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A review on Gait methodology and challenges

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Abstract—**The human gait identification has become a important research area in last two decades because of its towering applications. This human movement examination is a computer vision based behavioral biometric feature and belongs to the second generation biometrics. It does not require subject approval and hence can be captured from distance without the subject knowledge. Human movement examination involves methods for acquiring human gait, processing it, analyzing and understanding human motion/ action / emotion / behavior and validating it.The paper highlights numerous methods found in literature for model free and model based human motion analysis. Unlike previous survey papers the articles main emphasize is on the challenges posed by the covariate factors like different cloths, loading effect on subject and other factors like walking speed effects and their effects on the analysis. The article also gives the research background and current progress of gait analysis. In the last section the success rate and failure rate of many novel approaches by many authors are discussed.**

keywords: Gait, silhouette model-based, Model free, biometrics

I. INTRODUCTION

Three major approaches exists in human movement examination, the first is the machine vision based approach involving a video camera and image processing techniques. The second approach uses floor sensors, and special surface to device the gait information. The third approach involves wearing sensors on different body parts like legs, and arms to measure accretion. Amongst them the machine vision based approach is more popular. Therefore the paper concentrates mainly on the research developments taking place in this approach only. Vision based human movement examination has become an important behavioral biometric feature and find its application in the field of smart surveillance, athletic performance analysis, virtual reality, disease analysis related to legs etc. This has attracted lot of computer vision researches to involve in human motion analysis in recent years. The human vision based movement examination can roughly be categorized into two techniques namely model based and motion based(model free) techniques even though both the methodology have yielded good results, most of the works are carried out in a closed auditorium environment and with many assumptions, the objects considered are then matched more
under similar background conditions only.

In the model based/structured based gait analysis the human body structure is represented using graphics model parameter pertaining to different futuristic parameters. The motion based approach characterize the different motion patterns in human beings without any model parameters. Most of the times model based approach is carried out in constrained environment with usually high resolution video, where as the model free approach has strength to be carried out in outdoor condition and even at relatively lower resolution. It can even be used to obtain gait from larger distance. The various techniques used in gait analysis is shown in Figure-1.

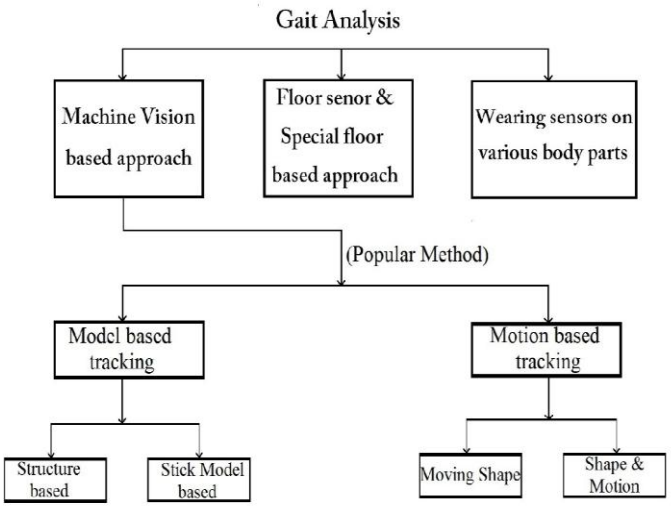

Fig-1: Gait Analysis

Further the paper content is divided into two sections, section 1 covers obtaining and analyzing the human gait under constrained environment, and second section examines the obtaining of human gait with covariant effects.

II. HUMAN GAIT ANALYSIS

The human gait analysis can be carried out in three steps firstly, acquiring the human gait cycle, secondly processing the acquired data to obtain the unique human gait, thirdly

understanding/validating the human behavior or action from the traced data.

A. Acquiring human Gait

The human Gait sample are obtained either from the standard database or by capturing video of the human subject under consideration. There are many standard database available for different actions the tabulation of the few available database is given below:

Table 1: Tabulation of Database

Name	Subj.	No. seq.	Views	Indoor(I)/ Outdoor(O)	Num. of Loc.
HumanID (USF)	122	1870	2	O	1
SOTON 2002	114	>2500	2	I/O	2
CMU MoBo	100	600	6	I	(Treadmill) 1
UMD 2002	44	176	1	O	1
SOTON Multimodal	>300	>5000	12	I	1
CASIA 2006	124	1240	11	I	I

In the second method the human gait is obtained by Individually creating the database by capturing the video under all the required modes with camera resolution of minimum 25 FPS / 30 FPS (most of them have used) and with different view angle of 00^0, 45^0, 90^0 to obtain the human gait frontally, laterally and obliquely,

after capturing the video of multiple gait cycle the pre-processing is performed to obtain best possible gait cycle of the subject from the existing video samples. Typically, gait cycle are detected using either the periodic variation of the width for the silhouette bounding box or by auto correction methods.

