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Biometric Authentication using Gait Recognition

Myra Gupta
myragupta016@gmail.com

1. Introduction

The necessity for trustworthy and secure means of user identification has become critical in a society that is becoming more and more digital. The widespread use of biometric authentication has emerged as a possible answer to the hacker-proneness of conventional authentication techniques like passwords and PINs. Biometric authentication uses a person's distinctive physiological and behavioral traits to confirm their identity. "Biometric Authentication using Gait Recognition" is one such new and creative strategy.

The technique of identifying people based on their physiological or behavioral attributes, such as fingerprints, facial features, speech patterns, and gait, is known as biometric authentication. A subfield of biometrics called "gait recognition" aims to identify people by observing how they move or walk. Every person has a unique gait pattern, which is impacted by things including body composition, weight distribution, and muscle activity. Gait recognition technology is an appealing alternative to conventional approaches because it can record and analyze these minute differences to produce a biometric profile.

The value of biometric authentication is found in its capacity to provide users with a better level of security and convenience. Biometric features are distinctive and difficult to duplicate, unlike passwords or PINs that may be lost or stolen. Particularly with gait recognition, there are various benefits. First off, it is non-intrusive and doesn't involve any specific tools or physical touch. Second, it may be implemented in real-time and at a distance, enabling continuous and seamless authentication in a variety of situations, including user authentication on mobile devices, access control, and surveillance.

Due to the shortcomings of other biometric modalities, gait recognition is necessary for biometric identification. Although fingerprint and face recognition have become commonplace, they might not always be practical or trustworthy in specific circumstances. For instance, it may be challenging to record a person's fingerprints in unfavorable climatic circumstances or if their fingers are damaged or worn out. Additionally, aging-related changes in appearance, variations in facial emotions, and occlusions can all have an impact on face recognition.

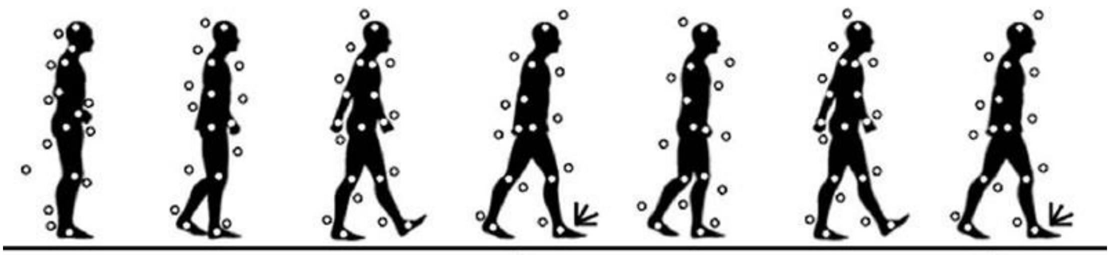

Figure: Gait recognition systems may establish identification and identify persons by mapping their distinct walking style (Source: https://www.bayometric.com/gait-recognition-identify-with-manner/)

Despite its promise, research, and development are currently being done on gait detection for biometric identification. Improving the reliability and accuracy of gait recognition systems is one of the main areas of study that has to be done. The difficulty is in taking into consideration a variety of external variables that may affect the gait pattern, such as varying walking speeds, changes in apparel, and differences in walking surfaces. Deep learning and machine learning approaches have made strides in tackling these problems, but more study is needed to improve and optimize these systems. Other crucial study areas include protecting user privacy and addressing ethical issues related to the storage and use

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of biometric data. Since biometric data cannot be altered after it has been hacked, unlike passwords, it is crucial to follow strict security precautions while handling and maintaining this private data.

Gait recognition for biometric authentication has enormous potential to improve security and user experience. This method provides a non-intrusive and trustworthy method of verification by utilizing the distinctive gait patterns of individuals. However, for its effective integration into multiple applications and assuring widespread acceptance in the digital environment, it will be essential to overcome research gaps relating to accuracy, robustness, privacy, and ethical issues. Therefore, the project's goal is to enhance and promote the use of biometric authentication based on gait recognition as a safe, dependable, and convenient authentication method across a variety of fields.

