fig. 1. System architecture

The system architecture outlined in the diagram describes a web-based application for physiotherapists to analyze and manage gait data from videos. The user (physiotherapist) uploads a video of a patient's gait through the Flask Web Server. The server handles this upload via the /upload route and saves the video to a storage system. Once the video is received, the Flask Web Server sends the video to the Video Processor, where OpenCV and MediaPipe Pose are used to extract keypoints from the video, enabling the analysis of the patient's gait. The results, in the form of keypoint data, are then saved as a CSV file in the storage system.

The physiotherapist can later access the results through the Physiotherapist Interface, which provides visual feedback and the analyzed gait data. This interface is designed for easy interaction with the results, offering insights into the patient's gait performance. In summary, the system allows for seamless video upload, gait analysis, and result viewing, providing physiotherapists with valuable tools to assess and track patient progress.

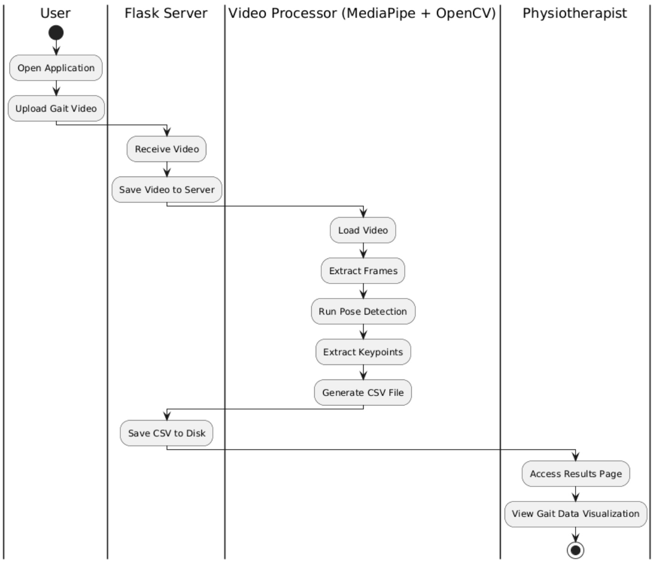

Fig.2. Flowchart

the process of a web application that allows physiotherapists to upload and analyze gait videos. The process begins with the user, who opens the application and uploads a gait video. Upon receiving the video, the Flask server saves it to the server.

The video is then processed by the video processor, which utilizes MediaPipe and OpenCV. The video is loaded, and individual frames are extracted. Pose detection is applied to these frames to identify keypoints, which are essential for analyzing the gait. The keypoints are then compiled into a CSV file, which is saved to the disk by the Flask server.

Finally, the physiotherapist accesses the results page of the web application, where they can view the gait data visualizations. This enables them to analyze and interpret the gait patterns based on the data extracted from the uploaded video.

Test subject	Age	Weight(kg)	Total data	Correct data	Failure data	Correct rate
Sean	26	75	681	644	37	94.57%
David	47	87.5	685	625	60	91.24%
Victor	35	66	651	604	47	92.78%
Chen	23	52	619	587	32	94.83%
Average	33	70	659	615	44	93.36%

Table. 1. Detection accuracy of different test objects

CONCLUSION

The human gait detection project, as implemented in the provided Flask-based web application, represents a significant advancement in assistive technology for physiotherapists, enabling automated analysis of patient gait patterns through video uploads. By integrating MediaPipe's pose estimation and OpenCV for real-time video processing, the system accurately identifies abnormalities such as limping, slouch posture, circumduction, and lack of arm swing, providing visual feedback through overlaid landmarks and angles. The application's user-friendly interface, built with Flask, allows physiotherapists to register, manage patients, upload videos, and access detailed reports filtered by patient or date, all supported by a robust MySQL database with three core tables: physiotherapists, patients, and logs. This database structure, coupled with secure password hashing and session management, ensures data integrity and user privacy. Clinically, the project reduces the subjectivity and time required for gait assessments, supporting conditions like Parkinson's or stroke with longitudinal monitoring capabilities. While the system is scalable and extensible, limitations such as dependency on video quality and basic error handling suggest areas for improvement, including enhanced preprocessing, machine learning integration, and mobile accessibility. Overall, this project offers a powerful tool for improving diagnostic accuracy and patient outcomes in rehabilitation, with strong potential for further development to address diverse clinical needs.