BEN ABEDKAR : Used the variation of the bounding box width for subject silhouette, to measure the gait periodicity. CHELLAPPA: proposed an adaptive filter to filter the foreground sum signal prior to the measurement of the gait cycle using the minimum of the signal. EKINICI M AYUKT : After taking silhouette for certain member of frames, Find its auto correction between two consecutive frames and do normalization by subtracting its mean and dividing by its standard deviation, and then smoothen it with symmetric average filter.

B. Processing :

The processing involves identifying the moving objects in the video frames(feature extraction) and classify them. The video could capture the vehicles, birds, moving animals and the people, the classification process needs to identity the human walking subjects from other moving objects in the scene and then the human subject of interest needs to be traced between the frames. Most of the work assumes that there is only one moving region and that is the object to be identified. Therefore processing essentially needs to identify the subject, classify it from other moving objects(if required) and trace it between the frames for the period of one gait cycle. There are many techniques suggested in literature to trace the moving objects the prominent amongst them are

Statistical Methods: - This method uses statically background and can be updated dynamically during processing. The method is more resistant to noisy shadow and lighting conditions.

Temporal differencing: - This method uses difference between two or three consecutive frames in an image sequence to extract moving regions. It is adaptive to dynamic environment but does pool extraction of the relevant subject.

Optical flow :- Optical flow describes coherent motion of points or features between image frames. The method is useful to extract moving objects even when camera is in motion.

Once the moving object is spotted the classification of the required moving object (human object) needs to be done because we need to eliminate other probable moving objects like vehicles, birds, animals etc.Broadly the human object classification can be performed using (a) model based classification (b) motion based classification. Shape based classification is model based classification which models the human body as skeleton, set of blobs ie blobs corresponding to head, hand, feet and arm. Motion based classification is non articulated or non-modeled way of classification in which the main concentration is given to periodicity of the human object under motion. The self-similarity measure is computed for its periodicity. It utilizes the whole motion pattern of the human body.

Model based tracking:

The geometric structures of human body can be represented as stick figure, 2-D contour or 3-D volumetric body segments can be approximated as lines, blobs, 2-d Ribbons & 3-d volumes.Stick figure representation & tracing: The stick figure is obtained in various ways by means of median axis transform (MAT) or Distance Transform. Model-based tracking traditionally, the geometric structure of human body can be represented as stick figure, 2-D contour or volumetric stick-figure representation can be used to approximate a human body as a combination of line segments linked by joints. The stick figure is obtained in various ways, e.g., by means of median axis transform or distance transform. The motion of joints provides a key to motion estimation and recognition of the whole figure.

Ai and Ji (2007) proposed an approach based on positioning of the human body joints for gait recognition system. At first, silhouettes extraction was done using normal background subtraction and morphological operations to get good quality silhouettes. Then, 12 positions of body joints coordinates

during walk were selected and calculated according to geometrical characteristics. The discrete Fourier transform was applied to compute angle features. Finally, the KNN classifier was used for subject matching. To evaluate the performance, the Soton gait database was used for experiment. The experimental results were also compared with other researcher results and the proposed results were reported to have achieved 78% recognition rates.

Guo: Represented the human body structure in the silhouette by a stick figure model which had ten sticks articulated with six joints. It transformed the problem into finding a stick figure with minimal energy in a potential field. In addition, prediction and angle constraints of individual joints were introduced to reduce the complexity of the matching process.

Junqiu e t al. (2008) proposed an integrated algorithm for tracking and segmenting silhouettes supported by gait recognition. The three modular approaches are tracking, 38 segmentation and gait recognition modules. The tracking module gives beginning input to the gait recognition module. The proposed tracking module is prepared based on the mean-shift algorithm. However, they created bounding box by tracking module. Furthermore, the tracking module outcome contained some inaccuracies due to background differences. Dynamic Time Warping (DTW) was described to get smooth gait sequences curve for recognition purposes. Nevertheless, they presented good quality gait silhouettes using Standard Gait Model (SGM). The Min-Cut algorithm was used for the interactive segmentation and improved the performance of subject segmentation. The experimental results reported that the proposed method improved initial tracking and segmentation results..