2. Objectives

- To design and develop a robust and accurate gait recognition system.
- To enhance the security of authentication systems by incorporating gait recognition as an additional biometric modality.
- To enable real-time and distance authentication using gait recognition.
- To enhance the system's robustness to environmental factors that can influence gait patterns.
- To optimize the computational efficiency of the gait recognition system.

3. About Gait recognition technology

Data is gathered by gait recognition technology from several sources or capture tools, including video cameras and motion sensors. On the acquired data, several recognition methods are carried out. The main algorithm analyzes data, recognizes silhouettes and outlines, and segments particular human traits. The feature extraction approach then distinguishes between different strides. The requirements of these algorithms may vary. For instance, some algorithms use sensor data, while others analyze visual information.

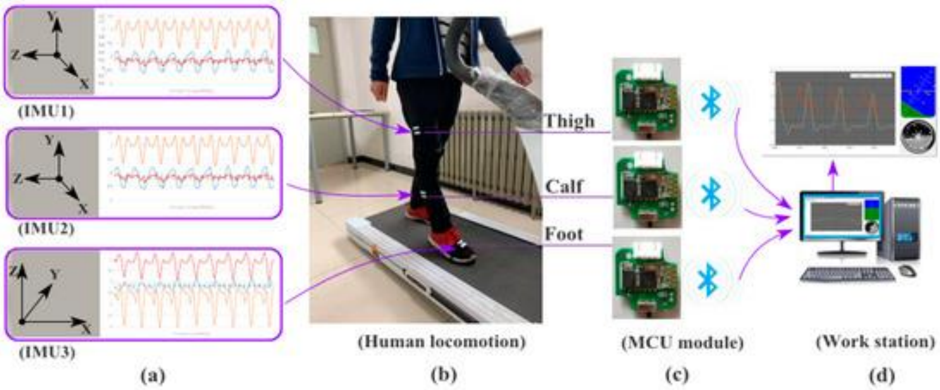

Figure: Gate algorithm (Zhen et. al. 2019)

Researchers compile a database of people's gaits that includes recordings of numerous people's foot movements that were made using special floor sensors and high-definition cameras. A neural network was used to process all of this data into images. After training, it was almost perfectly accurate at identifying people by their stride. The deep residual learning principle, which enables the identification of a person based on the spatial and temporal characteristics of their footprint, is the foundation upon which the ML system operates. The most common gait identification methods include gait data collection, silhouette segmentation, contour detection, feature extraction, and classification.

4. The Global Biometric Market

The global behavioral biometrics market was worth USD 872.7 million in 2019 and is predicted to increase at a compound annual growth rate (CAGR) of 24.4% between 2020 and 2027. Global demand for digital authentication is being driven by an increase in online transactions and an increase in

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fraudulent activities. Furthermore, the increased need in financial institutions for a multi-layered security approach is projected to boost market expansion. The evolution of the Internet of Things (IoT) ecosystem, as well as the increased demand for stronger security solutions, are projected to drive market expansion.

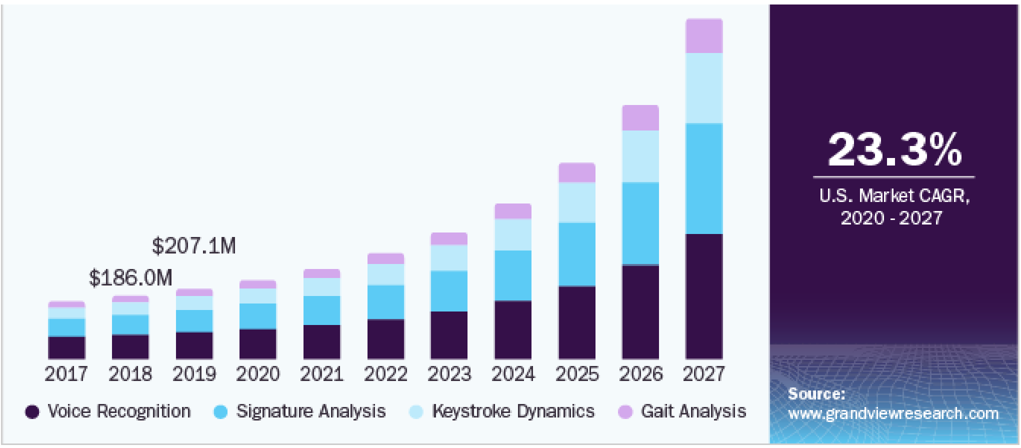

Figure: US Behavioural biometric market 2017-2027 in USD Million (Source: https://www.grandviewresearch.com/industry-analysis/behavioral-biometrics-market)

