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A Review on Human Gait Detection

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Abstract- The human gait is the identification of human locomotive based on limbs position or action. The tracking of human gait can help in various applications like normal and abnormal gait, fall detection, gender detection, age detection, biometrics and in some terrorist and criminal activity detection. The present work carried out is a review of various methodologies employed in human gait detection. The analysis describes that the different feature extraction and machine learning techniques to be adopted for the identification of human gait based on the purpose of the application.

Keywords: human gait, biometrics, machine learning techniques, feature extraction.

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Keywords: human gait, biometrics, machine learning techniques, feature extraction.

I. Introduction

Human gait describes bipedal, biphasic forward propulsion of the center of gravity of the human body which involves the movement of various parts of the body without any additional energy requirement. The gait pattern can be categorized based on the different limb movement.

The presented work is a survey carried out on human gait. The general steps involved in the human gait detection are the background subtraction, silhouette extraction, feature extraction and classification of gait based on the objective of the respective work carried out. On the whole, the gait detection can be generalized and can be represented pictorially as shown in figure 1.

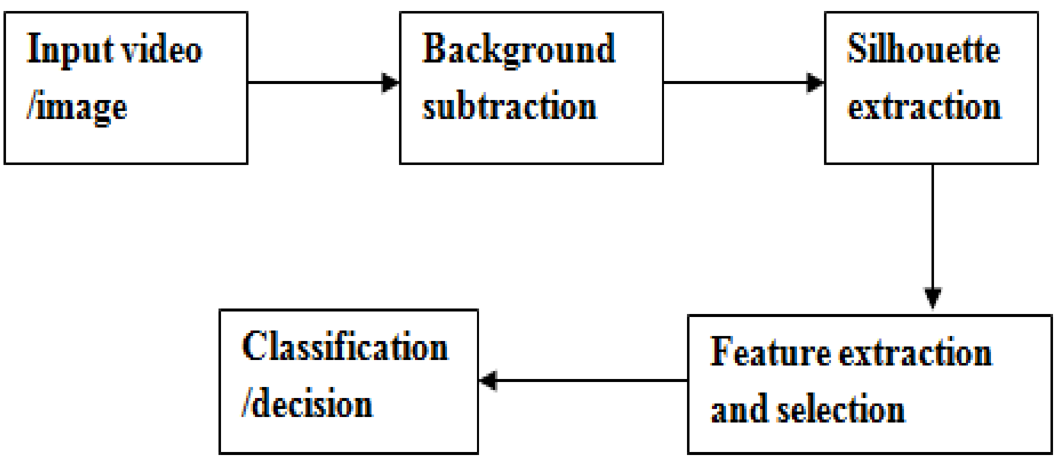

Figure 1: General Block diagram of a gait recognition system

The input to the gait recognition system is the video or the image captured from the camera. If video is the input, then it is subdivided into various frames and used as input to the gait recognition system. From the obtained image or video frame, the background is eliminated using some background subtraction methods. From that image, silhouette is extracted.

The silhouette extraction involves various methods like background subtraction, shadow removal, some morphological processes, etc. From the obtained silhouette the features are extracted. The extracted features are stride length, height, joint angle, etc. The complex feature extraction methods like PCA, LDA are used to extract prominent and essential features. The features selected play an important role in classification to make a decision of gait whether it is normal or abnormal.

II. Related Work

Kalyan Sasidhar and Satyam Satyajeet [1] proposed a wearable Smartphone based gait recognition system to detect normal and abnormal human walk. The limb movement is observed using the

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accelerometer inserted in the Smartphone. The data is acquired using an application AndroSensor. The runs on the phone remove noise; extracts peak and valley points in the signal. The features such as stride length, step length, speed, and cadence were extracted. For classification threshold based classification of computed metrics based on decision tree classifier is used. The decision categorizes them into normal, mild, moderate and severe class based on the extent of the abnormality.

In this work, the Smartphone eliminates the need of visiting the clinic and hospitals. The persons can clearly diagnose by themselves. Cheaper compared to other expensive medication methods and easily reachable to ordinary people, especially women who are busy with multiple tasks. The drawback of this proposed work is the device must be worn around the ankle which is difficult, and the wearable sensors are not suitable for aged people due to their forgetfulness, and it's not appropriate for large scale deployment.

B. S. Daga, A. A. Ghatol and V.M. Thakare [2] proposed a process in which the main objective of the work is to detect the fall detection. The camera footage was considered for the curvature scale space (CSS) features extraction, and the human activity is classified based on the support vector machine (SVM) extreme learning machine (ELM) technique. In this work, the advantage of the ELM along with sparse representation coefficient (SRC) is also discussed.