Niyogi and Adelson: used the spatial-temporal pattern in XYT space to track, analyze and recognize walking figures. They first examined the characteristic braided pattern produced by the lower limbs of a walking human, the projection of head movements was then located in the spatio-temporal domain, followed by the identification of other joint trajectories; finally, the contour of a walking figure was outlined by utilizing these joint trajectories, and a more accurate gait analysis was carried out using the outlined 2-D contour for the recognition of specific human.

Xiaxi et al. (2008) proposed the multiple views style for gait recognition. They argued that multiple views have unequal discrimination power and therefore, unequal contribution of recognition process. At first, they tested and evaluated all the views individually, and then combined all the results. They set a weight for each view based on its importance. For the test, at first, they selected fast walk and slow walk sequences. Six cameras were located in six different positions to capture the walking images. They then took bounding boxes of silhouettes from the original images for the subject, then align and normalise all the silhouettes into uniform dimensions. The most suitable views were found to be frontal and side views. The best result were obtained by using the product and the min combination rules. Using the CMU (MoBo) database, they achieved 92% recognition rate.

Model free approach:

appearance-based/model free approaches employ a compact representation to characterize the motion patterns of the human body without taking into consideration of the underlying model structure.

Shi and Youxing (2007) approached the appearance-based methods for gait recognition system. Individual silhouettes and contextual silhouettes were taken and 2D polar plane used at the centre of the silhouette. They analysed how subjects' walking appearance changed during a walk. The definition of appearance model is presented as a combination of histograms of individual silhouettes and contextual silhouettes. However,

the Jefferey divergence criterion and dynamic time wrapping technique was applied to calculate the similarity between test and reference sequences. In the experiment, the CASIA database was used, which contained 20 subjects and 12 sequences per subject for different viewing angles. The planned technique reported recognition rates of 92.5%, 98.75%, and 100% when k=1, k=2 and k=3 respectively.

Han e t al. (2005) represented the feature extraction process based on static and dynamic knowledge methods. First, the basic gait features were selected for analysis. Second, the gait cycle was detected based on successive peak values of the width and height. Discrete Cosine analysis was applied to get the periodical sequences. The silhouettes were marked into three sections, namely, upper body part, middle body part, and lower body part. Here the lower body part was selected to measure the walking 29 distance over one gait cycle time. However, joint angles were measured from lower dynamic body part. To classify the gait features, the Support Vector Machine (SVM) was used for testing and training dataset. The three gait databases, namely, Little and Boyd, CMU (slow walk) and NLPR achieved three different recognition rates of 100%, 90.2%, and 90.6% respectively.

Yangming and Guangjian (2008) proposed anatomical knowledge for gait recognition. At first, they extracted the human silhouettes from gait video sequences. Then, the anatomical knowledge was used to describe the silhouettes. For gait periodic analysis, the height and width periodic ratio was analysed based on local minimum and maximum gait period variations. The Hidden Markov Model (HMM) was applied to get a smooth gait periodic cycle for accurate results. The CMU MoBo database was selected for the experiment with high recognition rate achieved. Table 2 shows the various algorithm techniques used by the two approaches.

Table 2: approaches in model free and model based

Model free	**Model based**

Spatiotemporal pattern	Ellipsoidal fits
Shape of motion	Kinematic features
PCA +LDA	Stride
Moments	Human parameters blob
Unwrapped silhouette	Joint trajectories
Eigenspace sequences	Articulated model
Statistics	Stick model
Hidden Markov model	Layered deformable model
SIFT	
HOG	

III. CHALLENGES IN GAIT

In the unconstrained environment the effect of subject covariates like different clothing, walking speed, load carrying effect, Injury effect and occlusion effects, climatic conditions are necessary to be considered. The literature suggests that the work carried out on one or few of the above referred covariant for human gait recognition system has not yielded the encouraging results. Therefore the challenges still remain due to lack of understanding on effect of the covariates in gait recognition and its performance needs to be explored.

a. Different clothing covariant:

YaGun, et. Al. (2012) has proposed a random subspace method (RSM) framework for clothing invariant gait recognition by combining multiple inductive biases for classification these method without knowing the probe set clothing information, in the training set, it setup the multiple inductive biases. While in the testing stage, the corresponding weak learners are fused together for a decision committee and majority voting criterion is employed for the final classification decision. This method employs PCA (Principle component analysis), for feature extraction following the least reconstruction error criterion, PCA also removes a large amount of data redundancy. Experiments are conducted on OU-ISIR Treadmill database B which includes 32 combinations of clothing types and the recognition accuracy is given as 80.44%.