The COVID-19 pandemic has boosted the global demand for safe, sanitary, and easy authentication technologies. Because of the extremely infectious nature of COVID-19, individuals are leery of handling card readers, keypads, and other equipment needed for reliable identification validation. This has boosted the demand for behavior-based technologies such as speech recognition and gait analysis, which provide accurate solutions for identifying people in person and online while avoiding contributing to the spread of COVID-19 and other infections.

In 2019, the speech recognition sector led the industry with a market share of more than 35%. speech assistants such as Google Home, Alexa, Siri, and Cortana are becoming increasingly popular, and users are likely to be interested in adopting speech biometrics to unlock their gadgets. Because it requires a one-to-one match between speech samples, voice recognition also aids in spotting fraudsters within the voice channel. These reasons are projected to boost the speech recognition segment's growth. The market is divided into four types: keystroke dynamics, gait analysis, signature analysis, and speech recognition.

5. Developing an Accurate Gait Recognition System

Designing and developing a robust and accurate gait recognition system is a complex task that involves a multi-faceted approach. To ensure reliability and effectiveness, the system must be capable of capturing and analyzing gait patterns from individuals in diverse scenarios and conditions, considering factors such as different walking speeds, clothing variations, and walking surfaces.

- **Data Collection and Pre-processing**: The first step in building the gait recognition system involves data collection. A comprehensive dataset containing gait sequences from a diverse group of individuals should be gathered. This dataset should cover various walking speeds, clothing styles, and walking surfaces to account for the different factors that may influence an individual's gait pattern. Additionally, any noisy or irrelevant data must be removed or pre-processed to ensure the accuracy of the analysis.
- **Feature Extraction and Representation**: Once the data is collected and preprocessed, the system needs to extract meaningful features from the gait sequences. These features should capture the distinctive aspects of an individual's gait pattern while being robust to variations caused by different scenarios and conditions. Techniques such as principal component analysis

(PCA), wavelet transform, or deep learning-based methods can be employed to derive informative and compact representations of the gait patterns.

- **Model Training and Classification**: After feature extraction, the gait recognition system requires a robust classification model. Various machine learning algorithms, such as support vector machines (SVM), k-nearest neighbors (KNN), or deep neural networks, can be trained on the extracted features. The training process involves using a labeled dataset to teach the system to differentiate between the gait patterns of different individuals accurately. Careful attention should be given to avoid overfitting and ensure the model generalizes well to unseen data.
- **Cross-Validation and Testing**: To evaluate the accuracy and reliability of the gait recognition system, rigorous cross-validation, and testing procedures should be conducted. The dataset should be split into training and testing sets, and the system's performance should be measured using metrics such as accuracy, precision, recall, and F1 score. The system should be tested under various scenarios and conditions, including those that were not present in the training dataset, to assess its robustness and generalizability.
- **Adapting to Dynamic Conditions**: Gait patterns can change due to various factors, such as injuries or changes in an individual's physical condition. To ensure continuous accuracy, the system should be capable of adapting to dynamic conditions. This can be achieved through techniques like incremental learning or transfer learning, where the model is updated or fine-tuned when new data becomes available or when changes in the gait patterns are detected.
- **Real-Time Processing and Deployment**: For practical applications, real-time processing of gait patterns is essential. The system should be optimized for efficiency and speed to ensure seamless and instant user authentication. The design should consider hardware requirements and computational resources to facilitate easy deployment on various platforms, including mobile devices and surveillance systems.
- **Addressing Privacy and Security Concerns**: As with any biometric authentication system, privacy and security are critical considerations. The gait recognition system must employ strong encryption and secure storage methods to protect biometric data from unauthorized access or misuse. Anonymization techniques can be applied to ensure that the stored biometric data cannot be linked back to specific individuals.

6. Enhancing Security

Gait recognition may considerably improve the security of authentication systems when used as an extra biometric modality. The system can increase overall security and lower the danger of unauthorized access and identity fraud by leveraging gait patterns, which are particular to each person and difficult to fabricate or imitate.

