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Gait Based Human Identification: Using Deep Learning

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ABSTRACT :

Gait based human identification offers an effortless biometric solution using individuals unique walking patterns for identification and verification. This research develops a powerful system using deep learning methods to retrieve, interpret, and analyze gait features from video data. A multi-layer artificial neural network (ANN) is utilized, trained on the CASIA-B dataset, achieving high accuracy (97.13%) in different persons across a range of walking styles and environments. The system combines pose estimation via Mediapipe, automated feature extraction, and transfer learning for adaptability. Applications scope are surveillance, security, and forensic investigations. Results shows the model's scalability, reliability, and potential for real-world implementation.

Key Terms: Human Identification, Deep Learning, Biometric Authentication, Artificial Neural Networks (ANN).

1. INTRODUCTION

1.1. Biometric:

Biometric is an automatic method of identifying and verifying persons based on their unique physical or behavioral features. It involves using unique biological features like fingerprints, facial patterns, iris or retinal patterns, voice, hand shape, or walking style to determine a person's identity. Biometric systems extract these features, convert them into digital data, and store them for future comparison. By depending on biometrics, organizations can guarantee that only authorized individuals gain access to secure areas, systems, or services. Biometric authentication is considered more secure than traditional methods like passwords or ID cards because biometric patterns are difficult to forge or replicate.

1.2. Gait:

Gait refers to a person's unique way of walking or moving. It includes factors such as rhythm, stride length, speed, posture, and other attributes unique to every individual's walking pattern. Every individual has a unique gait influenced by factors like body structure, muscle strength, flexibility, and coordination.

1.3. Gait Analysis:

Gait analysis includes studying and calculating different factors related to how a person walks. It studies the movement of limbs, joints, and muscles during each step, providing understanding into biomechanics, balance, and potential abnormalities or physical challenges.

Gait analysis has both healthcare and general applications. In healthcare, medical professionals use it to diagnose and monitor conditions affecting gait, such as neurological diseases, orthopaedic injuries, or rehabilitation after surgery. It also assists in analysing the effect of treatments and approaches.

Other than healthcare applications, gait analysis is used in sports performance, biomechanics research, and forensic investigations. Athletes and coaches employ gait analysis to enhance performance, prevent injuries, and refine technique. Researchers uses it to study human movement and explore the mechanics of human movement. In forensic investigations, gait analysis assists in identifying individuals based on their unique walking patterns, particularly when other identification methods are challenging or unavailable.

Various techniques are integrated in gait analysis, varying from visual observation by trained experts to advanced methods like motion capture systems, force plates, wearable sensors, or computer vision algorithms. These technologies enable precise and detailed analysis of gait parameters, offering valuable information for a wide range of applications.

1.4. Biometric using Gait:

Biometric using gait analysis is the application of gait features as a biometric identifier, just like fingerprints or facial recognition. Gait biometrics utilize the unique features and patterns of an individual's gait to identify and authenticate their identity. This approach is based on the understanding that each person has a distinctive way of walking, including their stride length, step duration, body posture, and other gait parameters.

Gait analysis for biometric applications can be performed using different technologies, including video cameras, depth sensors, accelerometers, or pressure-sensitive Flooring. All these devices record and measure gait-related data, which is then processed and analyzed with the help of algorithms and pattern recognition techniques to extract unique features for identification.

Gait biometrics is a non-intrusive and can be captured remotely, which makes it appropriate for surveillance and access control. Its resistance to spoofing adds an extra layer of security compared to other biometric techniques. It finds applications in security, law enforcement, and forensics.

On the other hand some limitations do occur. Factors such as the type of shoes that are worn, conditions of the surface, or sickness may interfere with accuracy. Biometric methods or assistive measures may enhance reliability.

Overall, gait biometrics provides a non-intrusive and dependable means of identification from a person's unique walking style. Some of its uses include forensics, law enforcement, and security, offering further levels of protection and supporting investigations.