Matoski demonstrated in his work, the effect of time and certain type of clothing on the recognition he conducted three experiments on clothing analysis in experiment 1 the temporal data were matched over a period of time with subjects wearing different clothes, and shows that very high recognition results for all views are achieved if the same types of clothes are matched and when different types of clothes are used the recognition rates can fall to 40%. The experiment 3 investigates how the recognition rate is affected by change from one type of ordinary cloths to another versus extreme clothing variations such as overall suit and shows that the recognition rates clear eases significantly less if different but less extreme clothing clothing changes occurs. In conclusion he says the results could be improved if algorithms that re less sensitive to change in clothing are used.

Hussainetal constructed a large scale gait database ie OU-ISIR Treadmill dataset B which includes 68 subjects with up to 32 combinations of clothing type and based on this database he proposed technique which can adaptively assign more weight to the unaffected body parts, and less weight to affected body parts. This technique assumes that the clothing type appearing in testing stage is appearing in probe set but this assumption is hard to realize practically.

b)Loading effect covariant:

The impact of load coverage on human gait and body posture has been extensively carried out by many researches literature, they have emphasized on understanding the pattern change seen in gait recognition and there by full in recognition rate.

Pascoe etal carried out many experiments to understand the effect of carrying bags on gait kinematics for youth people. Pascoe reported that the stride length decreases while the gait cadence increases in response to the weight of the load. The same conservations were made by Attewells when he carried out an experiment on military per sonnet, observed that the gait angular data including the knee and femur angles are significantly affected with the increase in load.

Phillips et.Al. reported a correct classification rate of 61% using KNN for K=l employing silhouette based method on people carrying a briefcase.

I med Bovchrika also worked on improving the correct classification rate including the covariate factors like footwear clothing and load carriage. To derive the optimal subset of features, he used the CCR value computed by probing 440 samples of covariate data which includes 40 sequences from normal gait data and reported 73.4% of recognition rate.

c. Walking speed effect:

There is not much investigation has happened on the speed effect compared to that of other covariate effects. Based on a model based method for feature extraction

Yam reported the possible existence of an one two mapping between the walking and running gait patdata setters.

Boric etal. Observed features derived from silhouette of walking people are speed dependent therefore it suggested to have speed feature adjusting in preprocessing stage itself.

Imed Bouchrika observed the impact of speed variation on gait recognition, by constructing test consisting of 10 subjects recorded at different walking speed slow, normal and quick with each case having 4 trails. The recognition rate for both slow quick walking dropped largely to 60% and 50% respectively compared to normal walking archiving 86%.

Discussion and conclusions

The computer vision based human gait analysis is growing its popularity amongst the research community because of its growing applications. Human gait analysis finds its application in the fields of smart surveillance, virtual reality advance user interface, in military training program, In medical

field for diseases like cerebral palsy, Parkinson's and stroke in the field of sports to analysis and improve on the performances. The paper discuss gait analysis in two section in the first section the discussions were carried out on general frame work to process human gait analysis. In this we presented an overview of two different existing methods ie motion based gait analysis and model based human gait analysis even though existing algorithms in both the methods have yielded good results, they were carried out in constrained environment and with certain assumptions. Also in the first step the segmentation process suffers from many factors like weather, lighting, shadow occlusion and camera motion therefore reliability is still an issue in segmentation process when all these factors are considered. large number of gait recognition algorithms have been reported, it is important to note that gait biometrics is still faces many challenges.

The second section discuss on various covariate factors like different clothing, the effect of change in walking speed and loading effect causing the drop in human recognition performance. A study on covariates has reported a recognition rate of as low as 3% when covariates like different clothing, shoes, loading effect and change in walking speed was considered simultaneously. Therefore it hints on strong scope to revive the methods and techniques when considered practically. And more importantly the gait recognition needs to be taken out from indoor based studies on sample people to large population of real world data. The literature suggest that all these covariates need to be explored and analyzed at micro level to better the human gait recognition rate.

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