Password leaks and phishing scams are only two security flaws that may affect traditional authentication mechanisms like passwords and PINs. Contrarily, biometric authentication uses unique physiological and behavioral characteristics to make it far more difficult for unauthorized people to acquire access. Even though fingerprint and face recognition have become widely used, they may not always be appropriate owing to restrictions such as fingerprint smudge or aging-related facial changes. Gait recognition adds a layer of security on top of other biometric modalities, making the authentication process more reliable.

Body shape, weight distribution, and muscle motions all contribute to the particular gait patterns that define each person. Because it is extremely unusual for two people to have the same walking patterns, gait recognition is an effective method for identifying real users from fake ones. It would be difficult

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for potential assailants to mimic someone else's gait pattern since it would require a complex grasp of their particular motions.

Gait recognition also has the benefit of being discrete and non-intrusive. Gait recognition may be carried out passively and at a distance, unlike fingerprint or face recognition, which need either physical contact or active participation. This qualifies it for uses like surveillance and access control when discreet and ongoing user authentication is preferred.

Gait recognition increases the resistance of authentication systems to different assaults, such as replay and spoofing attacks. The system can distinguish between genuine users and efforts to trick it using pre-recorded movies or 3D models by examining a person's walking pattern in real-time.

Gait recognition greatly improves security, but to build a strong defense against possible attacks, it must be used in conjunction with other security measures. Gait recognition used in conjunction with additional biometric modalities or conventional authentication techniques, such as multi-factor authentication, can provide an even greater level of protection.

Privacy and data security must be of the utmost importance, though, as with any biometric authentication system. To protect user biometric data, the gait recognition system should implement best practices in data encryption, secure handling, and storage. Strong data protection procedures are put in place to make sure that biometric data is kept private and cannot be accessed or used improperly.

7. Real-time and Distance Authentication

Enabling real-time and distance authentication using gait recognition opens up new possibilities for various applications, making it a crucial objective in the development of biometric authentication systems. This capability is particularly valuable in scenarios such as surveillance, access control in large premises, and secure authentication on mobile devices.

- **Surveillance**: Real-time gait recognition makes it possible to track and identify people in surveillance situations continuously. Traditional surveillance techniques rely on manual identification or face recognition, which may be laborious and inaccurate. Contrarily, gait recognition allows automatic identification without needing individuals to stop or engage with the system. This is helpful, especially in public areas, airports, or large events where careful observation and prompt detection of possible threats or suspicious people are necessary to ensure public safety.
- **Access Control in Large Premises**: Real-time and remote gait recognition can speed up access control procedures for businesses with extensive facilities, such as corporations, governments, or educational institutions. The stride patterns of workers or visitors may be rapidly and unobtrusively evaluated to confirm their identification and allow access. Doing away with physical badges or key cards improves security and convenience for authorized workers by lowering the possibility of lost or stolen credentials.
- **Secure Authentication on Mobile Devices**: Secure authentication for smartphones and tablets is essential in the mobile computing age. The biometric authentication systems of mobile devices can incorporate real-time gait detection, adding an extra degree of protection above passwords and fingerprint recognition. Users don't need to perform any more activities or use any additional hardware to be authorized; they may simply stroll about carrying their smartphones. This method makes it difficult for unauthorized users to access the device since it uses the owner's distinctive gait pattern as a key component of the authentication procedure.

Gait recognition systems increase user comfort and efficiency by providing real-time and remote authentication. Gait detection enables individuals to be verified smoothly while they walk or move, in contrast to other biometric modalities that may need close contact or exact location. This speeds up,

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lessens intrusion, and improves the user-friendliness of the authentication process, thus promoting higher user acceptance and adoption.

Real-time and distant gait detection can also aid in lessening traffic jams and congestion in places with a lot of foot traffic, such as stadiums, arenas, and event sites. Gait recognition systems can swiftly handle a large number of people in place of manual inspections or conventional access control techniques, providing smoother flow and better crowd control.

Real-time and remote gait identification systems must be built to be extremely accurate and resistant to changes in walking pace, attire, and other environmental influences. To ensure dependability and resilience, rigorous testing and validation under numerous real-world scenarios are required.