2. Advantages and Disadvantages of Gait Analysis:

2.1. Advantages of Gait Biometrics:

1. Non-intrusive: Gait biometrics can be recorded from a distance without the need of physical contact, making it a non-intrusive biometric technique. People can be identified without their knowledge or involvement, making it suitable for applications such as surveillance or access control.
2. Difficult to Spoof: It is difficult to perfectly replicate someone's unique way of walking, therefore making gait biometrics impression- or spoof-resistant. This adds an additional layer of security and is spoof-proof.
3. Availability: Gait biometrics can be recorded through security camera networks, so it's easily available and deployable in most environments without the need for special hardware or sensors. This makes it cost-effective and easy to use.

2.2. Disadvantages of Gait Biometrics:

1. Variation in Gait: Gait can be influenced by changes in footwear, walking surfaces, or medical conditions. These changes may affect the accuracy of gait biometrics, which could result in false positives or negatives. Consistent recognition performance across various situations can be difficult to maintain.
2. Environmental Factors: Environmental conditions, including lighting, camera positions, or obstacles in the line of sight, can affect gait biometrics. These factors can introduce noise or distortions in the recorded gait data, which could impact recognition accuracy.
3. Range of Identification: Gait biometrics may have limitations in terms of the distance at which gait can be accurately captured and recognized. In some cases, getting clear and reliable gait data might involve having people within a particular range or walking towards them straightaway in the direction of the camera, which may restrict its practicality in some uses.

3. Challenges:

1. Dataset Collection: It is challenging to obtain a representative and diverse dataset for gait identification due to factors such as the collection of consent, recording gait data across varied environments, and maintaining demographic equality.

2. Same-group Variation: Gait patterns vary within individuals due to factors like walking speed, footwear, and physical conditions. Dealing with intra-class variability is essential to build a reliable gait identification model.

3. Environmental Factors: Gait is affected by environmental factors like lighting and walking surfaces, which add noise and impact recognition accuracy. Designing algorithms that are insensitive to environmental changes is a challenge.

4. Feature Extraction: Informational extraction features extracted from gait data is important for efficient identification. However, identifying relevant features that embrace distinctive elements of gait while reducing irrelevant variations is a complicated task.

5. Machine Learning Models: Selection of appropriate models for gait identification capable of capturing temporal dependencies is crucial. Modelling models that learn from gait sequences and generalize effectively is a challenge.

6. Limited Training Data: Acquiring a large, labelled dataset for gait identification is difficult, resulting in potential overfitting or inadequate generalization. Addressing the impact of limited training data is a challenge.

7. Ethical Considerations: Privacy and consent are ethical concerns in gait-based identification. Ensuring responsible data collection, storage, and usage practices are essential.