The high accuracy obtained from SRC classification. Faster computation and response time of the ELM technique. The disadvantage is subjected to physical space constraint. The system will be used in monitoring subject falls and being alone in the house or room cannot get attention or raise the alarm for immediate help.

Hoang Le Uyen Thuc, Pham Van Tuan and Jenq-Neng Hwang [3] proposed a work in which ordinary camera is used to capture the video of a person moving such as doing actions or walking. The human object is segmented using a GMM-based background subtraction algorithm. The extracted human is then post-processed via morphology operations to create a well defined binary silhouette. Feature representation using two separate feature descriptors, one for each application scenario, and shape-based feature descriptor is good enough to represent the gait. Seven values of Hu's moments were used as features. The abnormal event detected based on Hidden Markov Model (HMM). The final stage is to convey an SMS message to the pre-defined cell phone number to notify the caregiver of a detected anomaly.

The installation, operation, and maintenance of the camera systems are simple. It is also non-intrusive, continuous, and objective in nature. But it is subjected to space constraints and can be an Automatic fall detection system to timely support the victims.

Zijuan Liu, Lin Wang, Wenyuan Liu and Binbin Li [4] proposed discrete wavelet transform (DWT) and principal component analysis (PCA) algorithms are used to remove noise. The two-dimensional CSI frames are built using the amplitude information of CSI subcarriers for extracting feature of CSI subcarriers. The SVM classifier is used to classify the CSI data. If there is a human movement, the gait periodicity is analyzed using autocorrelation to identify whether the intruder is human or not.

Since WiFi is available widely, this system can be adopted to detect the intruder easily.

Mohammed Hussein Ahmed and Azhin Tahir Sabir [5] proposed a gait-based gender classification method using the 3D skeleton data obtained from the Microsoft Kinect sensor. A Kinect sensor supported with SDK provides a human skeleton for two people. Kinect provides an RGB image and image depth. However, in the proposed method the author uses only a skeleton model. The proposed method consists of four stages. The first stage is the creation of an application by SDK for Windows to record a 3D skeleton, which is then used to create a database with Kinect. Detecting a gait cycle for each subject is the second stage. The third stage involves feature extraction - in this paper, the skeleton-based dynamic feature extraction method is adopted. In the final phase, the Nearest Neighbor (NN), Support Vector Machines (SVM) and Linear Discriminant Classifier (LDC) were used as the classification methods.

The human gender is easily classified without any human intervention. The information is collected through non-contact and non-invasive methods.

Ait O. Lishani, Larbi Boubchir and Emad Khalifa and Ahmed Bouridane [6] describe GEI which represents human walk using a single grayscale image obtained by averaging the silhouettes extracted over one gait cycle. The features of the GEI image is extracted using Gabor filter bank-based feature extraction method. To obtain useful and informative features for classification a Spectral Regression Kernel Discriminant Analysis (SRKDA) feature reduction algorithm is necessary. The SVM classifier is used to evaluate the categorization.

The recognition rate of the proposed method is high compared to other existing methods. Hence it can be a promising system in biometric applications.

Guan Y.D, Zhu R.F., Feng J. Y, Du, K., Zhang and X.R. [7] establishes the human silhouette and gait period. The author has adopted Shifting Energy Image (SEI) as the feature of the image, and then Gabor Wavelet and Local Binary Pattern (LBP) feature extraction methods are applied. Finally, gait feature will be classified and recognized by using sparse representation coefficients (SRC). The robustness of the system is high.

Sneha Choudhary, Chandra Prakash and Rajesh Kumar [8] proposed a method consists of four steps. Gait Energy Image (GEI) is obtained by normalizing and averaging all the silhouette images in one gait cycle for all the subjects. The dimension of the GEI image is reduced by using principal component analysis. Five spatiotemporal parameters namely cadence, speed, height, stride length, stance period are calculated and concatenated with the reduced GEI Image. The reduced feature vector set is trained and tested using support vector machine and artificial neural network to classify whether it is male or female. The human recognition can be done from a far distance.

Nabeel Seedat, David Beder, Vered Aharonson and Steven Dubowsky [9] compare the force sensor based and accelerometer based motion monitoring system. The empirical mode decomposition (EMD) method is used to decompose, filter and reconstruct the respective kinematic signals. The threshold based peak detection is applied to estimate potential footfalls. The accelerometer sensor based system accuracy is good compared to the force sensor based system.