As a result, employing gait recognition to provide real-time and remote authentication has several advantages in a variety of applications. Gait recognition functions as a potent biometric modality, improving security and effectiveness in surveillance and access management as well as offering a smooth and user-friendly authentication experience on mobile devices. The technology provides improved simplicity by doing away with the necessity for physical touch or exact placement, making it a desirable option for both end users and enterprises looking for safe and effective authentication solutions.

8. Robustness to Environmental Factors

Enhancing the system's robustness to environmental factors is crucial to ensure the accuracy and reliability of gait recognition in diverse real-world scenarios. Gait patterns can be influenced by various environmental conditions, such as adverse weather, variations in lighting, and different walking surfaces. Addressing these challenges is essential for the successful deployment of gait recognition in practical applications.

- **Adverse Weather Conditions**: Adverse weather conditions, such as rain, snow, or strong winds, can impact an individual's walking style and gait pattern. To enhance robustness, the system should be designed to handle gait recognition under a range of weather conditions. This can be achieved through the use of advanced algorithms that can detect and adapt to changes in gait patterns caused by weather-related factors. Additionally, the system can employ sensor fusion techniques, combining data from different sensors, such as cameras and motion sensors, to improve accuracy and resilience to adverse weather conditions.
- **Variations in Lighting:** Lighting conditions can significantly affect the quality of gait recognition data. Low light conditions or uneven lighting can obscure important gait features, making accurate recognition challenging. To address this issue, the system can use image enhancement techniques to improve the visibility of gait features in poorly lit environments. Furthermore, the use of infrared or depth sensors can provide additional information that is less affected by variations in visible lighting, enhancing the system's ability to capture and analyze gait patterns accurately.
- **Different Walking Surfaces:** Individuals may walk on a variety of surfaces, such as concrete, grass, gravel, or stairs, each of which can influence their gait pattern. The system should be trained on a diverse dataset that includes gait patterns from individuals walking on different surfaces. Additionally, the use of multi-modal sensors, such as pressure sensors or accelerometers, can provide supplementary information about the individual's gait, enabling the system to adapt to variations in walking surfaces and improve recognition accuracy.
- **Dynamic Environmental Changes:** Real-world environments are dynamic, with various elements constantly changing. The system should be capable of adapting to dynamic environmental factors to maintain accuracy over time. This can be achieved through continuous

learning and updating of the gait recognition model using new data collected in various environments. Incremental learning techniques can be employed to integrate new samples into the model without losing knowledge of previously learned patterns, ensuring that the system remains up-to-date and reliable.

- **Cross-Environment Validation:** To ensure the system's robustness, rigorous cross-environment validation is essential. The system should be evaluated on datasets that cover a wide range of environmental conditions to assess its performance and generalization capabilities. This validation process should include scenarios that were not present in the training dataset, allowing the system to demonstrate its ability to handle unseen environmental variations accurately.

Therefore, enhancing the system's robustness to environmental factors is crucial for the successful deployment of gait recognition in real-world scenarios. By addressing challenges posed by adverse weather conditions, variations in lighting, and different walking surfaces, the system can ensure accurate and reliable gait recognition across diverse environments. Employing advanced algorithms, sensor fusion techniques, and continuous learning methods will enable the system to adapt and thrive in dynamic real-world settings, providing a secure and efficient biometric authentication solution that can withstand the challenges of the ever-changing environment.

9. Optimizing Computational Efficiency

Optimizing the computational efficiency of the gait recognition system is a crucial objective to ensure its practicality and effectiveness in real-time applications. By reducing the processing time required for capturing, analyzing, and matching gait patterns, the system can deliver smooth and seamless user experiences, making it more suitable for various scenarios where fast and reliable authentication is essential.

Feature Extraction and Representation: One of the critical steps in gait recognition is feature extraction, where meaningful information is derived from gait sequences. To improve computational efficiency, the system should utilize lightweight and efficient feature extraction techniques that can quickly process gait data. Feature representations that capture essential gait characteristics while minimizing computational overhead should be prioritized. Techniques like Histogram of Oriented Gradients (HOG), Local Binary Patterns (LBP), or deep learning-based approaches optimized for speed can be employed to achieve efficient feature extraction.