4. Gait analysis approach:

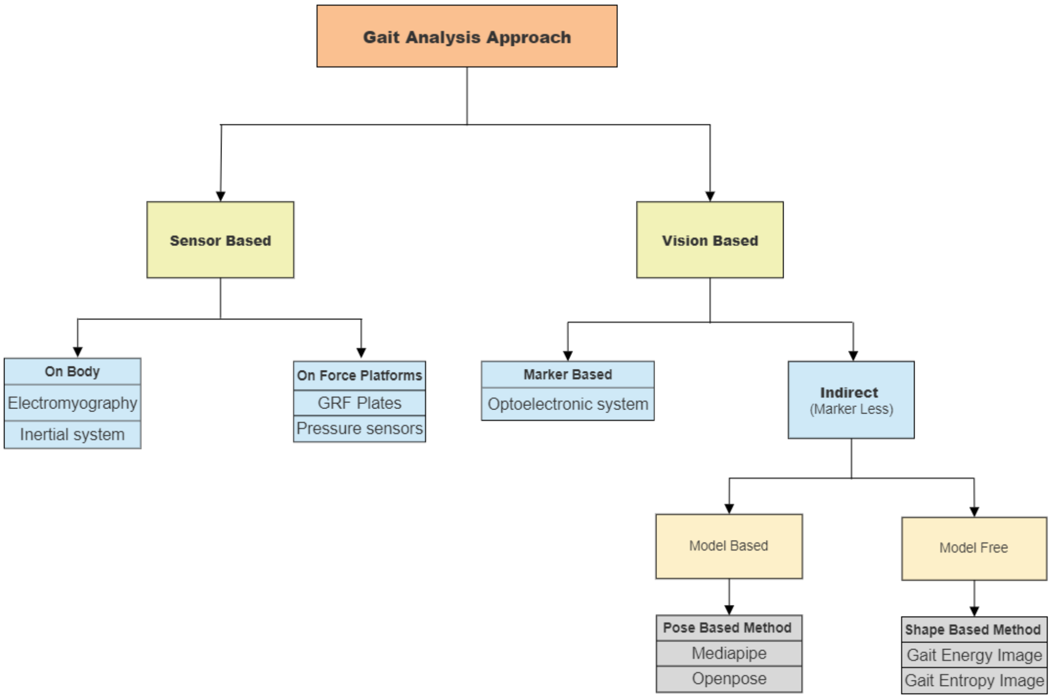

Fig 1: Gait analysis approach.

Two major ways of conducting gait analysis include vision-based and sensor-based.

4.1. Sensor-Based Gait Analysis:

A. On-Body Sensors:

Has electromyography (EMG) to record muscle activity and inertial systems (IMUs) to record joint angles, segment orientations, and walking movement dynamics.

B. On-Force Platform:

Includes force recording during walking.

i. Ground Reaction Force (GRF) Plates:

Built-in force plates that capture ground reaction forces and moments induced by the feet, offering information on gait symmetry, balance, and foot function.

ii. Pressure Sensors:

Insole or platform embedded to quantify pressure distribution applied by the feet, examining foot mechanics, weight-bearing symmetry, and gait abnormalities.

4.2. Vision-Based Gait Analysis:

A. Marker-Based:

Uses reflective markers and optoelectronic systems to track body movements in three-dimensional space, providing accurate measurements of joint angles, segment movements, and temporal parameters of gait.

B. Indirect (Marker Less):

Relies on computer vision algorithms to analyze gait patterns without markers.

i. Model-Based:

Utilizes mathematical or biomechanical models to estimate joint angles and segment movements based on body landmarks.

ii. Model-Free:

Extracts features from the shape or contour of body segments during gait without explicit modeling.

These approaches provide valuable information for analyzing gait biomechanics, identifying abnormalities, assessing functional limitations, and developing targeted interventions. Vision-based analysis offers precise tracking and flexibility through marker-based and indirect methods, while sensor-based analysis provides quantitative measurements through on-body sensors and on-force platforms. By combining these approaches, researchers can gain comprehensive insights into human gait, enabling advancements in rehabilitation, performance enhancement, and clinical diagnosis.

4.3. Model-Based approach:

The model-based approach in gait-based human identification involves creating mathematical or statistical models that represent an individual's unique gait pattern. These models capture the underlying structure and dynamics of gait using equations or statistical parameters. They offer interpretability, insights into the mechanics of gait, and the ability to incorporate additional information such as joint angles or ground reaction forces. However, challenges exist in accurately capturing the complexity of gait in real-world scenarios, requiring careful calibration and validation.

The model-based approach has practical applications in surveillance, access control, and forensic investigations. By analyzing gait patterns, these models enable identification based on distinct features, offering an alternative when other biometric modalities may not be applicable or reliable. Overall, the model-based approach in gait-based human identification provides a framework to develop robust gait identification systems by representing gait patterns mathematically or statistically.

4.4. Pose estimation:

Pose estimation is the process of figuring out an item or person's orientation and position within a scene. Pose estimation is a technique used in computer vision to monitor the movement and position of individuals, animals, or objects in a video stream or series of images.

Pose estimation may be done in a variety of ways, but one well-liked option is to employ deep learning-based models, such as convolutional neural networks (CNNs), which can learn to identify the important landmarks or key points on the item or person of interest. The stance of the item or person may therefore be inferred from these essential characteristics.