Wei-Yi Cheng, Florian Lipsmeier, Alf Scotland and Andrew Creagh [10] provide the continuous monitoring of the Parkinsons disease (PD) patients and motion monitoring. The sensor data for above 30000 hours were used. The convolution recurrent neural network was employed for human activity detection along with the extracted features.

The gait monitoring system is a promising system in the field of biometrics such as fingerprint, iris, DNA, and face. The consideration of gait for biometric would be advantageous compared to the existing one as the gait cannot be forged, and it is unique for each. Gait detection can play a significant role in the criminal and terrorist activities monitoring as they operate from a far distance. Since the gait detection doesn't involve any human contact, it can be analyzed from a considerable distance. Other than these the gait recognition would help in gender classification, age classification, fall detection and monitoring the aged people.

III. Gait Phases and Parameters

The complete gait cycle has two phases: the stance phase and the swing phase. The stance phase consists the time when the foot is in contact with the floor and the swing phase when the foot is in the air. Each gait phase is associated with the sub-phases such as initial contact, loading response, mid stance, terminal stance, and pre-swing. The swing phases are an initial swing, mid swing, and terminal swing.

Initial contact (heel strike): It is the moment that the foot contacts the ground.

Loading response: This phase begins immediately after the initial contact of the foot and continues until the lift of limb for swing phase.

Mid-stance: Period starts from the lift of the contralateral limb from the ground to the point where the body weight is aligned with the forefoot.

Terminal stance: This period starts after heel rising in the frontal plane and continues to prior to the initial contact of the contralateral limb.

Pre-swing: This phase starts from initial contact of the contralateral limb and ends with the lift of the ipsilateral limb from the ground.

Swing phase

Initial swing: This phase, also called toe off, is from lifting the foot off the ground until the knee flexion is increased to its maximum position.

Mid-swing: This phase begins immediately after knee flexion and ends when the tibia is vertical.

Terminal swing: This phase begins following the vertical tibia position to just before the initial contact.

The gait parameters can be listed as Cadence, Cycle frequency, Gait cycle time, Gait irregularity, Gait variability, Root mean square, Stance duration, Step asymmetry, Step duration, Step frequency, Step length, Step width, Stride duration, Stride frequency, Stride length, Stride velocity, Swing duration, Walking distance, Walking intensity, Walk ratio, Walking (gait) speed, Walking time and Walking velocity.

Cadence: Total number of completed steps or number of strides per minute.

Cycle frequency: The frequency obtained by performing the discrete Fourier transforms (DFT).

Gait cycle time: Time duration between two successive heel- strike events.

Gait irregularity: The average SDs of the left and right step times. It shows the variability in successive steps of the same foot.

Gait variability: The SD of gait parameters or their coefficient of variation (CV) i.e.

CV = SD/mean which is based on stride to stride fluctuations.

Root mean square: Root Mean Square (RMS) of the acceleration magnitudes.

Stance duration: The time from heel strike to toe off of the same foot. It is a percentage of the gait cycle.

Step asymmetry: The ratio of the difference between mean step times of individual legs to the combined mean step time of both feet.

Step duration: The time between heel contacts of the opposite foot.

Step frequency: Half of the fundamental frequency calculated using DFT.

Step length: Ratio of covered distance in meters to the number of completed steps.

Step width: Distance between the heels in the double support phase.

Stride duration: The time between two consecutive heel strikes of the same foot.

Stride frequency: Number of cycles per second (Hz).

Stride length: The distance between two consecutive heel strikes of the same foot.

Stride velocity: Ratio of the stride length to stride time.

Swing duration: The time from toe-off to heel strike of the same foot that can also be expressed a percentage of gait cycle.

Walking distance: Multiplication of mean step length over a specified duration by the number of steps.

Walking intensity: Calculated from the integral of the modulus accelerometer output.

Walk ratio: The ratio of average step length (in cm) to the cadence.

Walking (gait) speed: Having distance divided by the walking time.

Walking time: Measured using a stop watch.

Walking velocity: Distance covered/number of data points/sampling frequency.

Figure 2 shows the extracted silhouette from the original images after the morphological processes.

Figure 2: Original images and corresponding binary silhouette images [3]

Figure 3 depicts the GEI extraction. The GEI is the average of all the normalized images for the single gait cycle. The last section of the figure 3 shows the gait energy image (GEI).