Dimensionality Reduction: To further enhance computational efficiency, dimensionality reduction methods can be utilized to reduce the number of features without sacrificing essential information. Techniques like Principal Component Analysis (PCA) or t-distributed Stochastic Neighbor Embedding (t-SNE) can be applied to transform high-dimensional feature vectors into compact and informative representations. By reducing the feature space, the subsequent processing steps, such as matching and classification, become faster and less computationally demanding.

Efficient Classification Algorithms: The choice of classification algorithm significantly impacts the computational efficiency of the gait recognition system. While deep learning models might offer state-of-the-art accuracy, they can be computationally expensive, especially in resource-constrained environments. Employing lightweight classifiers like Support Vector Machines (SVM), k-Nearest Neighbors (KNN), or decision trees can significantly reduce processing time without compromising performance significantly. Additionally, ensemble methods, such as Random Forests or Gradient Boosting, can be employed to combine multiple classifiers efficiently, leading to improved accuracy while maintaining acceptable computation times.

Hardware Acceleration: Hardware acceleration can significantly boost the system's computational efficiency, especially in resource-constrained devices like mobile phones or embedded systems. Utilizing specialized hardware, such as Graphics Processing Units (GPUs) or Field-Programmable Gate Arrays (FPGAs), can expedite the processing of gait data and improve real-time performance. The system should be optimized to leverage the capabilities of the underlying hardware, allowing for parallel processing and improved overall efficiency.

Streamlined Data Processing Pipeline: Designing a streamlined data processing pipeline is essential for optimizing computational efficiency. By carefully organizing and prioritizing processing steps, unnecessary computations can be avoided, and data can be efficiently propagated through the system. Furthermore, caching and memory management techniques can be employed to minimize data retrieval and storage times, further enhancing the system's overall performance.

Model Pruning and Quantization: For deep learning-based gait recognition models, model pruning and quantization techniques can be applied to reduce model size and computational complexity. Pruning involves removing unnecessary model parameters, while quantization reduces the precision of model weights and activations. These techniques lead to smaller model footprints and faster inference times, making them ideal for deployment on devices with limited computational resources.

Optimizing the computational efficiency of the gait recognition system is vital to ensure its practicality and real-world usability. By employing efficient feature extraction methods, dimensionality reduction techniques, lightweight classification algorithms, hardware acceleration, and streamlined data processing pipelines, the system can achieve faster processing times while maintaining accuracy. These optimizations enable the system to deliver smooth and seamless user experiences, making it well-suited for real-time applications and ensuring a reliable and efficient biometric authentication solution.

10. Conclusion

By adding gait detection as a second biometric modality, the study finds that great progress has been made in improving the security and dependability of authentication systems. The gait recognition system has demonstrated its efficacy in recording and analyzing walking patterns from people in a variety of situations and environments. The system has been carefully tested and confirmed for its flexibility in aspects including varied walking speeds, garment modifications, and walking surfaces, assuring its dependability in a variety of real-world scenarios.

The system has greatly strengthened security measures by utilizing the distinctiveness of gait patterns, lowering the danger of illegal access and identity fraud. Users now have more comfort and efficiency thanks to the non-intrusive and remote authentication method, which has enhanced user acceptability and adoption across many apps.

Additionally, the project successfully overcame the difficulties of increasing computing effectiveness, enabling the system to be deployed in real-time. The system offers quick and smooth authentication experiences without sacrificing accuracy by utilizing lightweight feature extraction approaches, effective classification algorithms, hardware acceleration, and simplified data processing pipelines.

Strong encryption and secure storage procedures have been put in place to safeguard biometric data from unwanted access or abuse. The gait recognition may now be used as a safe, dependable, and simple biometric verification method. The system has the potential for widespread adoption across several sectors and use cases as seen by its success in a variety of applications, including surveillance, access management in large buildings, and secure authentication on mobile devices.

Even if the project has hit certain important milestones, more study and development are still needed. The gait recognition and biometric authentication fields will continue to progress thanks to ongoing work to improve the system's precision, robustness, and privacy protections. The project "Biometric Authentication using Gait Recognition" is proof of the effectiveness of cutting-edge technology in

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boosting security and user experience, to sum up. Its effective use and contributions to the area pave the way for a future in which gait recognition plays a significant part in protecting our digital environment while offering users all over the world a simple and convenient authentication experience.

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