Depending on the particular technique employed, pose estimation mathematics may be required. However, a few typical methods are as follows:

1. Image preprocessing: entails performing different changes, such as scaling, cropping, and normalisation, to the incoming picture or video stream.
2. Feature detection: Identifying important aspects in a picture that may be utilised to estimate a posture is known as feature detection. For instance, in the estimate of human poses, these traits may include body joints like the shoulders, elbows, and knees.
3. Feature matching: Finding the same features in several pictures or frames of a video stream is called feature matching. Techniques like feature tracking and optical flow can be used for this.
4. Pose estimation: It is the process of estimating the posture of an item or person using characteristics that have been recognised and matched. Numerous methods, including inverse kinematics, bundle adjustment, and optimisation, can be used to accomplish this.
5. Evaluation: This entails assessing the posture estimation method's correctness. Several metrics, including mean average precision (mAP) and mean squared error (MSE), can be used to accomplish this.

A mixture of computer vision, machine learning, and mathematics are all used in the complicated and multidisciplinary topic of posture estimation. posture estimation methodologies, feature identification and matching algorithms, data preparation, and results assessment must all be carefully taken into account for posture estimation approaches to be successful.

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4.5. Working of Pose Estimation:

There are several pose estimation methods, but one of the most common methods is a deep learning-based method, i.e., convolutional neural networks (CNNs). CNNs are a type of artificial neural network that is particularly well adapted to image processing and feature extraction.

Here, a CNN is learned on a set of images with labeled pose data. The CNN identifies features from the images relevant to the pose, e.g., the location of the joints of a human body or the vertices of an object. The trained CNN can then be utilized to predict the pose of a novel image.

The pose estimation process usually includes a number of steps:

1. Detection of an object or a person in a frame of image or video.
2. Feature extraction: Get the features of the object relevant to its position, e.g., joints or corners.
3. Pose estimation: Employ the features extracted to estimate the position and orientation of the object in 3D space.
4. Tracking: Track the pose of the object as it moves across the image or video frames.

Pose estimation is possible using a single image or a sequence of pictures (video). When it comes to video, pose estimation may be further refined by considering temporal information so that the movement of the object over time can be followed.

There are a number of mathematical equations that are engaged in pose estimation, depending on the actual algorithm or process being employed. Here are a few of the most important formulas engaged in pose estimation:

Perspective projection:

Given a 3D point P = (X, Y, Z) in the camera
coordinates and a given projection matrix P, the corresponding point on the image coordinate is expressed by:

css

[u v w] ^ T = P * [X Y Z 1] ^ T

x = u / w, y = v / w

where (x, y) are the coordinates of the projected point on the image plane.

Perspective distortion:

The perspective distortion caused by the camera can be modelled by a perspective transformation matrix H:

bash

[x' y' w'] ^ T = H * [x y 1] ^ T

where (x, y) are the original 2D image coordinates, and (x', y') are the transformed coordinates.

Nonlinear optimization:

Nonlinear optimization is used to minimize the error between the observed 2D features and the predicted 2D features obtained by projecting the 3D points onto the image plane. The optimization problem can be formulated as:

scss

argmin_P E(P)

where P is the pose parameters, and E(P) is the error function, which is used to measure the difference between the observed 2D features and the predicted 2D features. The optimization can be solved using techniques such as Levenberg-Marquardt or Gauss-Newton.

4.6. Pose estimation using mediapipe:

MediaPipe is a library for pose estimation developed by Google. The MediaPipe Pose Landmarker task allows us to identify the landmarks of human bodies in an image. We can use this task to identify key body locations and render visual effects on them. This task uses machine learning (ML) models that can work with single images or a continuous stream of images. The task outputs body pose landmarks in image coordinates and in 3-dimensional (x, y, z) world coordinates. It gives the 33 key body locations in 3-dimension.