Figure 3: Normalized and aligned images. The last image corresponds to Gait Energy Image [8]

The human gait is affected based on the weight the person is carrying. The variations in human gait during a normal walk is shown in fig 4 (a), while carrying bag is in fig 4 (b) and while wearing a coat is in fig 4(c).

Figure 4: (a) Normal walk (b) Carrying-bag (c) Wearing-coat

Figure.4. An example of GEI of an individual under three different conditions [6].

The human gait cycle is a significant parameter in the gait analysis. Figure 5 represents how the gait cycle can be identified.

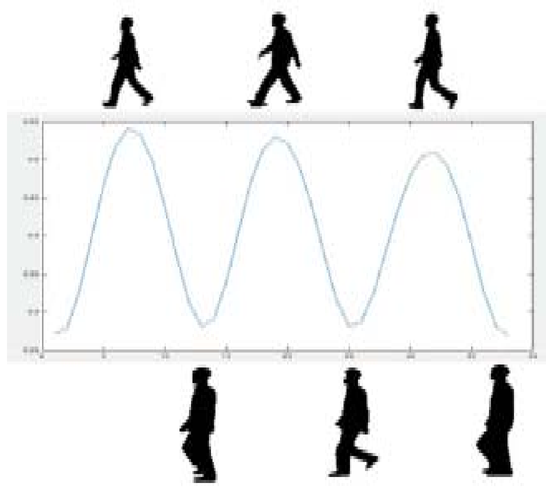

Figure 5: Identification of Gait cycle [8]

Figure 6 is the representation of the period of the human gait. It describes the period of human gait from CASIA-B dataset.

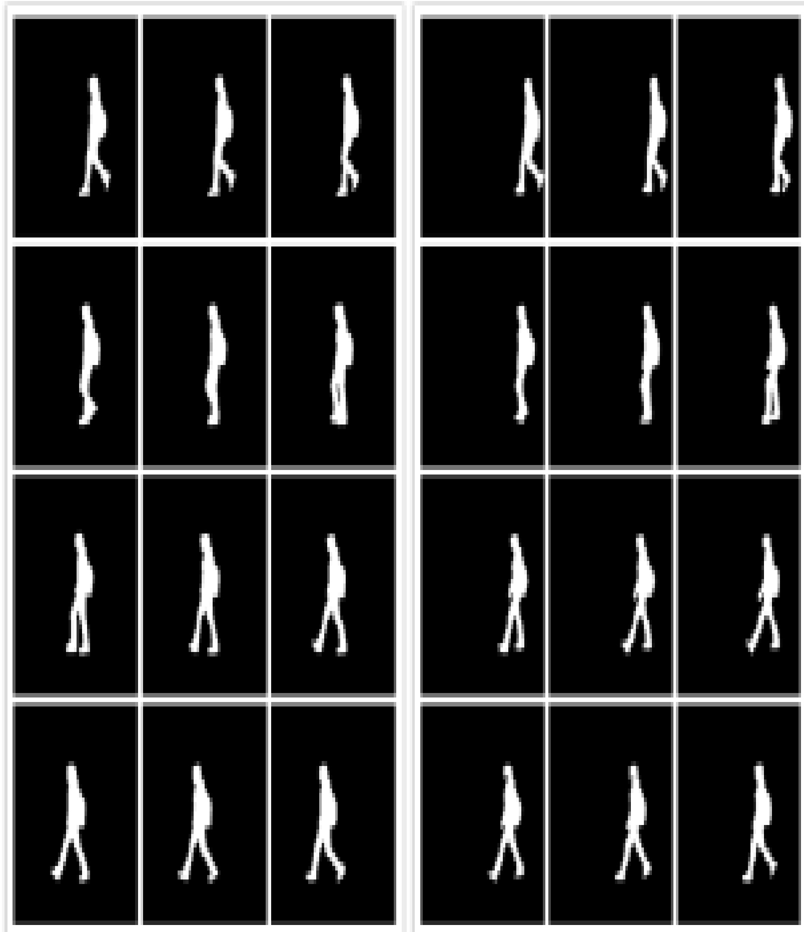

Figure 6: The period of human gait from CASIA-B dataset [7]

IV. Results and Discussion

The table1 shows the summary of the reviewed methodologies and their important parameters for gait analysis.

The table2 shows the tabulation of the reviewed methodologies based on the applications. Other than this the human gait detection has applications in sport, computer games, physical rehabilitation, clinical assessment, surveillance, human recognition, modeling, and many other fields.