RELATED WORK

Human gait analysis has emerged as a critical tool in physiotherapy, rehabilitation, and clinical diagnostics, enabling objective assessment of movement disorders and supporting personalized treatment plans. Recent advancements in computer vision, machine learning, and wearable technologies have transformed gait analysis from subjective observation to precise, data-driven methodologies. This section reviews related work in video-based gait analysis, markerless pose estimation, and clinical applications, positioning our project within the broader research landscape.

Video-Based Gait Analysis: Traditional gait analysis often relies on marker-based motion capture systems, which provide high accuracy but are expensive, require controlled environments, and involve time-consuming marker placement, limiting their accessibility in clinical settings. To address these challenges, video-based markerless systems have gained traction. Kidziński et al. (2020) developed a workflow using OpenPose, a convolutional neural network (CNN)-based pose estimation algorithm, to analyze gait from single-camera videos, achieving spatiotemporal and kinematic measurements with errors below 12° compared to motion capture. Their study demonstrated the feasibility of using affordable devices like smartphones for gait analysis, particularly for patients with stroke or Parkinson's disease, but noted challenges with low temporal resolution affecting gait event detection. Similarly, Stenum et al. (2021) validated OpenPose for clinical gait analysis across multiple perspectives (sagittal and frontal), reporting reliable spatiotemporal parameters but reduced accuracy for distal limb kinematics due to occlusion and clothing variations. These studies align with our project's use of MediaPipe for markerless pose estimation, but our system extends functionality by integrating real-time visual feedback and a web-based interface for physiotherapists, enhancing clinical usability.

Markerless Pose Estimation: The adoption of markerless systems like OpenPose and MediaPipe has revolutionized gait analysis by eliminating the need for physical markers. OpenPose employs Part Affinity Fields (PAFs) to detect up to

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135 keypoints, enabling robust joint tracking even in non-conventional clothing. However, its accuracy can degrade in low-light conditions or with occlusions. MediaPipe, used in our project, offers a lightweight alternative with improved computational efficiency, making it suitable for real-time applications on standard hardware. Viswakumar et al. (2022) explored MediaPipe for gait analysis in neurodegenerative diseases, reporting high intra- and inter-rater reliability for spatiotemporal parameters but highlighting challenges with small sample sizes and occlusion risks. Our project mitigates some of these issues by optimizing video processing with OpenCV and providing a user-friendly interface for physiotherapists to upload and analyze videos, ensuring practical deployment in diverse clinical settings.

Clinical Applications and AI Integration: Machine learning (ML) has enhanced gait analysis by enabling automated feature extraction and classification of gait abnormalities. A survey by Papavasileiou et al. (2022) identified six key applications of ML in gait studies, including health monitoring, pose tracking, and abnormal gait detection, with deep learning models extracting features from raw spatiotemporal data without extensive preprocessing. For instance, Costilla-Reyes et al. (2021) used deep learning to classify healthy versus pathological gaits, achieving high accuracy in detecting neurological disorders. While these studies focus on classification, our project emphasizes real-time detection and visualization of specific abnormalities (e.g., limping, slouch posture) using angle calculations from MediaPipe landmarks, directly supporting physiotherapists' diagnostic workflows. Additionally, wearable sensor-based systems, such as those reviewed by Muro-de-la-Herran et al. (2014), use accelerometers and gyroscopes for gait analysis but require patient compliance and specialized hardware, unlike our non-intrusive video-based approach.

Web-Based Systems for Clinical Use: Few studies have integrated gait analysis into accessible web platforms. Abu-Faraj et al. (2024) discussed the need for scalable, user-friendly systems to bridge the gap between advanced gait analysis and clinical practice, emphasizing the role of biomechanical modeling and data management. Our project addresses this by developing a Flask-based web application with a MySQL database, enabling physiotherapists to manage patient data, upload videos, and access detailed reports. This contrasts with standalone systems like OMGait, which, while affordable, lack integrated data management and reporting features. Our system's ability to log analysis results and generate filtered reports enhances longitudinal monitoring, a critical aspect of rehabilitation.

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