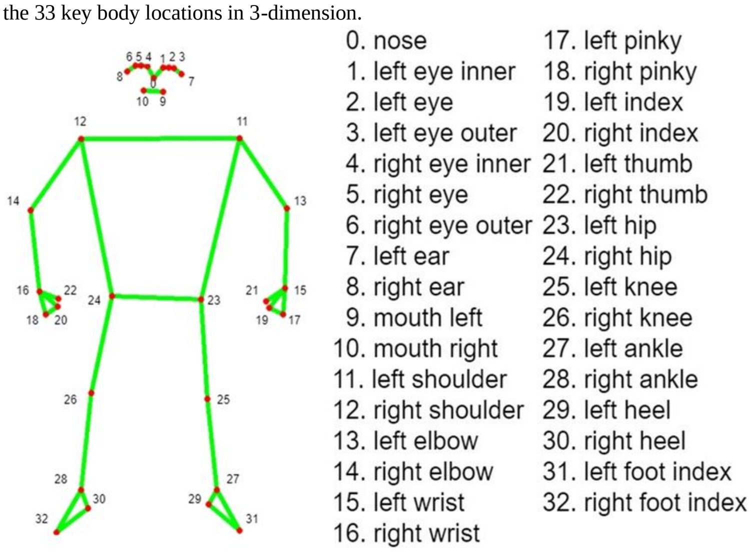

Fig 2: Key location spotted by Mediapipe library.

4.7. ANN:

The biological neural networks in the human brain served as the basis for the development of artificial neural networks (ANNs), a kind of machine learning model. Applications for ANNs include time-series analysis, natural language processing, and picture recognition. Gait characteristics acquired from movies or other sensor data are frequently analyzed using ANNs in the context of gait-based human identification.

A branch of machine learning known as deep learning uses ANNs with several layers to extract complicated patterns and representations from data. Applications like image recognition, audio recognition, and natural language processing have seen the most success with deep learning.

Using deep learning methods, a deep neural network is taught to recognize people based on the characteristics of their stride. Typically, computer vision techniques like pose estimation or motion analysis are used to extract the gait features from video data. A deep neural network is then trained to correlate particular gait traits with particular people using the retrieved features as its input.

Multiple layers of neurons typically make up the deep neural network architecture used for gait-based human identification. While the output layer generates the classification result (i.e., the identification of the person), the input layer gets the gait characteristics retrieved from the video data. The hidden layers, which sit between the input and output layers, get smarter with time.

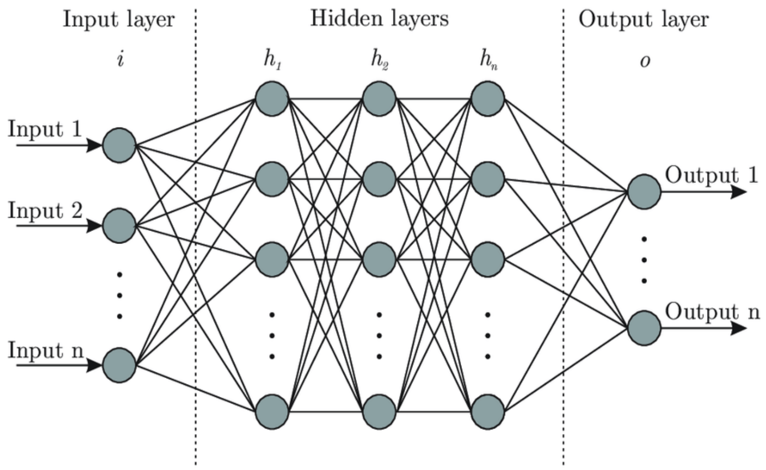

Fig 3: Architecture of ANN.

In order to reduce the discrepancy between the anticipated output and the actual output for a set of training examples, the weights and biases of the neurons in each layer must be optimized during the training of a deep neural network. Backpropagation is a common algorithm used for this, which determines the gradient of the loss function with respect to the network parameters and modifies the parameters in the direction that minimizes the loss.

5. CONCLUSIONS:

The research investigates a strong gait-based human identification system through deep learning methods. By leveraging unique walking patterns as a biometric, the study achieves a highly accurate, non-intrusive, and scalable solution for human identification. With the CASIA-B dataset and pose estimation models such as Mediapipe, the model proves flexible and effective in a wide range of conditions. ANN structure and transfer learning are used in the system for solving problems like intra-class variability and conditions.

Applications range from security, surveillance, and healthcare to showing potential for real-world deployment. Although promising, the future will involve focusing on enhancing robustness, expanding datasets, and solving ethical problems like data privacy.

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