Table 1: Summary of various approaches and their parameters for gait detection

Sl. No.	Author	Year	Accuracy (%)	Complexity	Classifier	Dataset
1	Kalyan Sasidhar, Satyam Satyajeet	2017	90	Low	Decision tree classifier	Real time Accelerometer sensor data
2	B. S. Daga, A. A. Ghatol, V.M.Thakare	2017	99.6	High	ELM-SRC	Data from Microsoft XBOX gaming console
3	Hoang Le Uyen Thuc, Pham Van Tuan and Jenq-Neng Hwang	2017	93.24	Low	HMM	HBU-Le2i
4	Zijuan Liu, Lin Wang, Wenyuan Liu and Binbin Li	2016	94	Low	SVM	CISCO WRVS4400N wireless router is used as AP to transmitter data. Intel 5300 NICs is used as MP to receive data
5	Mohammed Hussein Ahmed, Azhin Tahir Sabir	2017	96.67, 91, 90	High Low Low	NN LDC SVM	Data from Kinect sensor
6	Ait O. Lishani, Larbi Boubchir, Emad Khalifa and Ahmed Bouridane	2016	91	Low	SVM	CASIA Gait database (dataset B)
7	Guan Y.D, Zhu R.F., Feng J. Y, Du, K., Zhang, X.R.	2016	99	High	SRC	CASIA Gait database B
8	Sneha Choudhary, Chandra Prakash, Rajesh Kumar	2017	98.16	High	SVM	CASIA Gait database B
9	Nabeel Seedat, David Beder, Vered Aharonson and Steven Dubowsky	2018	86	Low	EMD	PAMMII
10	Wei-Yi Cheng, Florian Lipsmeier, Alf Scotland and Andrew Creagh	2017	90	Mid	CNN	PRX002/RG7935

Table 2: Segregation of the methods based on the applications

Sl. No.	Application	Methods/Papers
1	Normal and Abnormal gait analysis	A Smartphone based personalized gait diagnosing system[1]
2	Fall and Position detection	[2],[3],[4],[9]
3	Gender detection	[5],[8]
4	Terrorist or Criminal activity monitoring	[5]
5	Medical applications	[1],[10]
6	Biometrics	[6],[7]

V. Conclusion

The work presented is a literature review work on human gait recognition. The silhouette extraction, feature extraction, and classification are the main steps involved in the gait recognition. The various methods were presented by the authors and all are reviewed in this work.

References Références Referencias

1. Kalyan Sasidhar, Satyam Satyajeet," iKnow How You Walk - A smartphone based personalized gait diagnosing system", IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2017.
2. B. S. Daga, A. A. Ghatol, V.M. Thakare," Silhouette Based Human Fall Detection Using Multimodal Classifiers For Content Based Video Retrieval Systems", International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), 2017, IEEE.
3. Hoang Le Uyen Thuc, Pham Van Tuan and Jenq-Neng Hwang," An Effective Video-based Model for Fall Monitoring of the Elderly", International Conference on System Science and Engineering (ICSSE), 2017, IEEE.
4. Zijuan Liu, Lin Wang, Wenyuan Liu and Binbin Li," Human Movement Detection and Gait Periodicity Analysis Using Channel State Information", 12th International Conference on Mobile Ad-Hoc and Sensor Networks, 2016.
5. Mohammed Hussein Ahmed, Azhin Tahir Sabir," Human Gender Classification based on Gait Features using Kinect Sensor", 2017, IEEE.
6. Ait O. Lishani, Larbi Boubchir, Emad Khalifa and Ahmed Bouridane," Gabor Filter Bank-based GEI Features for Human Gait Recognition", 2016 IEEE.
7. Guan Y.D, Zhu R.F., Feng J. Y, Du, K., Zhang, X.R.," Research On Algorithm Of Human Gait Recognition Based On Sparse Representation", Sixth International Conference on Instrumentation & Measurement, Computer, Communication and Control, 2016 IEEE .

8. Sneha Choudhary, Chandra Prakash, Rajesh Kumar," A Hybrid Approach for Gait based Gender Classification using GEI and Spatio Temporal parameters", 2017, IEEE.
9. Nabeel Seedat, David Beder, Vered Aharonson and Steven Dubowsky, "A Comparison of Footfall Detection Algorithms from Walker Mounted Sensors Data", 2018, IEEE.
10. Wei-Yi Cheng, Florian Lipsmeier, Alf Scotland and Andrew Creagh," Smartphone-Based Continuous Mobility Monitoring of Parkinsons Disease Patients Reveals Impacts of Ambulatory Bout Length on Gait Features", 2017, IEEE.